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CARE OF FLEET POST OFFICE
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RESTRICTED

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

Subject: Target Report - Japanese Anti-Aircraft Fire Control.

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

1. Subject report, covering Target O-30 of Fascicle O-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lt. Comdr. E. L. Delmar-Morgan, RNVR, with the assistance of Lt.(jg) D. H. Jackson.

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31769

JAPANESE ANTI-AIRCRAFT FIRE CONTROL

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

FASCICLE O-1, TARGET O-30

JANUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

JAPANESE ANTI-AIRCRAFT FIRE CONTROL

A careful examination of all Japanese fire control systems and particularly anti-aircraft systems discloses any number of quite excellent ideas, many of them well carried out, but mostly they are in details only and not original basic conceptions. An example of the former is the simple sine wave mechanism, a description of which has been included in this report. There were no fire control systems either for long or short range based upon the "line of sight" gyro with one degree of freedom or the free gyro. The use of gyros was strictly limited to providing artificial horizons.

Based on standard principles, there were many new Japanese fire control systems such as the RAIUN, the Type III, and the BIODOBAN Type II.

In the field of short range, high angle fire control, all Japanese systems were based on the course and speed sight principles. The Japanese made very complicated course and speed systems, while admitting apparently to themselves, that the primary errors of estimation of target course, speed and range were out of all proportion to the small corrections applied for wind, drift, parallax, etc. Descriptions have been given of two of these types of course and speed sight director systems (Type 95 and Type 4 Mod. 3) but not of the remainder, some of which were simpler, as nothing of value would be gained by describing various types of outmoded systems.

The most outstanding characteristics of Japanese anti-aircraft fire control were (1) optics, (2) the limited application of power follow-ups, and (3) the use of optical methods for hand follow-ups.

The best features of the standard Japanese long range High Angle Fire Control System Type 94 are (1) careful design, (2) unity of thought, and (3) excellent layout. A visit to the aircraft carrier RYUHO at Kure Naval Base confirmed these impressions. The director both inside and out was spotlessly clean and tidy; the layout was excellent. There were no untidy cables, pipes, tubes, or excrescences. The inside of the director had polished linoleum on the false deck and was supplied with indirect lighting giving an impression of excellent cooperation between designers, manufacturers, and navy yards.

In blind firing systems and autofollowing with rate aiding, Japanese naval designers had not progressed far. Although some of their ideas were up to date, they were handicapped by the bombing of their industrial plants capable of fine precision work. As a result the accuracy of radar systems was not good enough for high angle fire, and the resulting operational practice was for the radar to put a searchlight or a group of searchlights roughly in the correct place in the sky and then to track optically in the normal manner.

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LIST OF ENCLOSURES

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REFERENCES

Location of Target:

Kure Naval Arsenal

Yokosuka Naval Arsenal

Nippon Optical Company (TOKYO)

Japanese Personnel Interviewed:

Jiro, ICHINOI, Commander, IJN (Ret). Fire control designing engineer; Kure Naval Ordnance Experimental Laboratory and Head of Fire Control Factory 1940 - 1945; attached to First Technical Institute, YOKOSUKA, from April 1945 to August 1945.

Mr. FUKAEDA, designing engineer, Nippon Optical Company, Mizunokuchi, TOKYO, from 1943 to date.

OKUDA, Lieut. Cdr., IJN (Ret). Gunnery Officer of the battleship NAGATO.

Related Reports:

For information on stable elements, stable verticals, gyro horizons, servo mechanisms and magnetic torque amplifiers which operate with the high angle fire control systems described herein, refer to NavTechJap Report, "Japanese Surface and General Fire Control", Index No. O-31.

For references on equipment other than that referred to above, such as synchros, wiring diagrams, etc., refer to NavTechJap Report, "Japanese Fire Control", Index No. O-29.

INTRODUCTION

Although the target brief calls for a descriptive report of shipborne anti-aircraft fire control, it is thought that the report should also include Japanese naval anti-aircraft fire control for land use. In spite of the fact that such anti-aircraft fire control systems are for land use, they are fundamentally naval conceptions -- designed and manufactured by naval fire control engineers and contractors, and intended to be operated by naval personnel -- for the defense of naval bases and naval arsenals.

The standard shipborne naval anti-aircraft fire control system is the type 94 (KYUYON SHIKI KOSHA SOCHI) and is the equivalent in many respects of the U. S. Mark 37 Director System. The firm which made this system, Nippon Optical Company, was still to a large extent intact and the staff was still available, making it possible to obtain from the chief design engineer, Mr. FUKAEDA, a small pamphlet describing the system. This pamphlet is included as Enclosures (D) and (E).

The system which preceeded, in order of development, the Type 94 KOSHA SOCHI was the Type 91, and this was equivalent in many respects to the U. S. Mark 33 System.

In the introduction to NavTechJap Report, "Japanese Surface and General Fire Control", Index No. O-31, there is given a complete list of Japanese terms used for the different systems; for this report some excerpts are listed in order to identify the systems. Because the Japanese system of nomenclature is so complex, it has been found useful to use their words and descriptive titles. The following are the terms encountered in this report:

HOIBAN .... Low Angle Director
KOSHAKI .... High Angle Director
SHAGEKIBAN .... Low Angle Computer
KOSHA SHAGEKIBAN .... High Angle Computer
BIODOBAN .... High Angle Computer
KOSHA SOCHI .... High Angle Fire Control System
DENTAN HOIBAN .... Radar Director
KOSHA SHAGEKI SOCHI .... Short Range High Angle Director

This report covers all the naval anti-aircraft systems in existence at the close of the war and also those under development, including high angle systems for large guns.

THE REPORT

Part I
JAPANESE ANTI-AIRCRAFT FIRE CONTROL

A. Type 91 High Angle Director System (KOSHA SOCHI)

1. General. This high angle director system consists of director and computer combined on one pedestal with no plotting room, no stable element, and is similar to the U. S. Mark 33 System. The only difference is the absence of a rangefinder in the Japanese System.

The Type 91 was designed in the late 1920's and ships were being equipped with this system in 1930. It was designed principally for high angle, but it is also suitable for surface fire. It is a full tachymetric system based on polar coordinate principles and identical in its approach to the problem with the Vicker's Army Predictors.

The optics are leveled and cross-leveled by the leveller and cross-leveller so that the director is, in fact, tri-axial in just the same way as the Type 94.

The system is cumbersome to operate and requires eleven operators. Of these eleven, ten actually operate the director and one is a communication member. There are no servos or follow-ups; instead, pointers are matched.

The photographs in Figures 1 and 2 show the Type 91 removed from BB NAGATO. It is identical to the model shown in Figure 3 where it can just be seen through the camouflage to the left of the rangefinder tower on BB HARUNA shown in Figure 4.

The distribution of the operating personnel is as follows:

Forward	a. Cross-Leveller
	b. Leveller
Aft	c. Total elevation follow-up for cross-level correction.
	d. Lateral and vertical spotting corrections, initial settings for wind, time of flight follow-up.
	e. Lateral and vertical deflection
Starboard	f. Trainer
	g. Compass follow-up
Port	h. Layer
	Level and cross-level converter (i.e., resolver from horizontal to deck values)
	i. Range, range rate and range spotting

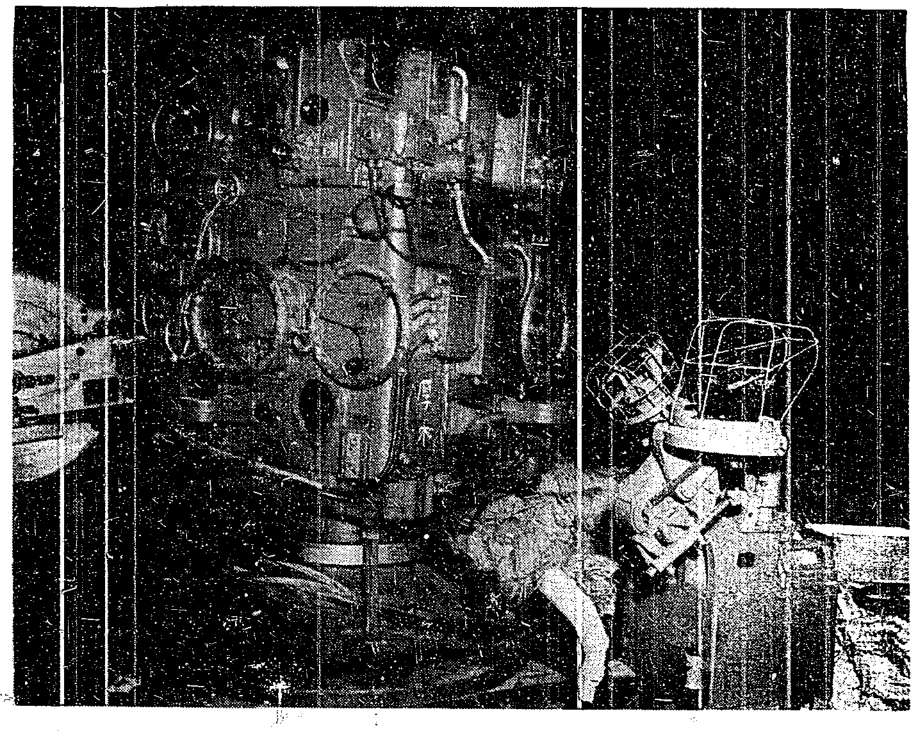


Figure 1
TYPE 91 HIGH ANGLE DIRECTOR

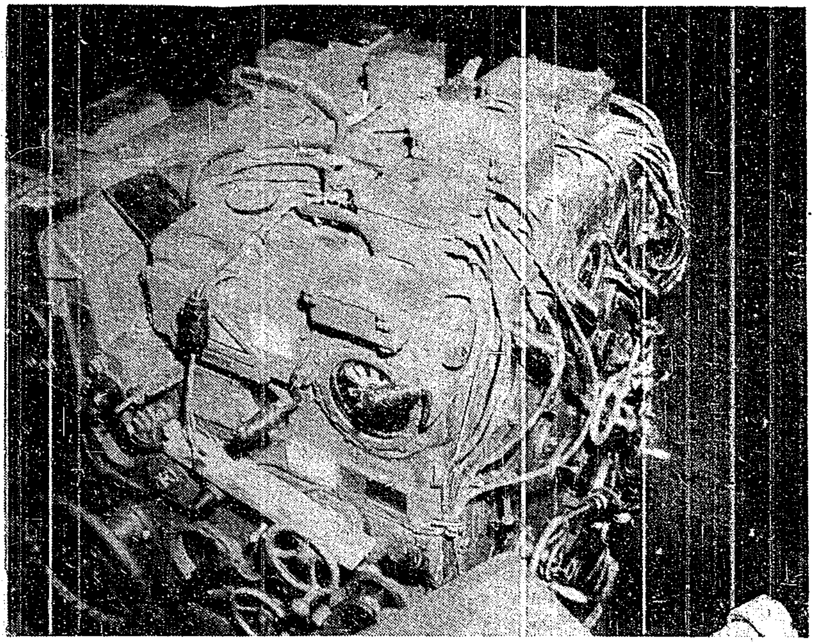


Figure 2
TYPE 91 HIGH ANGLE DIRECTOR

Figure 3
TYPE 91 HIGH ANGLE DIRECTOR,
BB HARUNA

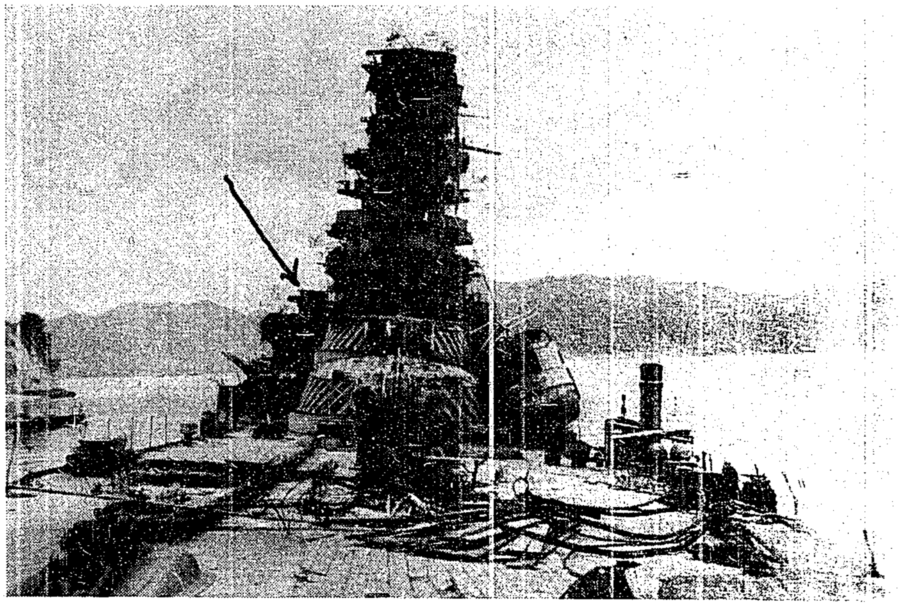


Figure 4
BB HARUNA

2. Solution of the Problem

Elevation:

$$\alpha + \sigma + i_3 + \phi + \omega_1 + \Delta\phi + \alpha_{ie} + \alpha_e$$

α Present elevation

σ Vertical deflection

i_3 Correction due to deck tilt

ϕ Super elevation

ω_1 Correction due to wind and own ship speed

α_{ie} Daily corrections (barometric height and I.V. correction)

α_e Spotting

Training:

$$\beta + \delta + Z + \omega_2 + \epsilon + M + D_c$$

β Present bearing

δ Lateral deflection

Z Drift

ω_2 Correction due to wind and own speed

ϵ Cross-levelling correction

M Parallax

D_c Spotting correction

Time of Flight:

$$T = T_o - T_e$$

T_o Time of flight

T_e Correction (including dead time (t) and $t\,\frac{dT}{dt}$ correction

3. Weights and Sizes. The physical dimensions of the director are: one meter square, two meters high and three tons in weight.

4. Efficiency of the System. The system was handicapped by the fact that the rangefinder was separate from the director and it was found very difficult for the rangetaker to be on the same target as the director, not only because the rangefinder was separate, but also because the rangefinder had no level or cross-level assistance and was, in fact, bi-axial.

Since equipment was based upon slant range instead of height, it differed in this respect from the Vicker's System from which it was taken; and therefore, enabled correct solutions to be made for diving and climbing target. This feature was a theoretical advantage rather than a practical one as the task of Operator Number 5 (lateral and vertical deflection) became difficult when there was much roll or pitch.

The training of the director was manual and there was no form of rate aiding in the instrument.

The system was primarily designed as an anti-aircraft system, but it was also used for surface fire. Surface fire at dusk or under poor light conditions was stated to have been very bad because of the inefficiency of the sights, telescopes, and optical systems as regards their light transmitting qualities.

This system was still in use in the Japanese Navy at the close of the war, being substituted as quickly as possible by the more satisfactory Type 94. Maintenance was difficult but not frequent in the absence of power follow-ups and electronics.

No sketches or schematic diagrams have been made of this system since it is considered obsolete.

B. Type 94 High Angle Director System (KOSHA SOCHI)

1. General. The Type 94 System was the standard Japanese naval fire control system in use at the close of the war.

It was fully tachymetric, consisting of a tri-axial director (KOSHAKI-Type 94) and a computer (in a plotting room below decks) incorporating a spherical resolver for deck tilt. There were several modifications and improvements to the system over a period of years and in the latest ones a stable vertical based upon a pendulous gyro took the place of optical leveling and cross-leveling in the director.

The system as a whole is similar to and can be compared with the U. S. Mark 37 System. It is an outgrowth of the Type 91 and retains many of the same basic features, i.e., it is a polar coordinate system depending on accurate slant range and provides solutions for diving and climbing targets.

It has hydraulic training using the tilting plate pump principle, which was lacking in the Type 91. This hydraulic training is not automatic or rate-aided.

2. The Director. The director (KOSHAKI) pictured in Figures 5 and 6 is shown installed in the aircraft carrier RYUHO in Figure 7. The rangefinder is cross-leveled and leveled as are the layer's and trainer's optics. It is capable of directing fire against surface targets as well as aircraft, but even in the latest ships (YAMATO and MUSASHI Class), the directors were not equipped with any radar antennae for blind fire, although radar range is used for the system.

3. The Computer. The computer (KOSHA SHAGEKIBAN) is similar both in size and weight with the U. S. Mark I Computer. Its operation is mechanical throughout except for the magnetic clutch type of follow-up, a sample of which has been sent to the U. S. and a description of which is given in the documents which have been seized and sent to the U. S. The computer contains a spherical deck tilt corrector (instead of flat linkages as in the Type 91) for converting tri-axial data to bi-axial data. Follow-up is by an optical system and this can be seen at the left end of the computer in Figure 8. The accuracy of this optical follow-up is not known, but it is unlikely to have been very successful in view of the many different versions of this gear that appear in succeeding modifications. The computer has a range plot, the main purpose of which is to obtain a good range rate by aligning a slit of light with the slope of present range. A description of the system and more particularly the computer is given in Enclosure (D) which was prepared by the Nippon Optical Company. In addition, Enclosure (E) contains design data seized at the Nippon Optical Company and is considered to present a fair analysis for design errors. In addition to the foregoing, some further figures and limits follow.

4. Description

a. Production: The NIPPON KIGAKU KOGYO KAISHA and their subsidiaries were responsible for the production. Some additional information on this firm is given in NavTechJap Report, "Japanese Ordnance Research, Testing and Training", Index No. O-38.

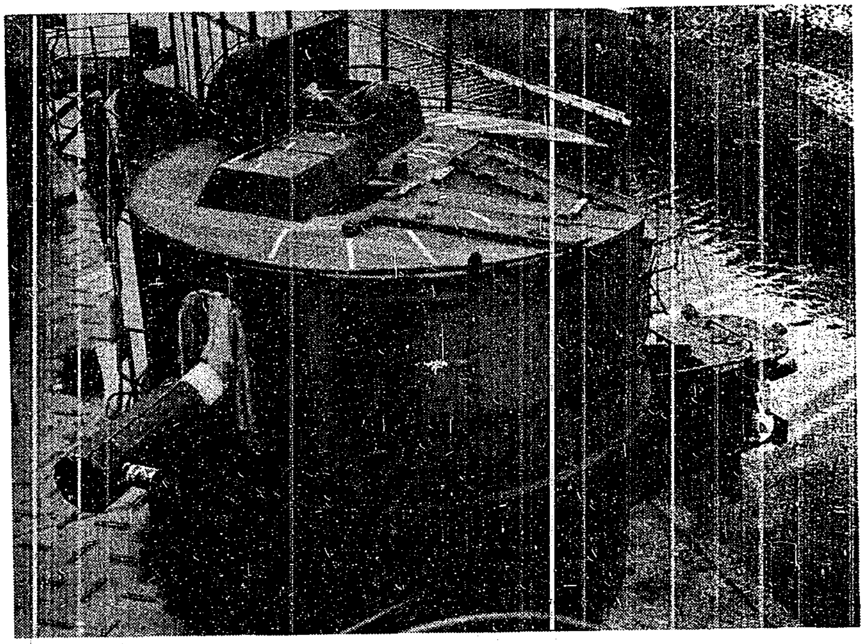


Figure 5
TYPE 94 DIRECTOR

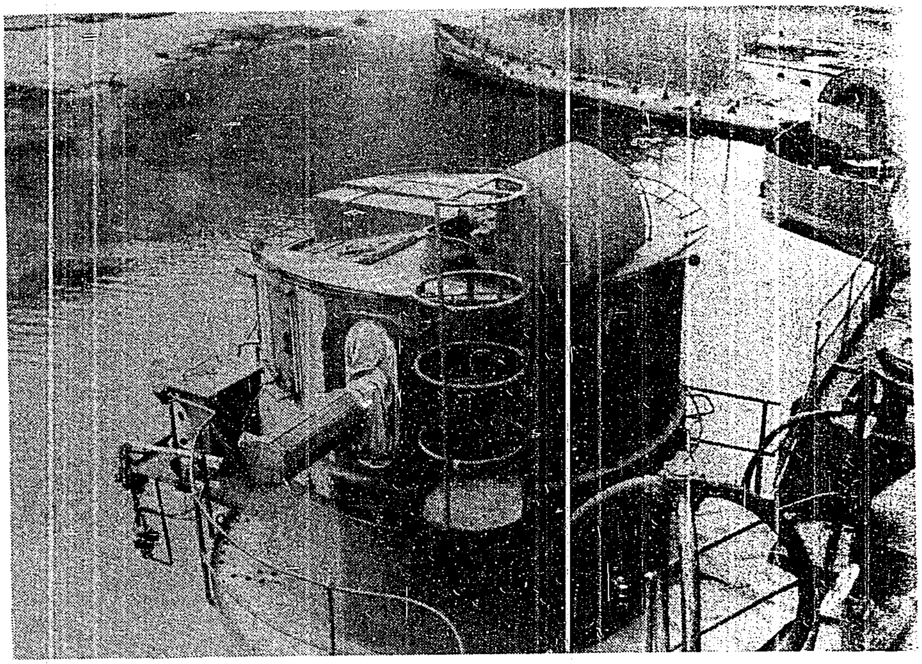


Figure 6
TYPE 94 DIRECTOR

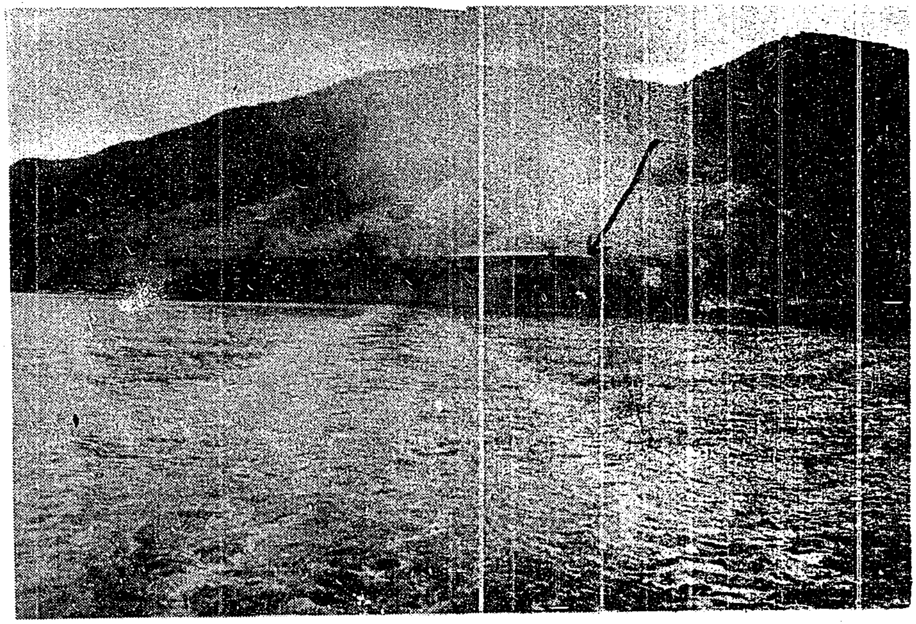


Figure 7
TYPE 94 DIRECTOR
CARRIER RYUHO

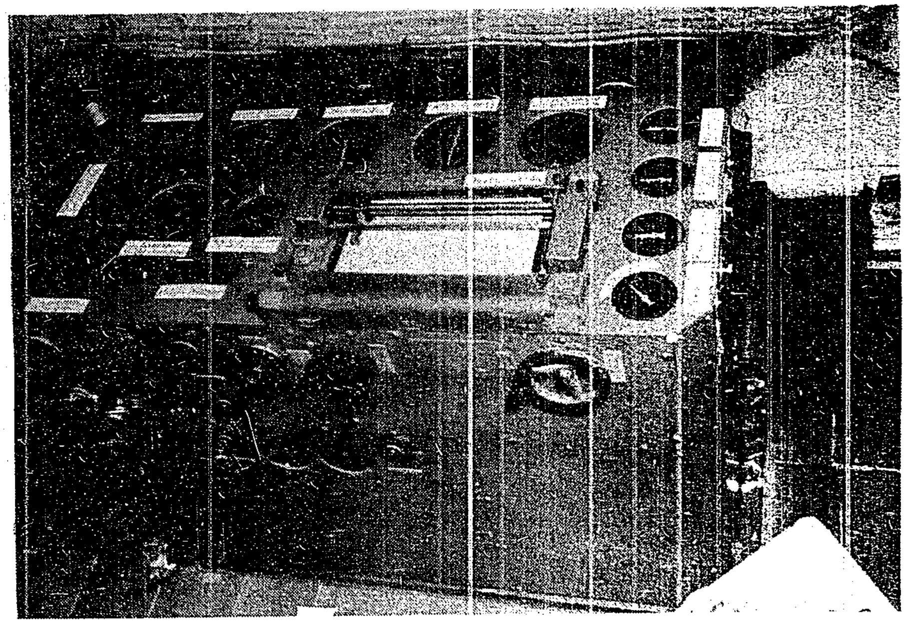


Figure 8
TYPE 94 COMPUTER, DESTROYER HANAZUKI

Production of this equipment commenced in June 1937, using designs dated about 1933 or 1934, at a rate of 5 units per month and at a cost of approximately 136,000 yen each.

b. Limits and requirements:

Speed of Operation	
Elevation	8°/sec
Training	16°/sec
Accuracy of Solution	
Train and Elevation	12 minutes of arc
Fuze	0.02 seconds
Average Time for Smooth Tracking	20 seconds
Solution Time	10 to 20 seconds
Inputs to the Computer	
Present Range	1.5 to 20 km. (Auto)
Present Height	0 to 10 km. (Hand)
Elevation Angle	-15° to 105° (Auto)
Training Angle	$\pm 220^\circ$ (Auto)
Cross Roll	$\pm 10^\circ$ (Auto)
Roll	$\pm 15^\circ$ (Auto)
Training Spotting Correction	±200mm (Hand)
Elevation Spotting Correction	±200mm (Hand)
Future Range	850 to 12,500 m (8cm gun)
Future Range	750 to 15,000 m (10cm gun)
Future Range	700 to 12,500 m (12 & 12.7 cm guns)
Range Rate	±500 knots (Hand)
Range Correction	±3000 meters (Hand)
Range Spotting	±3000 meters (Hand)
Fuze Correction	±10 seconds (Hand)
Outputs from Computer	
Lateral Deflection	$\pm 45^\circ$ (Auto)
Vertical Deflection	$\pm 30^\circ$ (Auto)
Fuze	1 to 43 seconds (Auto)

c. Physical dimensions and weight:

Computer	
Length	1.5 m
Width	0.58 m
Height	0.92 m
Weight	1¼ tons
Director	
Working Circle	5 m dia
Pedestal of Director	1.8 m dia
Height	1.6 m
Weight	3½ tons

d. Transmissions:

Name	Transmitter	Type	From	To
Range	Power Selsyn	Single (500m/rev)	Director	Computer
Present Elevation	Power Selsyn	Single (1°/rev)	Director	Computer
Present Training	Power Selsyn	Single (2°/rev)	Director	Computer
Inclination	Power Selsyn	Single (2°/rev)	Director	Computer
SHIP-Lateral Deflect	Diff. Selsyn	Single (3°/rev)	Director	Guns

Name	Transmitter	Type	From	To
Vertical Deflect	Diff. Selsyn	Single (3^{o}/rev)	Director	Guns
Fuze	Selsyn	Single	Computer	Guns
LAND-Lateral	Diff. Selsyn	Double (28^{o},360^{o})	Director	Guns
" Vertical	Diff. Selsyn	Double (10^{o}, 90^{o})	Director	Guns
Fuze	Selsyn	Double (10', 50")	Computer	Guns

5. Modernization. Below are listed the most modern improvements to this system at the close of the war:

a. Opening fire on an estimated enemy course and speed before computed quantities could be transmitted to the director and without waiting for the solution time to expire.

b. Easier mass production (e.g. no ball bearings less than 1/8" dia).

c. Radar range and, later still, elevation and bearing for indirect and blind fire.

d. Tolerances of 10' of arc in both training and elevating.

e. Better target designation and target acquisition.

f. A calculated accuracy at 25^{o} angle of sight, 45^{o} bearing and provision for, a 500 knot target.

g. No three dimensional cams; used instead ballistic drums with curves thereon, operators used hand follow-up.

h. No wind correction mechanism installed for wind corrections to range or to vertical deflection.

i. No range plot for rate of change of range but rate intergrators used instead for fuze prediction.

In fact few of these improvements were ever carried out on this system and it was due to the difficulties in realizing these improvements that the Type III (shipborne) system was introduced. This system is described in Part I (E) of this report.

C. Electrical AA Computer For Large Caliber Guns

1. General. A description of Japanese anti-aircraft fire control would not be complete without a brief description of an electrical AA computer designed to provide a form of barrage fire for large caliber guns. Figure 9 shows this computer secured to the end of the main low angle table (SHAGEKIBAN Type 92) of BB NAGATO. This, however, is only one part of the device, the other parts include an attachment to the range plot for providing future range to a bulkhead unit which contains drums with paper and metal cruves with follow-up arrangements. (See Figures 10 and 11.) The only remaining components are target speed and target angle transmitters in the director. A description of each of the two main portions follows.

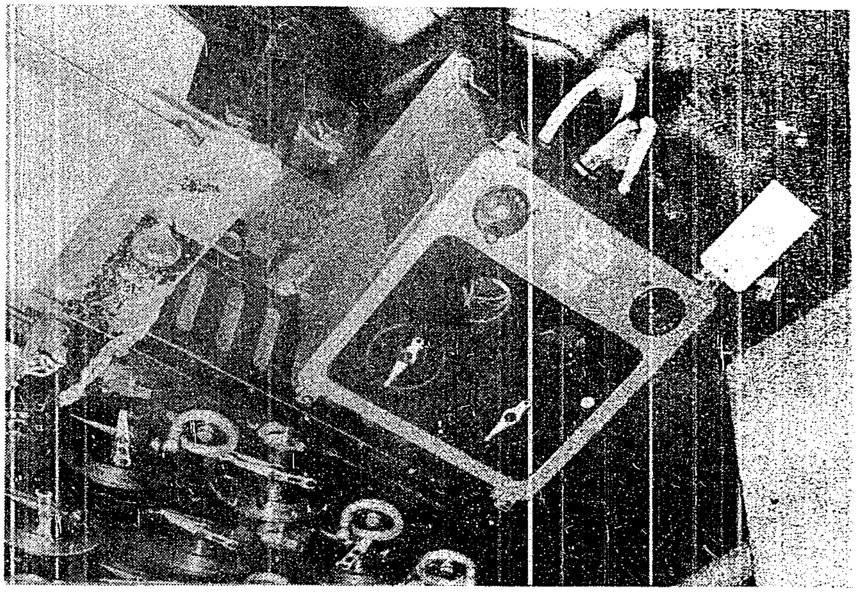


Figure 9
ELECTRICAL AA COMPUTER, BB NAGATO

2. <u>Deflection Calculator</u> (The Bulkhead Unit). One drum is calibrated for vertical deflection and the other for lateral deflection. The hand cranks are therefore rotated in terms of $\frac{\sin\alpha_1 T_1}{R_1}$ and $\frac{T}{R_1 \cos\alpha}$ respectively to satisfy the equation

$$\delta = \frac{v \cos\theta}{R_1 \cos\alpha} T \quad \text{for lateral deflection and}$$

$$\sigma = \frac{v \sin\theta \sin\alpha_1}{R_1} T \quad \text{for vertical deflection.}$$

Where

v - target velocity

θ - target angle

R_1 - future range

α_1 - future angle of sight

T - time of flight

Range rate being $\frac{dR}{dt} = v \sin\theta \cos\alpha_1$

3. <u>Deflection Transmitter</u>. These transmitters are turned by handles which rotate potentiometers to provide an electrical balance in the circuit of which the deflection calculator is a part. When the two voltmeters read zero, the conditions are satisfied and the correct deflections are transmitted to the guns.

4. <u>Deflections</u>. Deflections so calculated are not very accurate and there are no corrections for parallax or dip (parallax due to vertical base).

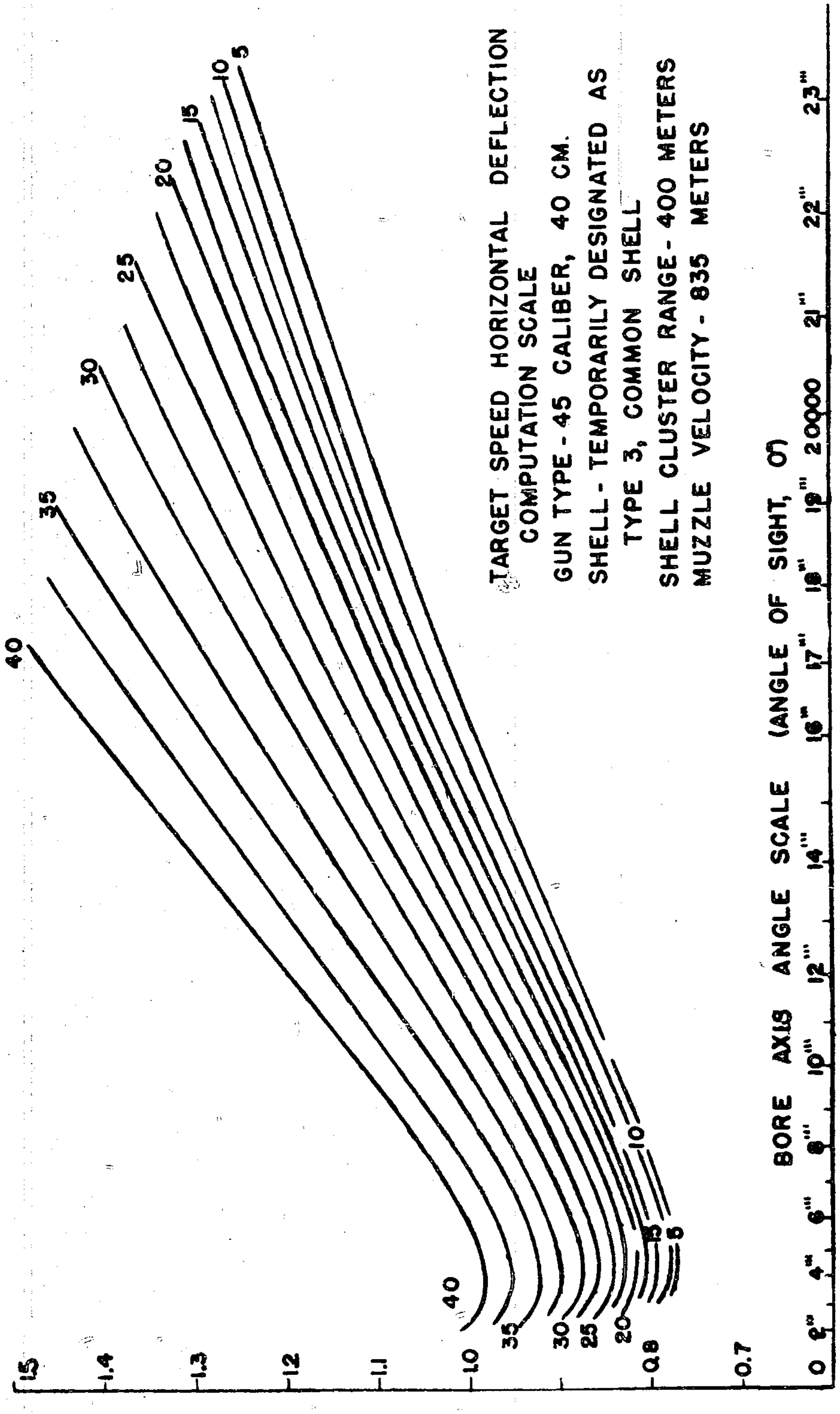
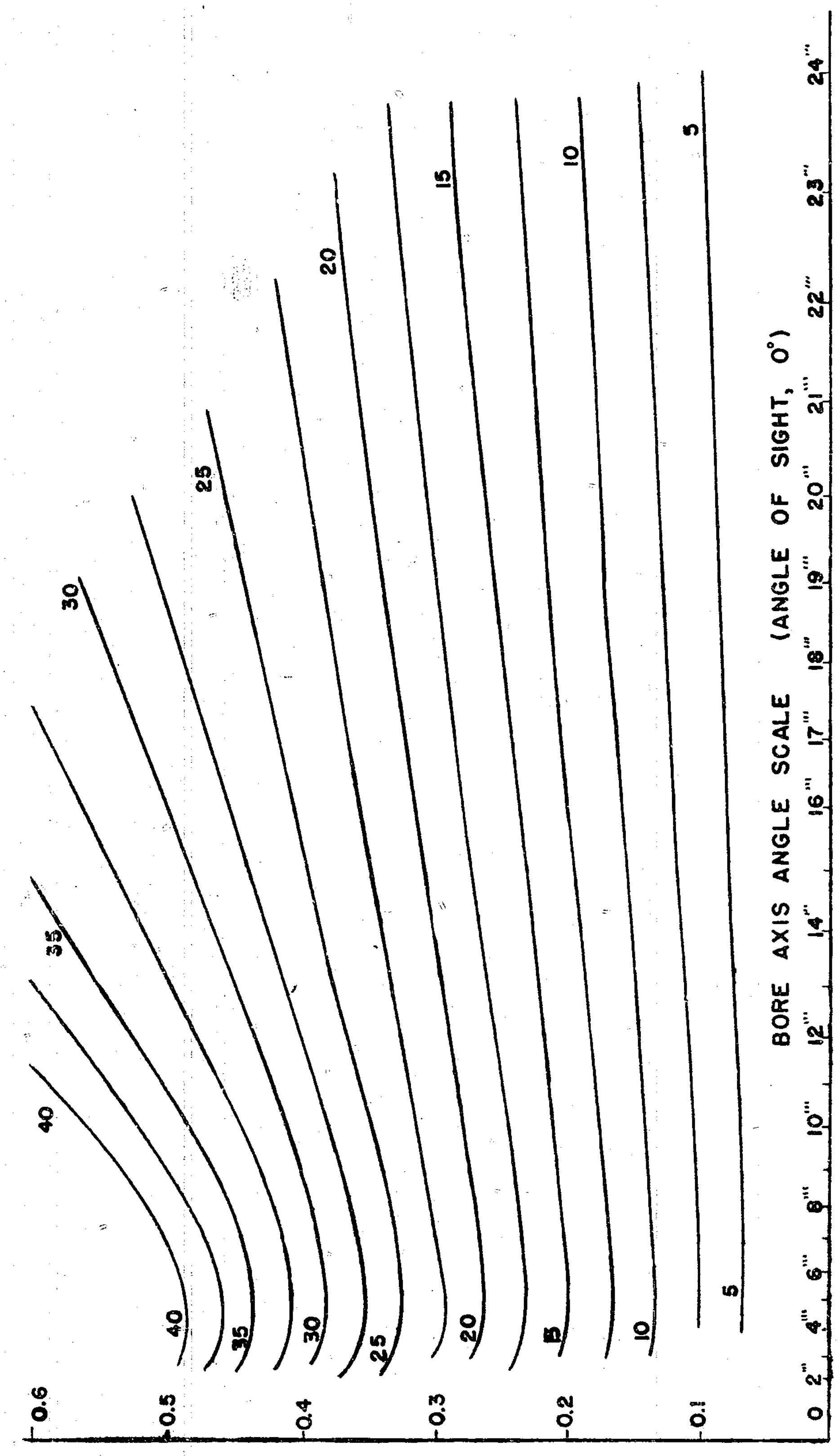


Figure 10a
CURVE USED WITH FIGURE 9



TARGET SPEED VERTICAL DEFLECTION
COMPUTATION SCALE
GUN TYPE - 45 CALIBER, 40 CM.
SHELL TYPE - TEMPORARILY DESIGNATED
AS TYPE 3, COMMON SHELL
SHELL CLUSTER RANGE - 400 METERS
MUZZLE VELOCITY - 835 METERS

Figure 10b
CURVE USED WITH FIGURE 9

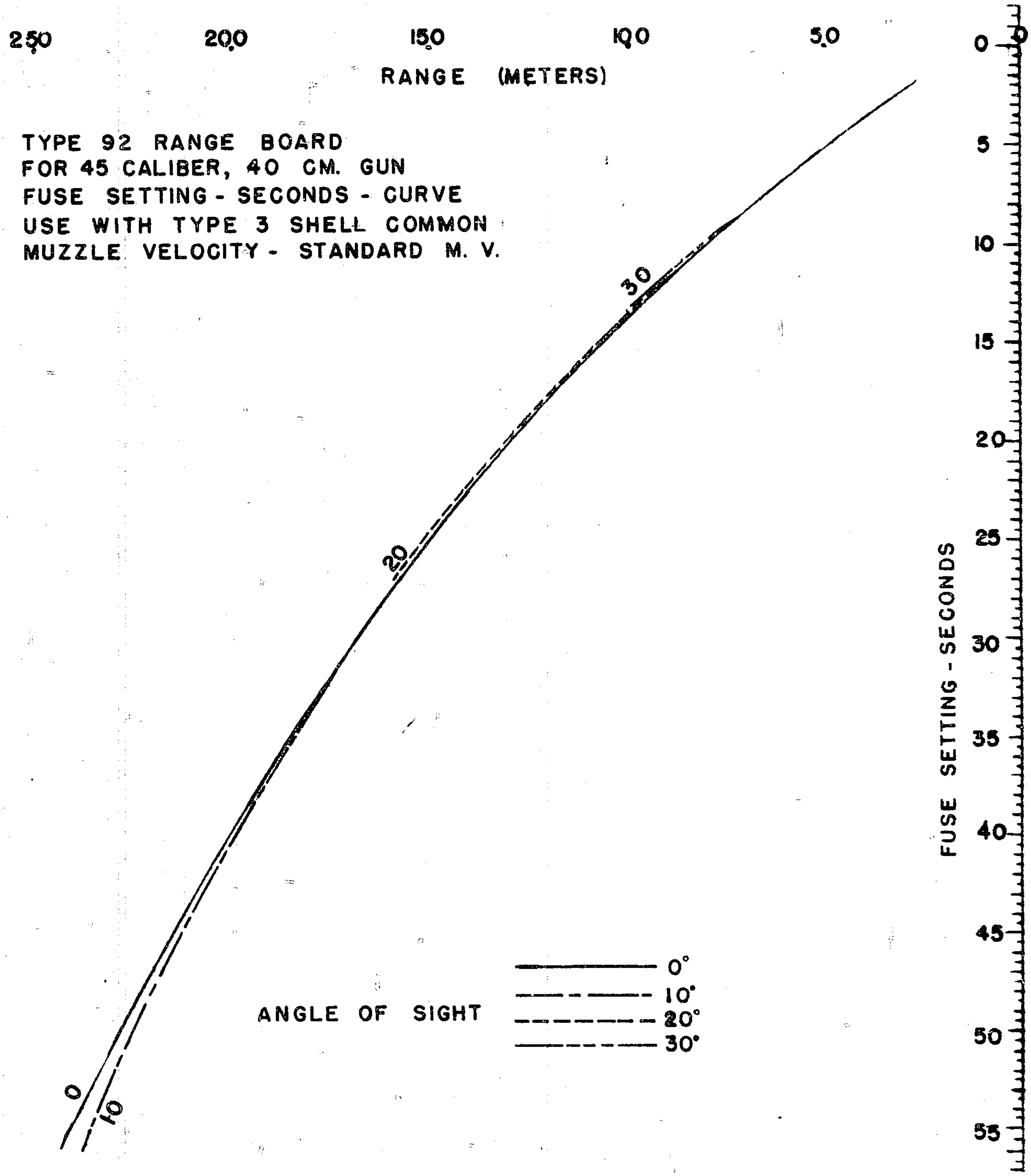


Figure 11

CURVES USED WITH FIGURE 9

Only barrage fuzes were fired with this system and it is understood from interrogations that the equipment was designed initially for use against torpedo bombers. YAMATO and MUSASHI had such devices fitted to their SHAGEKIBAN Type 98.

D. Card System for H.A. Fire for Large Caliber Guns

This card system is not unlike the card system at one time in use in the U. S. Navy and at different times advocated in the British Navy. It is only of interest from a documentary point of view and a brief description is given for this purpose.

1. Input Data Required. Target speed, target inclination and continuous readings of present range.

2. Output Data Required. Future range (for the correct selection of fuze), vertical and lateral deflections.

3. Theory Upon Which the Cards are Based. Figure 12 shows the relationship between present and future range for an approaching target where:

O represents present range

P represents the range at the time of firing

Q represents future range

Assuming that t_1 is time required to use the table (2 to 3 seconds)

t_2 is time required to transmit the data to the gun by telephone (3 to 4 seconds)

t_3 is time required for setting the fuze (5 seconds)

t_4 is loading time (20 seconds)

t_5 is time for obtaining an accurate range cut (15 seconds)

t_6 is time of flight,

and if $\frac{dR}{dt}$ is the range rate, we get

$$R' = R - (t_1 + t_2 + t_3 + t_4)\frac{dR}{dt} \quad (1)$$

$$R_1 = R - (t_1 + t_2 + t_3 + t_4 + t_5 + t_6)\frac{dR}{dt} \quad (2)$$

For NAGATO $(t_1 + t_2 + t_3 + t_4)$ was considered to be a constant and equaled 45 seconds.

Therefore $$R' = R - 45\frac{dR}{dt} \quad (3)$$

Equations (2) and (3) are the fundamental equations to obtain R' and R_1 from any present range R for different values of range rate so that, if present range and range rate are accurately and continuously known, future range and the correct instant for firing can also be continuously obtained. See Figure 13.

4. Practical Application. Ranges from 3000 to 24,000 meters are tabulated in 1000 meter intervals and range rate from zero up to 360 knots in 20 knot intervals with the cards prepared as in Figure 14 for range and deflection. The control officer then applies the present position data, telephones the

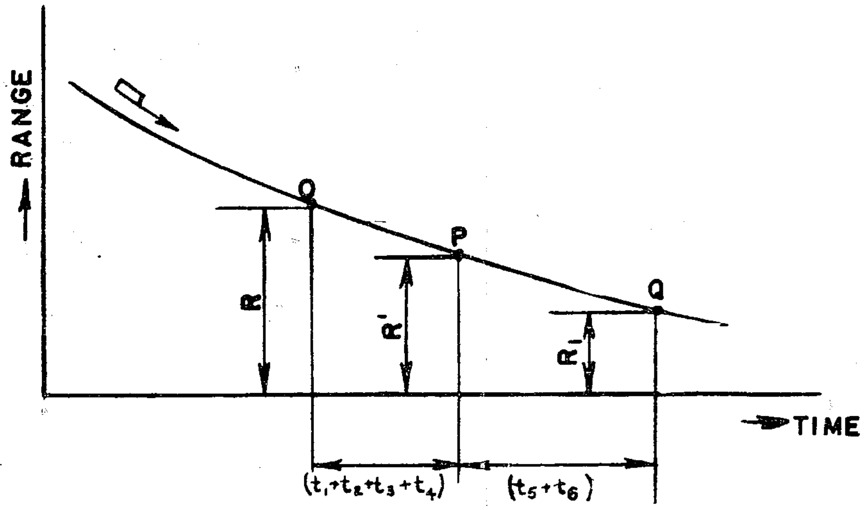


Figure 12
RANGE RATE DIAGRAM

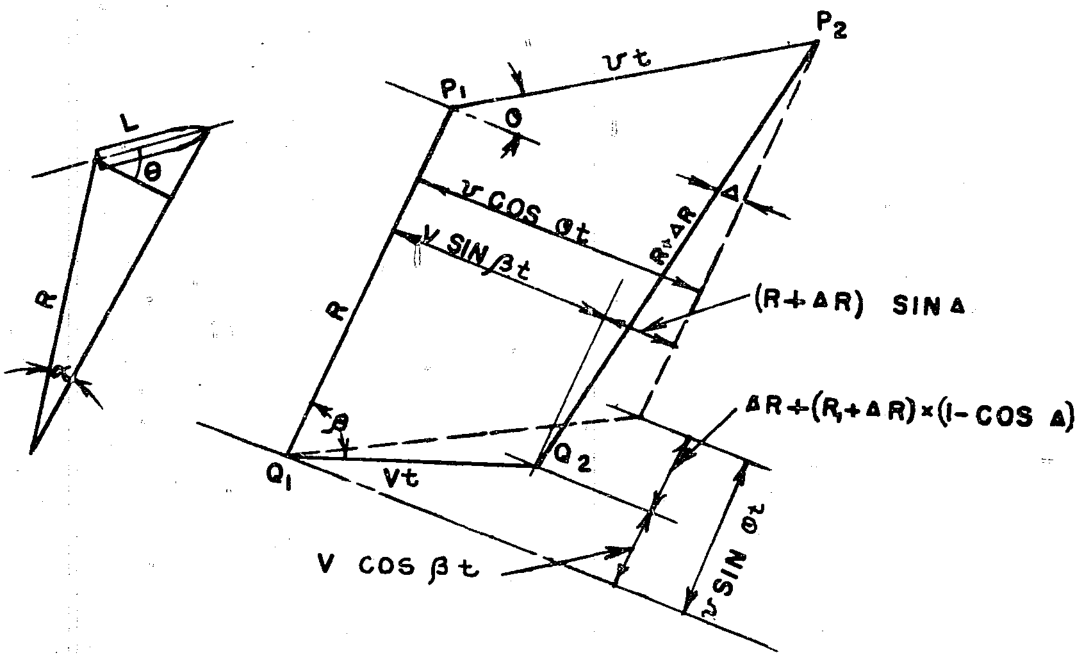


Figure 13
DETERMINATION OF FUTURE RANGE AND INSTANT FOR FIRING

R_1 \ dR/dt	360	340		260		200	180
240	/	/		R'/R		/	/
230	/	/		R'/R		/	/
220	/	/		R'/R		/	/
				R'/R			
				R'/R			
				R'/R			
				R'/R			
30	/	/		R'/R		/	/

EACH TARGET SPEED

R_1 \ θ	90°	80°		10°	0°
240		V/L			
230		V/L			
30		V/L			

Note : V - Vertical Deflection
L - Lateral Deflection

Figure 14
TYPE OF TABLES USED WITH CARD SYSTEM

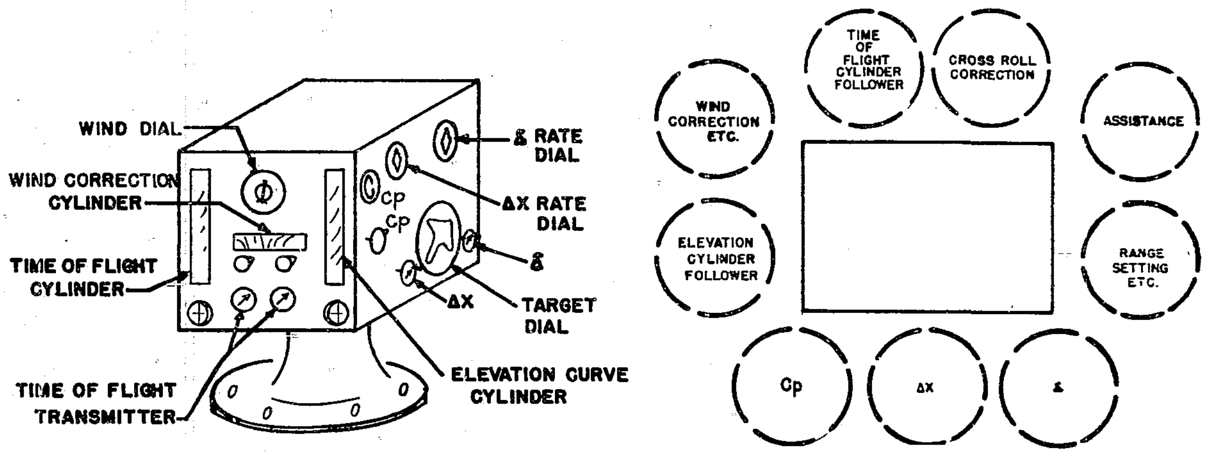


Figure 15
TYPE III DATA COMPUTER FOR SHIP USE, GENERAL ARRANGEMENT

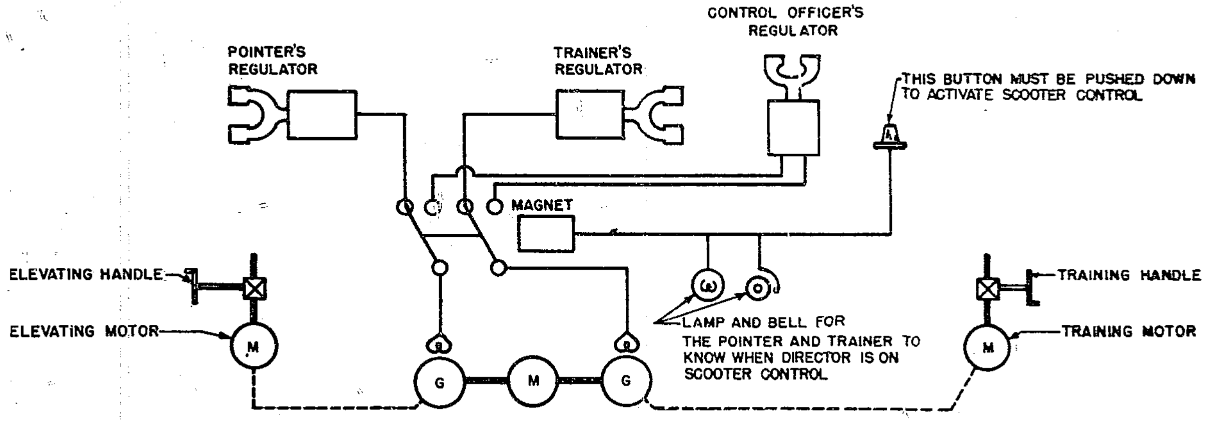


Figure 16

TYPE III DIRECTOR, SCOOTER CONTROL

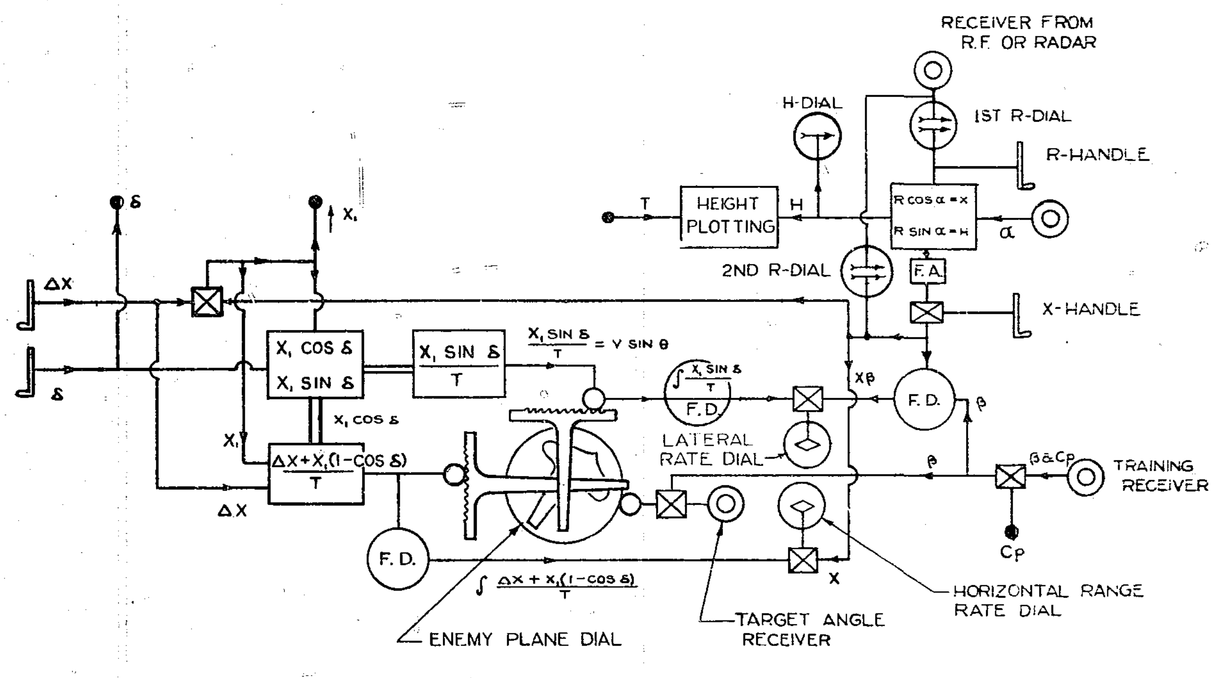


Figure 17

TYPE III COMPUTER, SCHEMATIC

deflections to the guns, and with a buzzer system indicates the fuze setting. When the actual present range is ripe the control officer presses the firing gong which rings in the L.A. Director (HOIBAN) and the layer and trainer press their triggers.

5. The crews had to be practiced continuously for any degree of efficiency. Even accepting human errors, it was difficult to obtain consistant results.

E. Type III Anti-Aircraft Fire Control System (KOSHA SOCHI) For Ship Use

1. General. This system is a shipborne equipment in contra-distinction to the Type III for land use, a description of which follows in section F of Part I. There is no similarity between the two systems, the same type number being indicative only that they were conceived at approximately the same time.

The evolution of this system began after the Battle of Midway in July 1942 at which time it was found that the standard Type 94 System even with modern improvements introduced as a result of war experience, did not meet the requirements of the Japanese Navy.

The Type III is essentially an H.A. System and was intended to supercede the Type 94. Kure Naval Arsenal was selected to manufacture the equipments. The primary requirements in the design of the Type III were to provide a rapid solution time, to ensure that layer, trainer and control officer were observing the same target and to reduce to a minimum the possibility of target discrimination errors. The system of prediction is based upon the rectangular coordinate system and is fully tachymetric. The computer (KOSHA SHAGEKIBAN) transmits gun data direct to the guns (series principle). Other special features are as follows:

a. Complete blind fire using radar data.

b. Control officer has scooter control for slewing to train the director on to any target which he selects.

c. An estimated target course and speed can be set so as to get approximate deflections without having to wait for a solution time.

d. Simple conversion to other ballistics.

e. No ballistic three dimensional cams - hand follow-ups instead.

f. Highest possible accuracy with wind corrections to future range and vertical components of deflection.

2. Computer (KOSHA SHAGEKIBAN). The following, in brief, are the equations to be solved.

$$v \cos \theta T = x_1 \sin \delta \text{ and}$$

$$v \sin \theta T = \Delta x + x_1 (1 - \cos \delta)$$

From these we get

$$v \cos \theta = \frac{x_1 \sin \delta}{T}$$

and

$$v \sin \theta = \frac{\Delta x + x_1 (1 - \cos \delta)}{T}$$

Now

$$v \cos \theta = \frac{x\ \delta\beta}{\delta T}$$

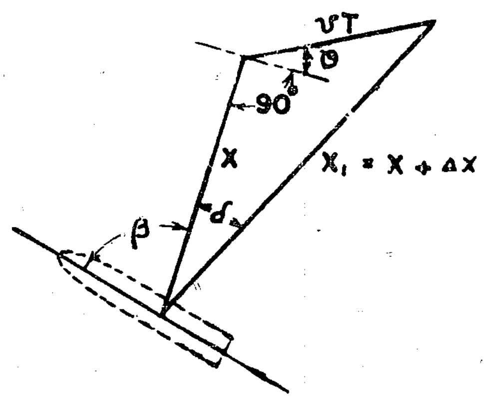


Figure 18
TYPE III, VECTOR DIAGRAM

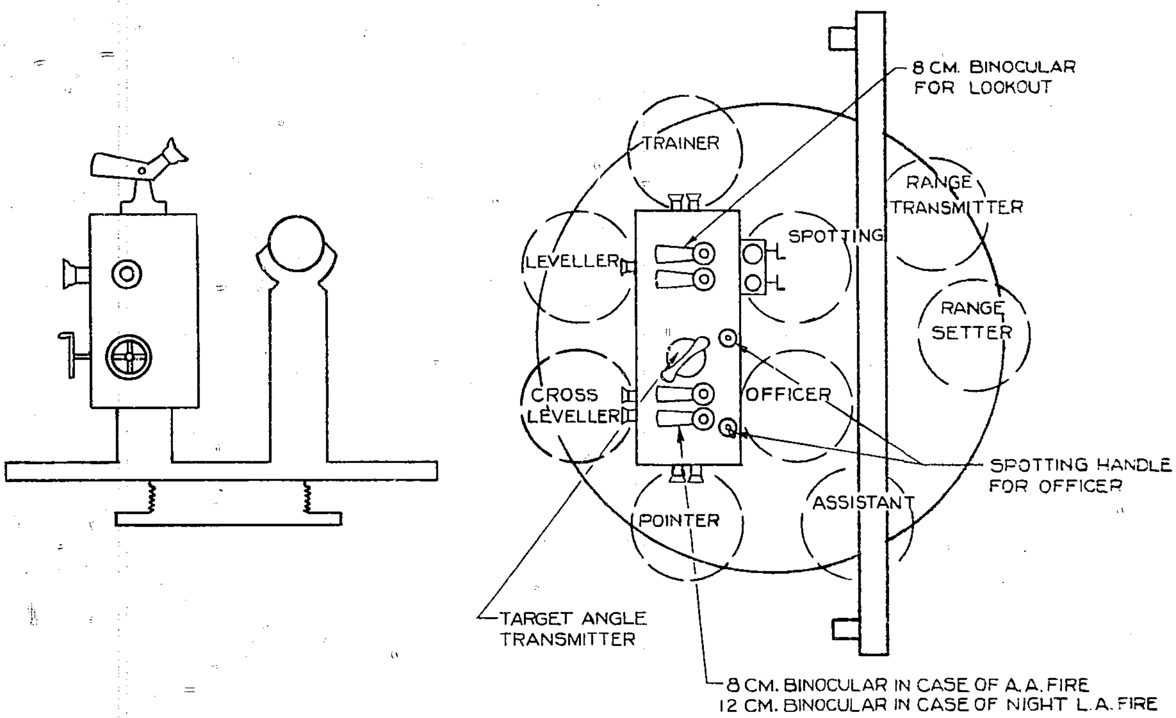


Figure 19
TYPE III DIRECTOR, GENERAL ARRANGEMENT

and
$$y \sin\theta = \frac{dx}{dT}$$

So we get expressions:
$$\frac{x\,d\beta}{dT} = v\cos\theta = \frac{X_1 \sin\delta}{T}$$
$$\frac{dx}{dT} = v\sin\theta = \frac{\Delta x + x_1 (1 - \cos\delta)}{T}$$

For the mechanical solution to the problem, therefore, the following are used:

$$x\,\beta = \int \left(v\cos\theta = \frac{x_1 \sin\delta}{T}\right) \ldots\ldots\ldots\ldots (1)$$

and
$$x = \int \left[v\sin\theta = \frac{\Delta x + x_1 (1 - \cos\delta)}{T}\right] \cdot\cdot (2)$$

The mechanical output from an integrator provides the correct solution to equation (1) if β is an input to the disc, and x is the displacement of the ball cage from the center. Expression $x_1 \sin\delta/T$ comes from multiplying linkages and is fed into the ball cage of another integrator so that the output is $\int v\cos\theta$. These two quantities are subtracted in a differential and the difference shows up on a rate matching dial. By rotating the hand wheel in terms of δ the rates are then matched and equation (1) is satisfied.

Equation (2) is solved in a similar manner. If, when tracking a target, it is necessary to keep handle δ rotating, it indicates a continuously altering target speed, target course, or both, so that in the case of the latter, approximate predictions on a curved course can be obtained. Superelevation and time of flight are obtained by following-up the indicated height on the curves on the drum for superelevation and T_f. The solution of the balliatic functions are carried out in the same way.

This equipment was never completed, but manufacture of the prototype was well underway at the end of the war.

No drawings or data of any sort exist for this equipment, but the five illustrations may give an idea of the general principles.

F. Type III Anti-Aircraft Fire Control System (KOSHA SOCHI) For Land Use

1. General. Chronologically the Type III Anti-Aircraft Fire Control System (KOSHA SOCHI) for land use was more advanced at the close of the war than the Type III System for ship use and one experimental model had been completed. This particular piece of equipment (computer, not director) was actually seen at Toyokawa Naval Arsenal and was one of the very few pieces of equipment in the whole of the area which had not been completely destroyed by fire or by bombing.

This computer for use with the newest type high velocity gun (12.7cm, 50 cal, Type I) had been designed with the following considerations in mind:

a. High accuracy at extreme range; 30,000 meters (plan range).

b. High accuracy for ordinary corrections such as ballistic wind, temperature, and initial velocity.

c. Large separation of gun batteries and directors up to a maximum of 500 meters.

d. Strict economy of materials and labor.

e. Suitability for mass production methods.

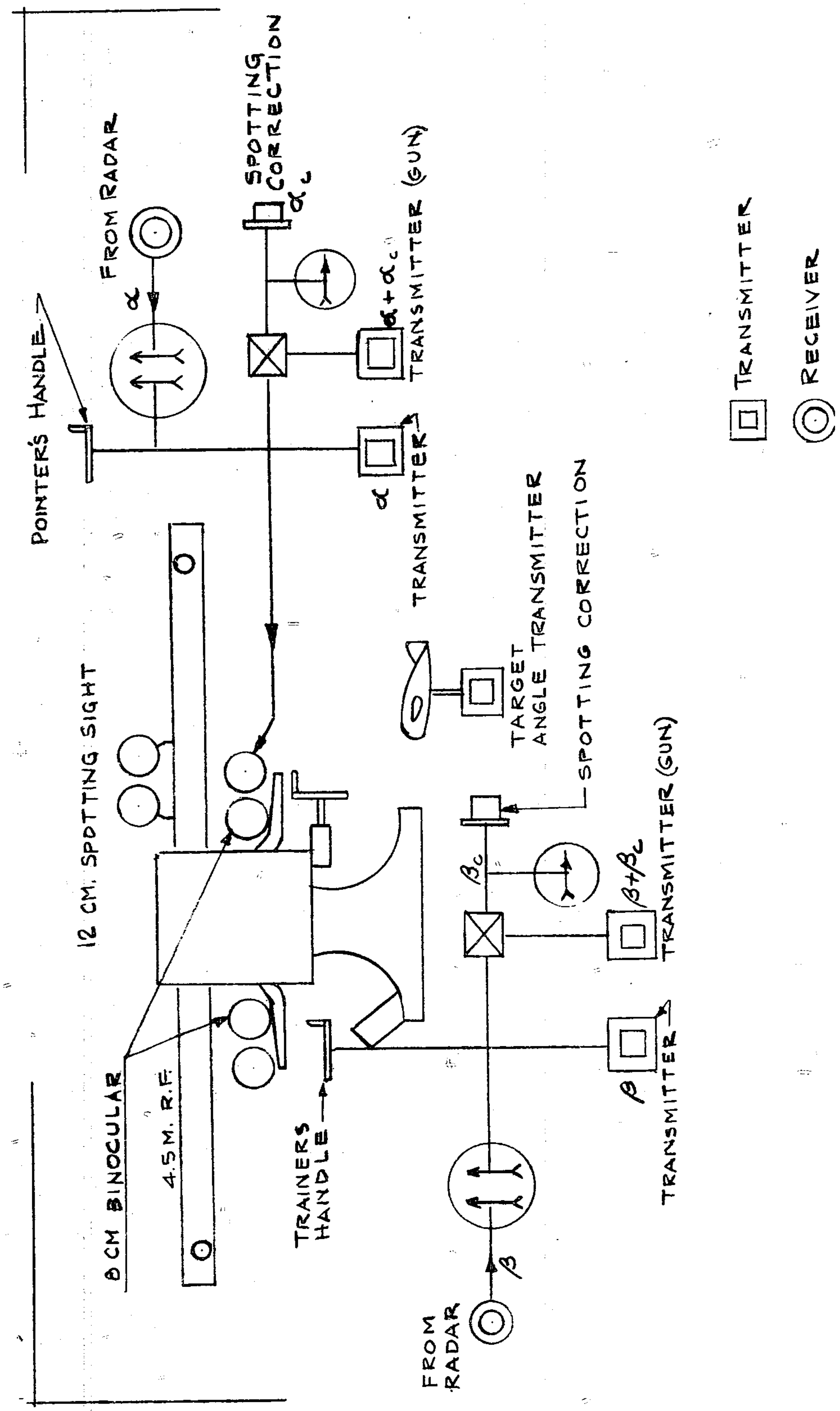


Figure 20
TYPE III DIRECTOR FOR LAND USE, LAYOUT

f. Suitability for easy alteration to other ballistics.

g. Disregard for economy of weight, space and the number of personnel required since it was for land use at fixed positions.

h. Most transmissions, particularly for (a) and (b) were two speed--course and fine--to obtain maximum accuracy.

i. Complete blind fire, but not autofollowing, by radar was considered to be of primary importance.

Although both this equipment and the RAIUN Type 5 (a description of which follows in Part I, section G) are primarily for land use, they have a place in these descriptions of naval fire control since they have as their background naval philosophy and naval design; moreover, they were made under naval auspices at naval arsenals and were to be used by naval personnel.

2. Director (KOSHAKI). This is of the conventional type and similar to the regular Type 94 but without cross-leveling arrangements or sights for level and cross-level. It mounts the standard 4.5 meter rangefinder and has the usual selsyn transmissions. It also has receivers for radar data so that by matching pointers the director can be following radar information instead of optical information. The director arrangements are shown in Figure 20 from which it will be seen that it is not powered or rate aided and the operating personnel are as follows:

a. Layer

b. Trainer

c. Range setter

d. Range transmitter

e. Spotter

3. Computer (KOSHA SHAGEKIBAN)

a. Basic theory. Computations are based on the rectangular coordinate method and the regular formulae are solved:

$$x_1 \cos(\beta + \delta) - x \cos\beta + D \cos\mu = V_x T \cdots\cdots (1)$$

$$x_1 \sin(\beta + \delta) - x \sin\beta + D \sin\mu = V_y T \cdots\cdots (2)$$

The basic theory is similar to that used in the Sperry Army Predictor, though the method of solving the equations is different and is shown briefly in the schematic diagram Figure 21. The chief characteristics of this computer is that it is in five separate pieces with mechanical shafting connecting the first four and electrical wiring only to the fifth. It is arranged in this manner for the sake of convenience and because for land purposes no economy of space or weight is necessary. In order to obtain the highest accuracy possible very large resolvers are used (about 2 feet in diameter). Time of flight is produced by following a curve upon a drum and ballistic corrections are made up from:

(1) Vertical and lateral deflection due to wind velocity.

(2) Time of flight correction due to wind velocity.

(3) Vertical deflection due to I.V. drop and air density.

(4) Time of flight correction due to I.V. drop and air density.

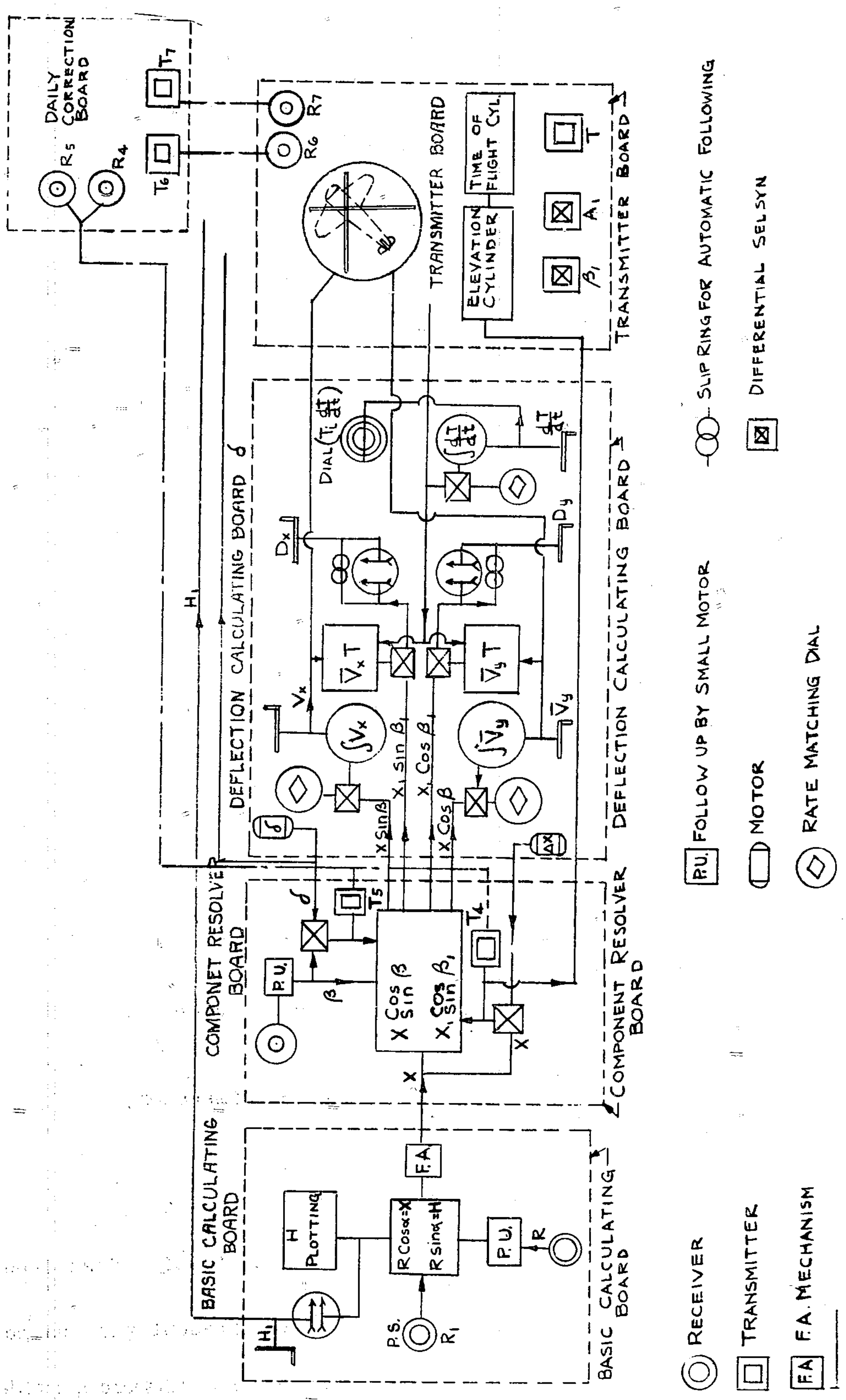
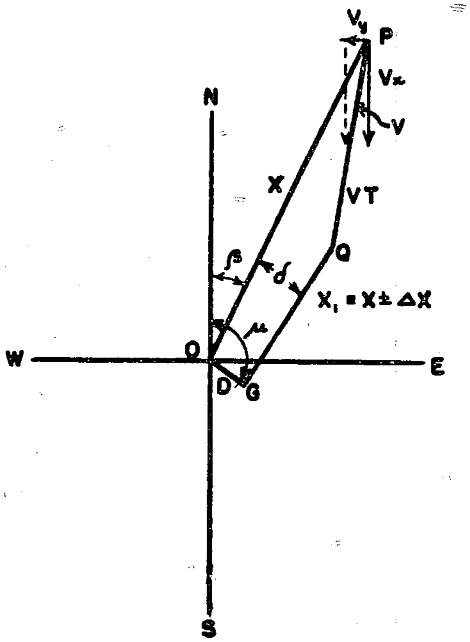


Figure 21

TYPE III DATA COMPUTER, SCHEMATIC



O Position of director

G Position of gun

P Present position

Q Future position

x Present horizontal range

$x_1 = \Delta x + x$ Future horizontal range

T Time of flight

D Distance between director and gun

δ Lateral deflection

μ Azimuth bearing of gun with respect to director

β Compass bearing of target

V_x, V_y, V_z, Velocity components of V(V_z third dimension)

Figure 22
TYPE III VECTOR DIAGRAM

b. Physical arrangements. The five boxes can be briefly described as follows (see Figure 23):

(1) Slant range and elevation are received, present plan range and height are calculated.

(2) Component resolvers solve $x \cos \beta$, $x \sin \beta$, $x \sin(\beta+\delta)$ and $x \cos(\beta+\delta)$

(3) Deflections are calculated by rate mechanisms. δ and Δx are obtained also, by means of following a pointer on a drum, the time of flight correction resulting from dead time is calculated.

(4) Time of flight and quadrant elevation are obtained by following curves on cylinders. Corrections to vertical deflections and time of flight from the ballistic correction box show up on selsyn receivers. These corrections are added differentially to the vertical components to provide gun elevation. Lateral deflections however, are added directly to the outgoing gun training transmissions.

(5) The corrections are calculated by electrical resolvers (i.e. Wheatstone Bridge type of circuit, similar to the principle employed in the Electrical AA Fire Control System for the main battery of NAGATO). The various ballistic functions which can be obtained by future horizontal range and height are determined by following curves on cylinders, the rotations of which are proportional to future range.

c. The data required are:

(1) Superelevation

$\psi = \psi_o + \psi_1$ where ψ_o is standard superelevation and ψ_1 is correction including wind, I.V. correction, etc.

(2) Lateral deflection (D_T)

$$D_T = \delta + Z + \Delta$$

where δ is lateral deflection and Z equals drift and Δ wind correction.

(3) Time of flight T_1 and T_2 (Fuze time)

$$T_1 = T_o + T^1$$

where T_0 equals standard time of flight and T^1 equals correction including wind, I.V. drop, and air density.

$$T_2 = T_1 + \Delta T + T_c$$

where T_c is correction due to dead time

$$T_c = T_1 \frac{dT}{dt}$$

where T_1 = dead time)

ΔT = correction for powder fuze

d. Arrangement of personnel. This is shown in Figure 23

G. Type 5 Anti-Aircraft Fire Control System for Land Use, "RAIUN" (Thundercloud)

1. History. Of all the Japanese fire control systems this, perhaps, is the most interesting, as it represents the very latest and most up-to-date thinking at the close of the war. Comdr. ICHINOI was responsible for most of the design and planning.

The scheme was an attempt to defend the vital Kure Area against B-29 attacks. The equipment was actually finished and satisfactory trials com-

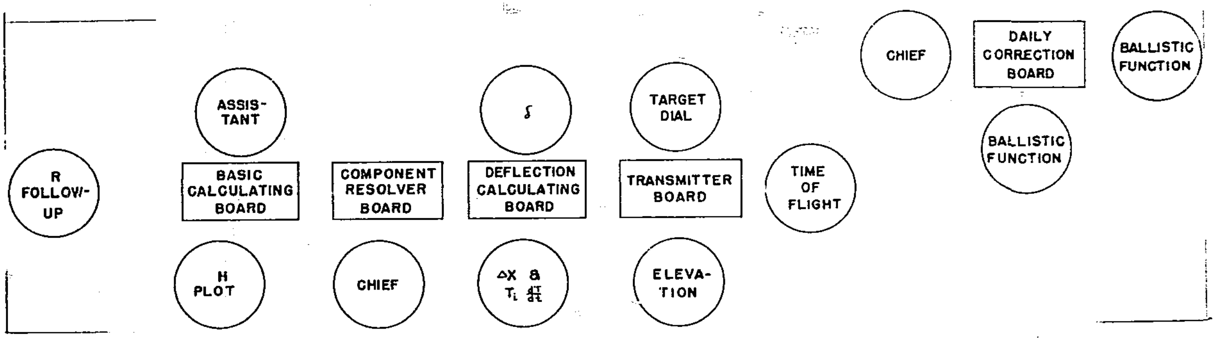


Figure 23
TYPE III, ARRANGEMENT OF PERSONNEL

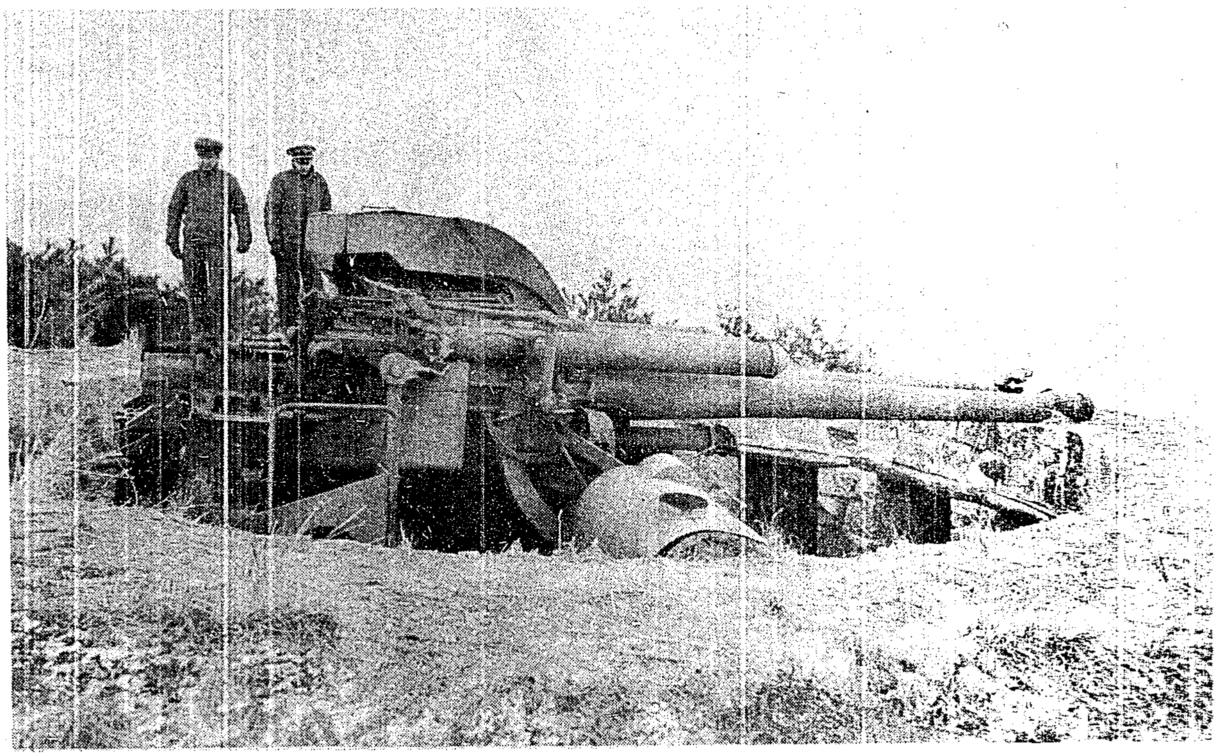


Figure 24
RAIUN TWIN MOUNTING

pleted when the war came to an end.

2. General Description. The whole purpose of the scheme was to provide the maximum concentration of fire in the smallest possible three dimensional pattern in the sky.

The gun batteries to be controlled were spread out on the hill tops surrounding KURE. There were five batteries in all, each battery consisted of three twin 12.7cm guns (Figures 24 and 25). This meant 30 guns capable of firing, say, 10 rounds per minute or a total, therefore, of 300 rounds per minute.

There was a further proposal to lay cables to anchored cruisers so as to control their guns with the data from the RAIUN.

In addition, it was hoped to use a Type III (land) equipment suitably modified for 16-inch guns so that battleships could also engege attacking bomber formations with their main armament when conditions permitted.

Excluding the ship's batteries, however, and considering the five groups of three twin mountings only, one of the groups was known as the main battery and the others as auxiliary batteries. Each battery had its own optical rangefinder (Figure 26) and auxiliary director, but the main battery had in addition the radar antenna and main director of which the latter was identical to the KOSHA SOCHI Type III already described.

The calculating mechanism for providing gun data for transmission to these batteries was housed in a building halfway down the mountain side and associated with a general communication center close by.

This calculating mechanism was the heart of the RAIUN and consisted of seven large units (0.8m x 0.6m x 0.6m). These units (see Figure 27) performed quite separate and special functions as follows:

a. Setting Unit. So called because all initial settings are made in this unit, such as wind speed, target speed and ballistic data.

b. and c. Transmission Unit. For transmitting gun data corrected for time of flight and quadrant elevation to two auxiliary batteries each. (See Figure 28.)

d. Deflection Unit. For providing lateral deflection, drift, and bearing, and transmitting this data to four auxiliary batteries. (From this it will be seen that two transmission units are required for the four auxiliary batteries and these are mechanically connected to the setting unit--as is also the deflection unit.)

e Firing Unit. So called since the actual fire of the batteries is controlled from this unit. It consists of a plot providing time of flight data; the guns are fired only when the fuzes become "ripe" or, in other words, when the time of flight is such that all bursts occur at the same instant of time (at the same place). See Figure 29 and the right hand diagram of Figure 31.

f. Situation Unit. This is a plan position indicator and is supplied with radar data so that the control officer can observe the position of attacking bombing formations and select a new target if necessary. The original scheme was arranged for present position data, but this was altered to future position information since this provided the control officer with more "up-to-date" information.

g. Type III Data Computer (KOSHA SOCHI). The standard design of data computer is described previously. In the equipment at KURE,

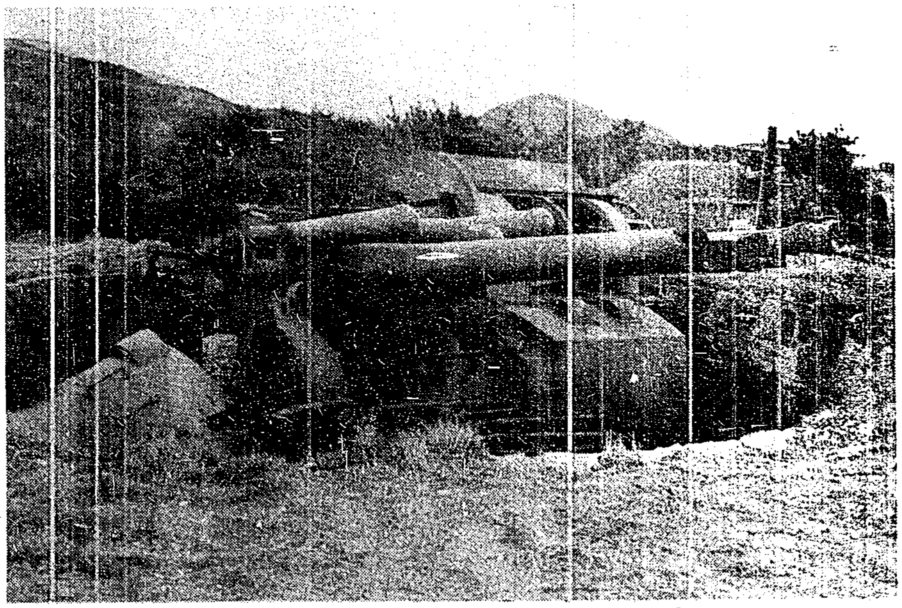


Figure 25
RAIUN TWIN MOUNTING

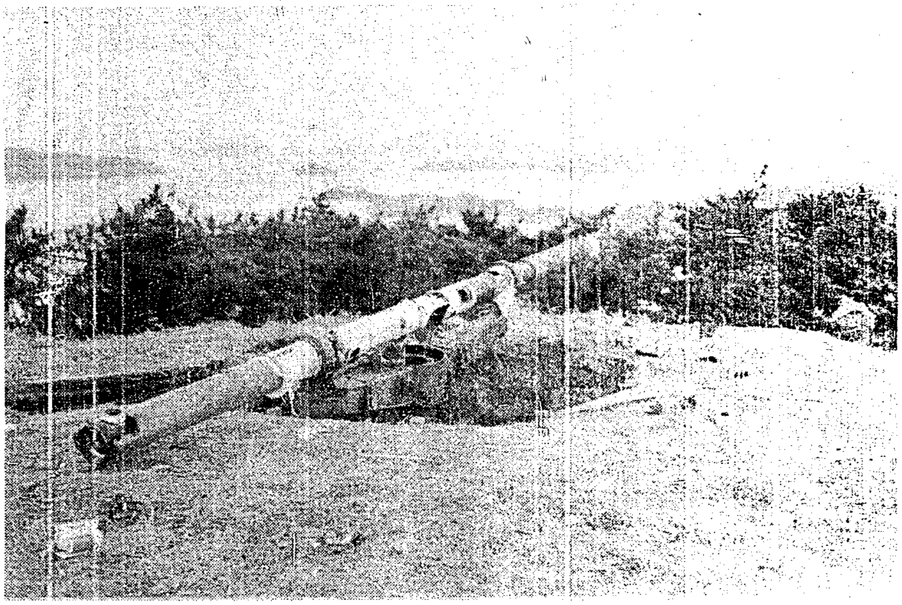


Figure 26
RAIUN RANGE FINDER

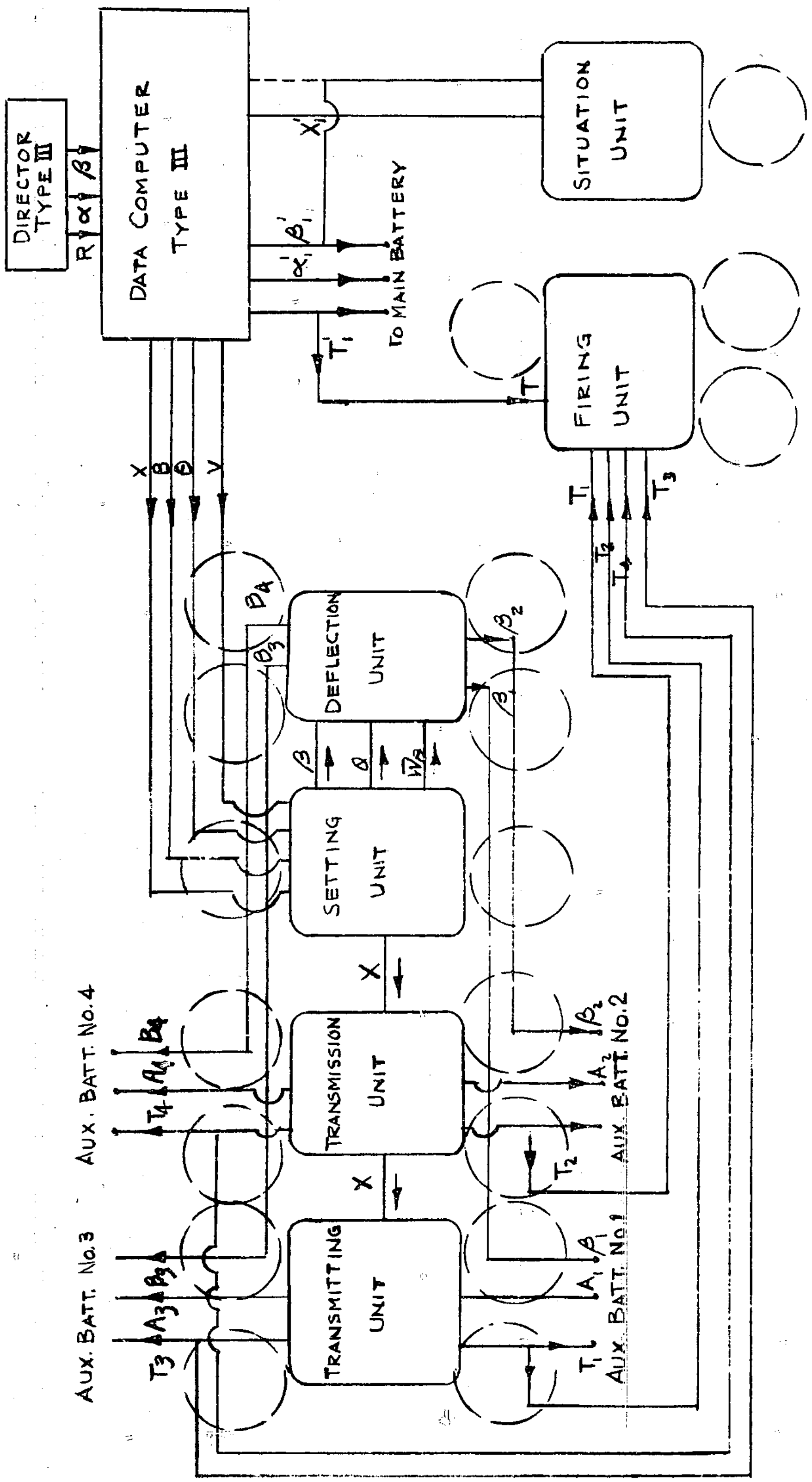


Figure 27
RAILN GENERAL ARRANGEMENT

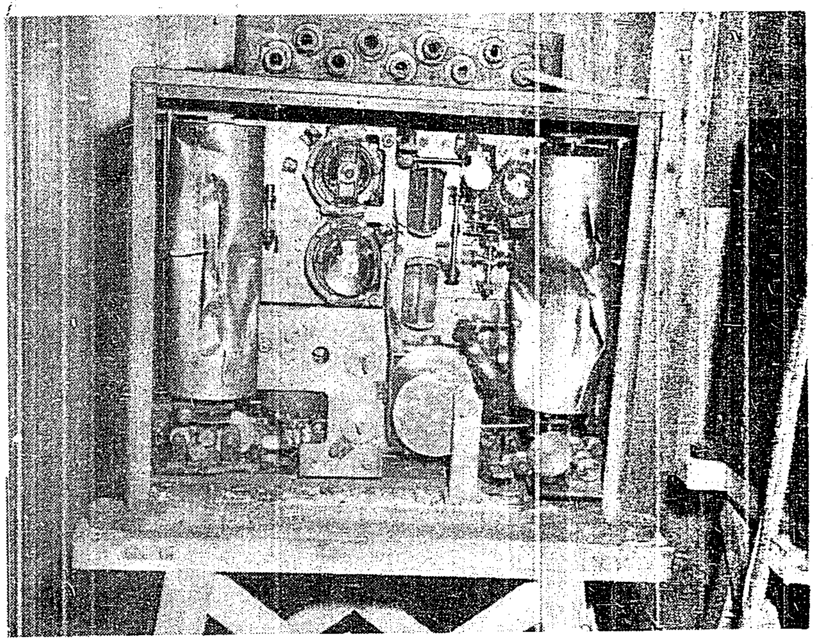


Figure 28
RAIUN TRANSMISSION UNIT

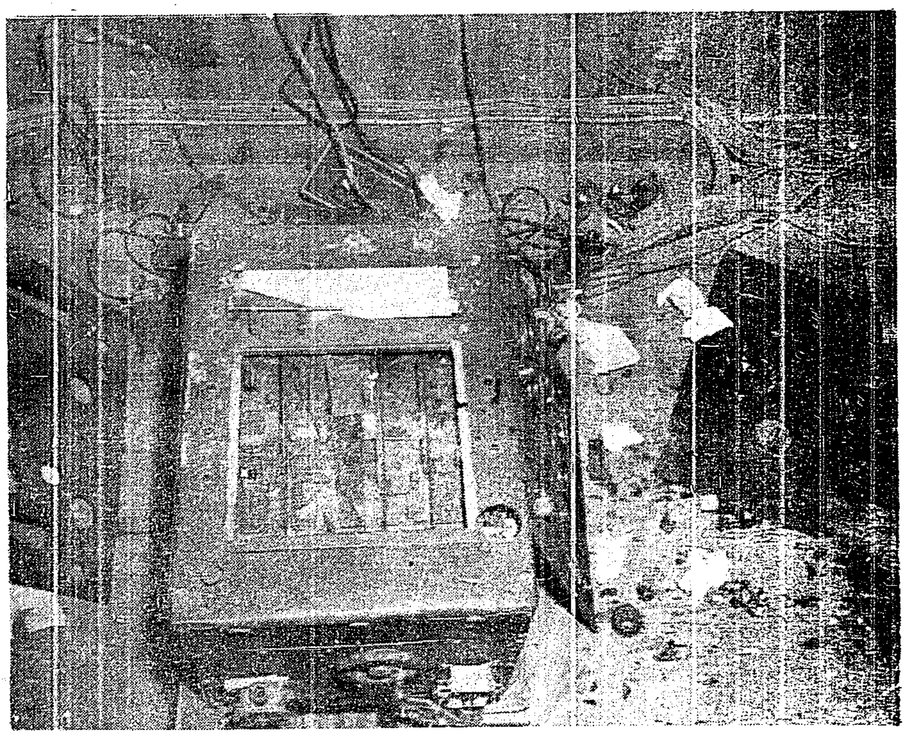


Figure 29
RAIUN FIRING UNIT

however, the Type III data computer was missing and a simplified type with resolvers had been in use. The Type III would have been installed when available.

3. Mechanisms and Formulae

a. Resolvers. The solution of trigonometrical ratios in the RAIUN is performed by electrical resolvers. The resolver used is an ordinary selsyn whose three phase winding has been converted to two phase and whose "stator" could be rotated as well as the rotor and independently of the latter. This is done in order to obtain $\xi \sin(\theta - \phi)$ or $\xi \cos(\theta - \phi)$ in the form of a voltage. If a voltage equal to Σ is given to the stator and the stator and rotor turned to values of θ and ϕ respectively, then the voltage in the phase of the rotor will be proportional to ξ sin or ξ cos and the other will be ξ cos or ξ sin. Figure 30 shows how this can be done. It will be seen that by means of a voltmeter G_1, $\xi \cos(\theta - \phi)$ can be read or by using a potentiometer and zero method with G_2, $\xi \sin(\theta - \phi)$ can be obtained in terms of the mechanical rotation of a handle. Figure 30 also shows how two vectors A and B can be added and a resultant vector C obtained by completing the parallelogram for solving:

$$C = A\cos(\beta - \beta_1) - B\cos(\beta_2 - \beta)$$

and

$$A\sin(\beta_1 - \beta) - B\sin(\beta_2 - \beta) = 0$$

These vectors are solved by the resolver method as shown in Figure 31 in which G_1 indicates the zero position voltmeter. The handle β must be rotated until the voltmeter G_1 is at the zero position and handle C rotated until G_2 is at zero. (Some modifications had been made to this scheme; the two rotors were not rigidly coupled but had a differential between them. The stators under these conditions could be fixed. Since the motions between rotor and stator are only relative, it is reasonable that by this method $\beta_1 - \beta_2$ can be solved equally well.) It can now be seen that this resolver method is well adapted for solving a pentagonal figure as shown in Figure 32 in which G_1 represents the gun position and 0 the director.

In its simplest form, this pentagon can be reduced to a triangle when the gun is sited with the director and there is no wind vector.

The number of pentagons to be solved in this manner are equal to the number of auxiliary batteries. The solution of these pentagonal figures is really the heart of the RAIUN System. It will be appreciated, therefore, that there are no parallax problems in this system and the problem is solved separately for each gun position.

b. Calculated functions and quantities.

(1) Wind. Suppose that the projectile is moved L meters due to the wind during the time of flight T, then L/T represents some velocity of the wind (but different from the actual wind velocity W_V) and also a function of W_V, range, and height.

(2) Time of Flight and Superelevation. These are obtained by following-up the regular height curves of time of flight and quadrant elevation, the rotation of which is in terms of horizontal future range.

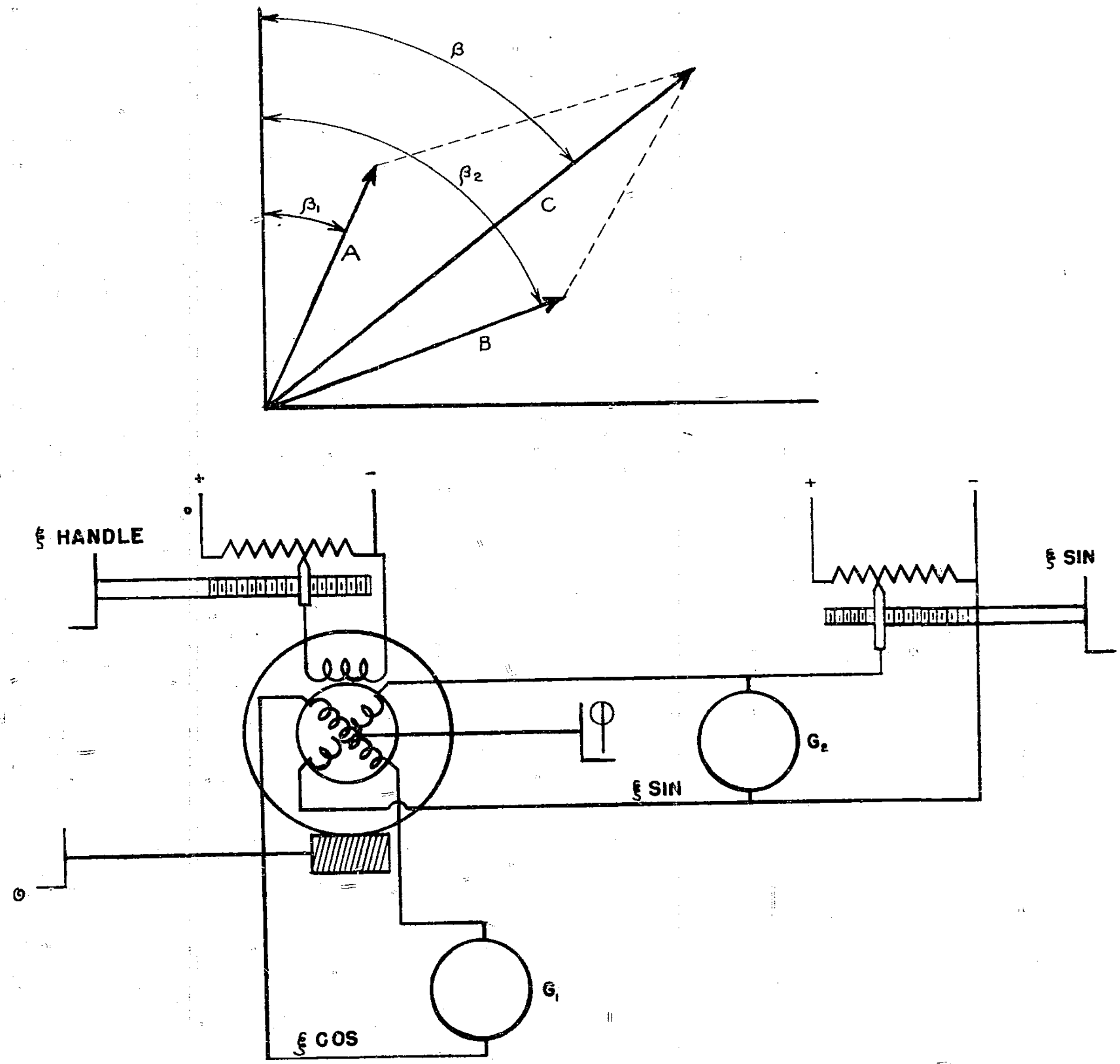


Figure 30
RAIUN RESOLVER PRINCIPLE

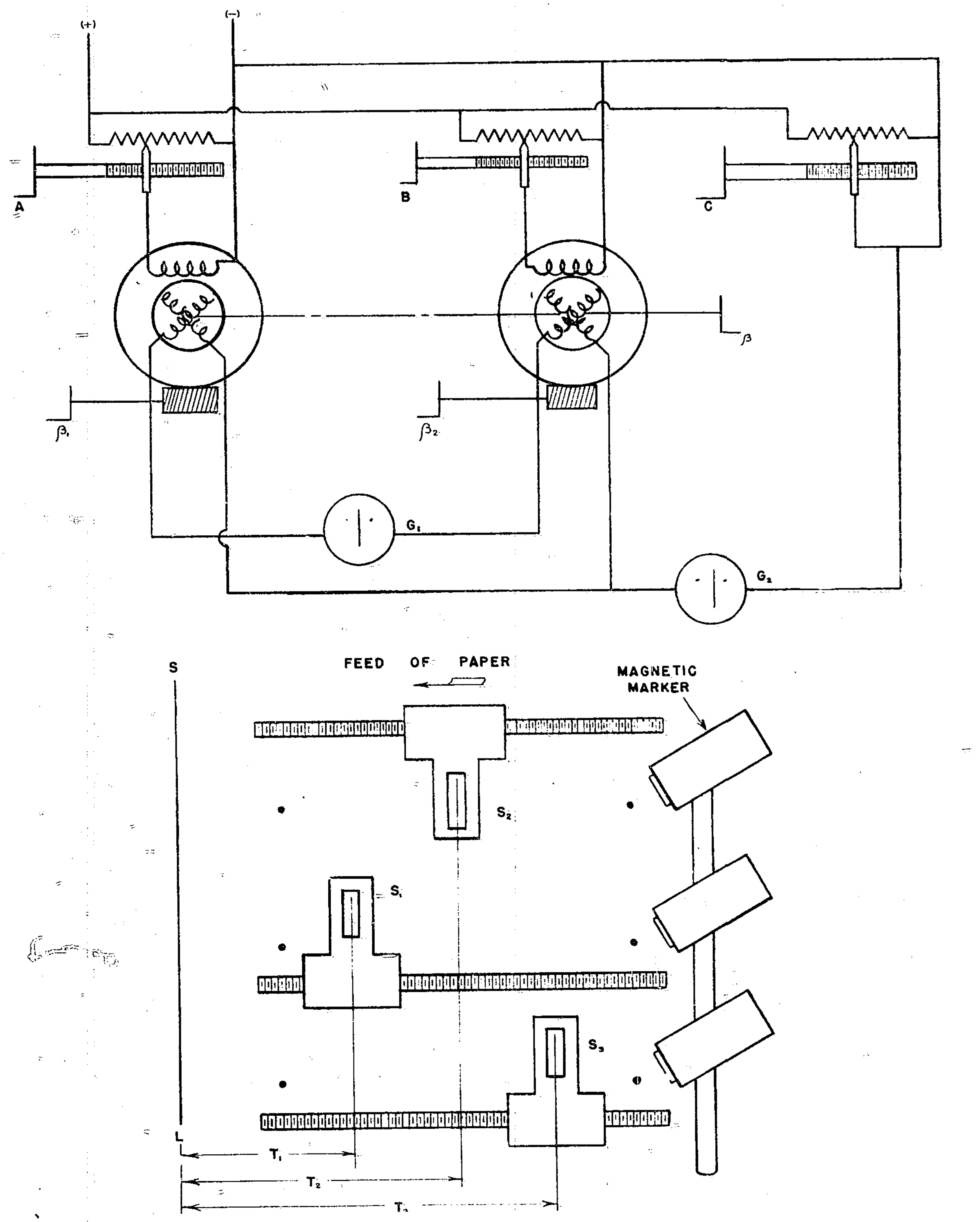
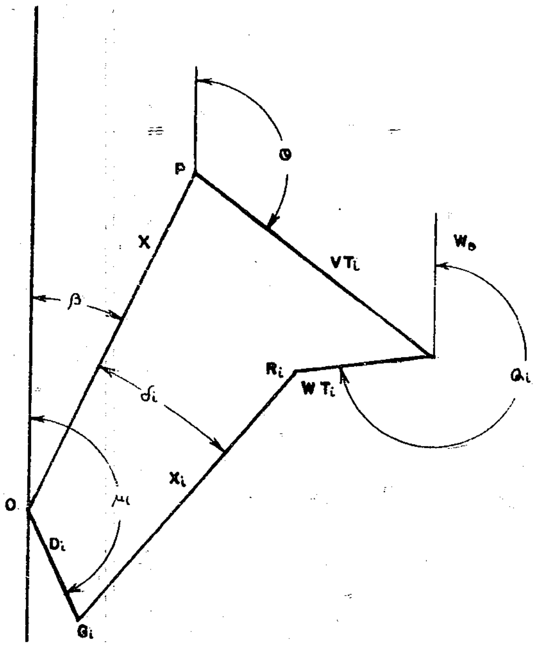


Figure 31
RAIUN RESOLVER PRINCIPLE



O-POSITION OF MAIN DIRECTOR (MAIN-BATTERY)
P- PRESENT POSITION OF TARGET
G_i- NO i AUX-BATTERY
D_i-DISTANCE OF AUX-BATTERY FROM O
μ_i-ANGLE OF AUX-BATTERY
T_i-TIME OF FLIGHT REFERRED TO NO i AUX-BATTERY
Q_i FUTURE POSITION OF TARGET WITHOUT WIND REFERRED TO G_i
R_i- FUTURE POSITION OF TARGET REFERRED TO G_i
X_i- FUTURE HORIZONTAL RANGE
V- TARGET HORIZONTAL VELOCITY
W -FUNCTION OF WIND VELOCITY W_v, X_i & HEIGHT
Θ, W_o - TANGENT ANGLE & DIRECTION OF WIND

Figure 32

RAIUN SOLUTION OF PENTAGON

(3) Fuze Time. The method of obtaining simultaneous bursts has been referred to in paragraph 2 under the heading "Firing Unit". The paper moves in the direction of the arrow (see Figure 31, right hand diagram) and the slits in the carriage throw light up to the underside of the paper. The distance of each slit of light from the base line SL represents the time of flight for each battery. Each battery, therefore, is fired when the correct moment is determined by the plot operator who pushes the appropriate button.

4. <u>Accuracy of Electrical Resolvers</u>. The component electrical resolvers referred to earlier have an accuracy of not better than 2° owing to a poor sine wave form. These resolvers were adapted from ordinary synchros, but it was planned to design some specially for the job for which an accuracy of 1° was desired.

Two of the resolvers have been sent to the United States for further study. Two of the time of flight and quadrant elevation drums have also been shipped.

H. <u>H.A./L.A. Destroyer Fire Control Systems - Type 2 HOIBAN and Type 2 BIODOBAN</u>

1. <u>General</u>. This system was specially designed for use in large destroyers as an all purpose equipment. The designers were faced with the task of designing a computer suitable for both L.A. and H.A. fire; although the BIODOBAN did meet the requirements, the complications were considered to be out of all proportion. For instance, instead of making the equipment basically suitable for either H.A. or L.A. (that is to say, for large angular rates or alternatively small angular rates) an attempt was made to use the same mechanisms to provide equal accuracy for both extremes by the interposition of change gears and clutches operated by change-over handles. To change over, therefore, from H.A. to L.A. and vice versa, required very careful drill and a complicated lining up procedure.

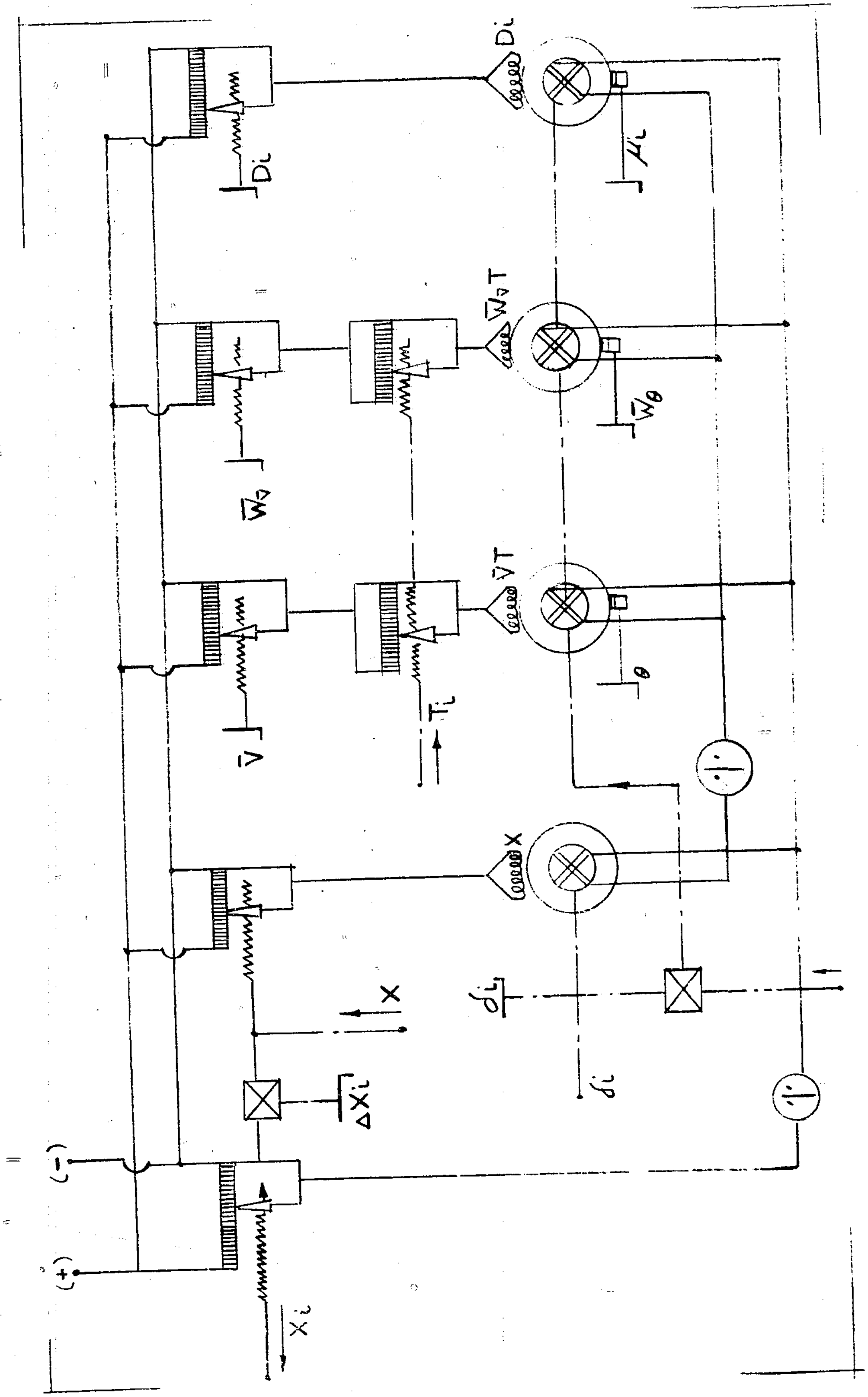


Figure 33

RANGE RESOLVERS - SCHEMATIC DIAGRAM

In spite of the extreme complication necessary to obtain equally accurate H.A. and L.A. fire and inasmuch as guns used were primarily L.A. weapons, (12.7cm, 50 cal) the ships fitted with these equipments were not satisfactory for H.A. fire.

The system belongs to the conventional "series" type of system and gun transmissions are made direct from the computer.

2. Type 2 (HOIBAN) Director. The director (see Figure 34) is entirely enclosed in a tower and the whole structure is trained by hydraulic power. The director is bi-axial and there is no cross-leveling of the optics as in the full H.A. systems. On the top of the tower is mounted a 3 meter rangefinder which is free to train (separately from the tower) and the operator moves it quite easily. In the tower in addition to the regular layer's and trainer's sights, there are two others; one for the control officer for spotting and the other for use as an inclinometer (target angle).

The following personnel are required for operation:

a. Trainer
b. Layer
c. Range setter
d. Range taker
e. Control officer
f. Control leveller
g. Inclinometer operator
h. Communications
i. Communications

Figure 34 shows the positions of these men. Under conditions of H.A. fire, the operator previously carrying out the duties of inclinometer operator becomes the leveller and level is transmitted by differential selsyn to the computer (BIODOBAN).

Its size is 2 meters in diameter and 2½ meters high and weighs 4½ tons. This director was designed and manufactured in Kure Arsenal.

3. Computer (BIODOBAN) Type 2. This H.A./L.A. Computer (see Figure 35) is stated to be the most complicated piece of fire control equipment made by the Aichi Clock Company.

The method of prediction is the "angular rate multiplied by time" principle using rate integrators. In more detail it may be stated as follows:

a. Range rate due to target movement is obtained from a range plot.

b. For vertical deflection, the vertical rate component is multiplied by time of flight.

c. For lateral deflection; the lateral rate component is multiplied by time of flight.

To get these rates, the rate matching method is adopted and the following equations are solved mechanically:

(1) Range

$$R_1 = R + \int \frac{dR}{dt} + \Delta R_1 + R_{ic} + T_1 \frac{dR}{dt}$$

where R_1 is future range

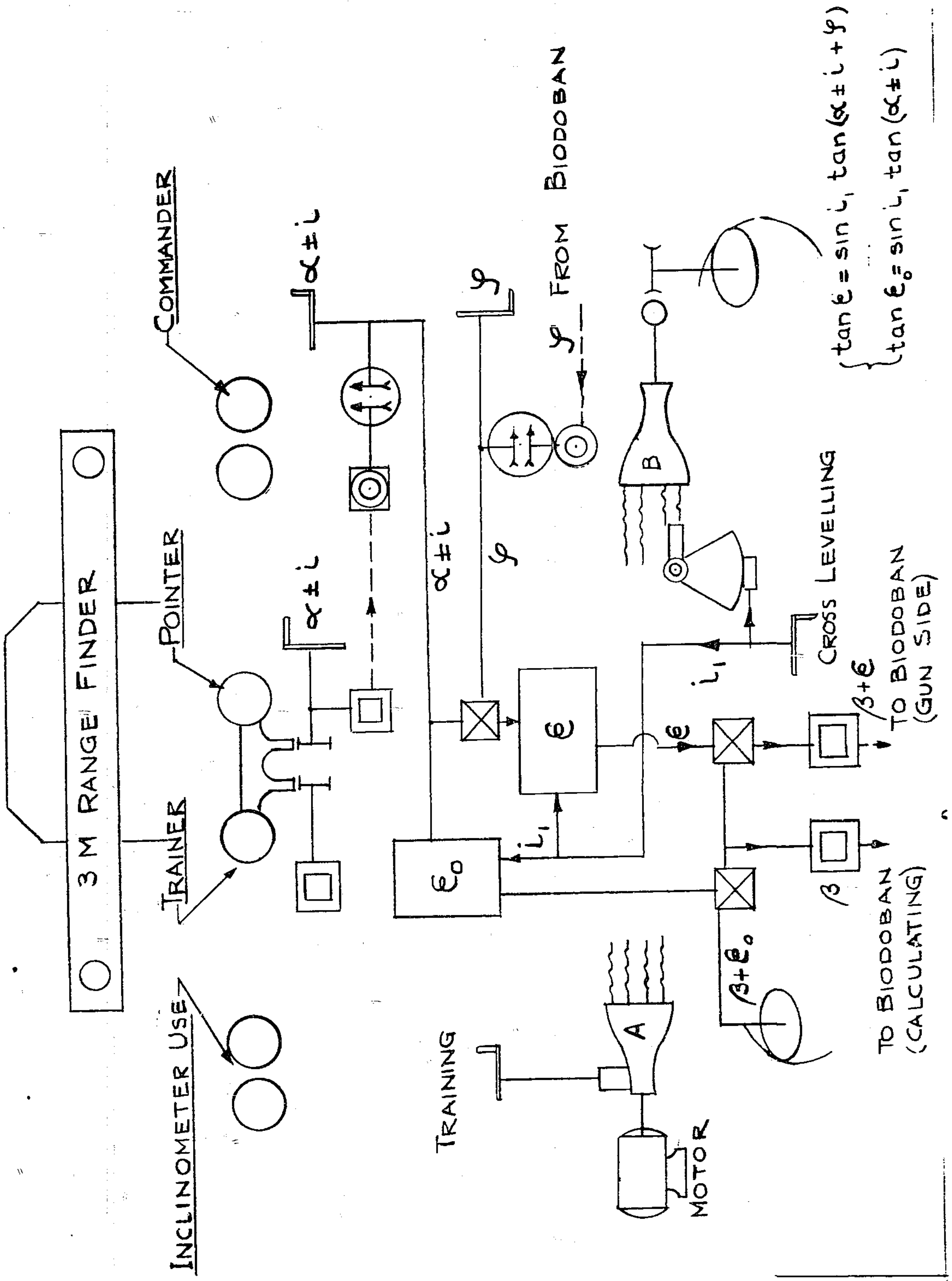


Figure 34

TYPE 2 DIRECTOR (HOIBAN)

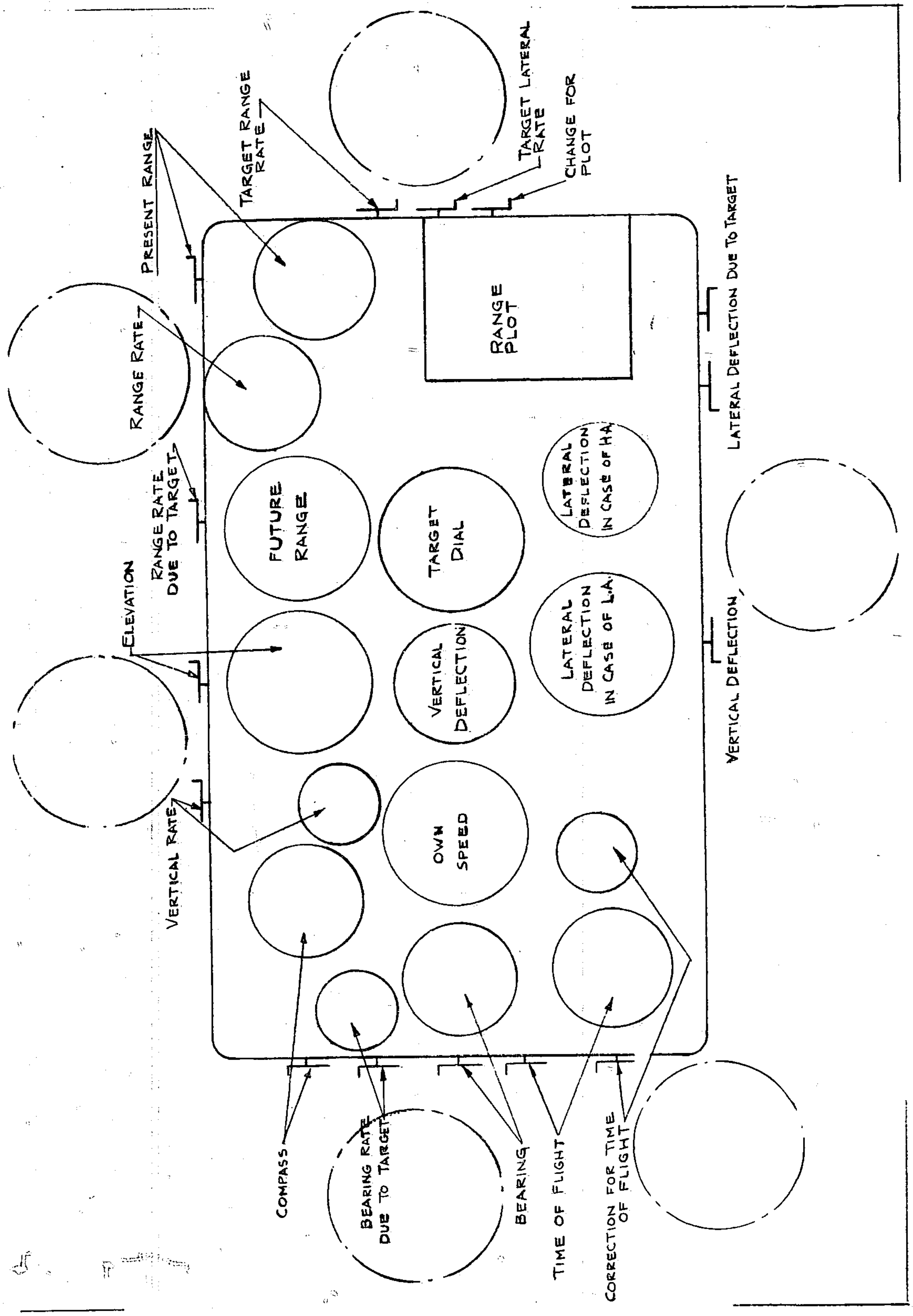


Figure 35
TYPE 2 COMPUTER (BIODOBAN TYPE 2)

ΔR_1 is range difference due to target speed

R_{1c} is daily correction plus own speed correction plus spotting

T_1 is time required to obtain range cut

(2) Vertical Deflection

$$\phi + \sigma + \Delta\sigma + \Delta\phi = \text{total deflection}$$

where ϕ is superelevation

σ is vertical deflection

$\Delta\sigma$ is spot

$\Delta\phi$ equals dip

and $\phi = \phi_0 + \phi_1$ with ϕ_0 being superelevation in the case of L.A. and ϕ_1 being the correction obtained from a three dimensional cam for correction in H.A. This vertical deflection is added by differential selsyn to the director setting to provide gun elevation.

(3) Lateral Deflection D_T

$$D_T = D + S + Z + D_c$$

where D is the deflection due to target speed

S is the deflection due to own speed

Z equals drift

D_c equals spot

(4) Time of Flight T_1

$$T_1 = T_0 + T_h + T_c$$

where T_0 equals time of flight in the case of L.A.

T_h equals correction to time with H.A.

T_c equals correction for dead time, etc.

The size of BIODOBAN is 1.36 x 0.75 x 0.9 meters and its weight is 1.25 kilograms.

I. Type 5 Blind Fire H.A./L.A. Destroyer and Light Cruiser Fire Control System (DENTAN HOIBAN)

1. General. The urgent need of a radar director (to take the place of the HOIBAN Type 2) and to work with the BIODOBAN Type 2 brought about in 1944 the design of the DENTAN HOIBAN.

One of the primary considerations was that there should be as little alteration as possible to the HOIBAN Type 2 or to the BIODOBAN Type 2.

The new blind firing director remained, therefore, a two axis design; it became somewhat heavier and taller on account of the radar antenna and rather more complicated on the training side due to the addition of more follow-ups.

It is unfortunate that there are no drawings or handbooks for this equipment, as it represented the latest ideas in Japanese fire control equipment for destroyers and light cruisers. The only information which has been gathered is from Commander ICHINOI.

Figure 36 shows the director and the disposition of personnel within it.

2. Operation of the Director. In order to keep the director trained upon a target by observation of a spot of light in the trainer's cathode ray tube, the training component is split into two parts (see Figure 37):

a. Change of bearing due to target speed.

b. Own ship alteration or course.

The amount of alteration due to training on account of own ship's alteration of course is transmitted from the computer (BIODOBAN Type 2) through a differential to the sensitive side of the hydraulic training unit. The change of bearing due to target speed is added to this quantity through a differential and transmitted to the computer where predictions are carried out as already described.

The diagram shows that the director can be trained from three places:

a. The control officer's T_1 transmitter.

b. The radar operator's T_1 transmitter.

c. The trainer's handwheel.

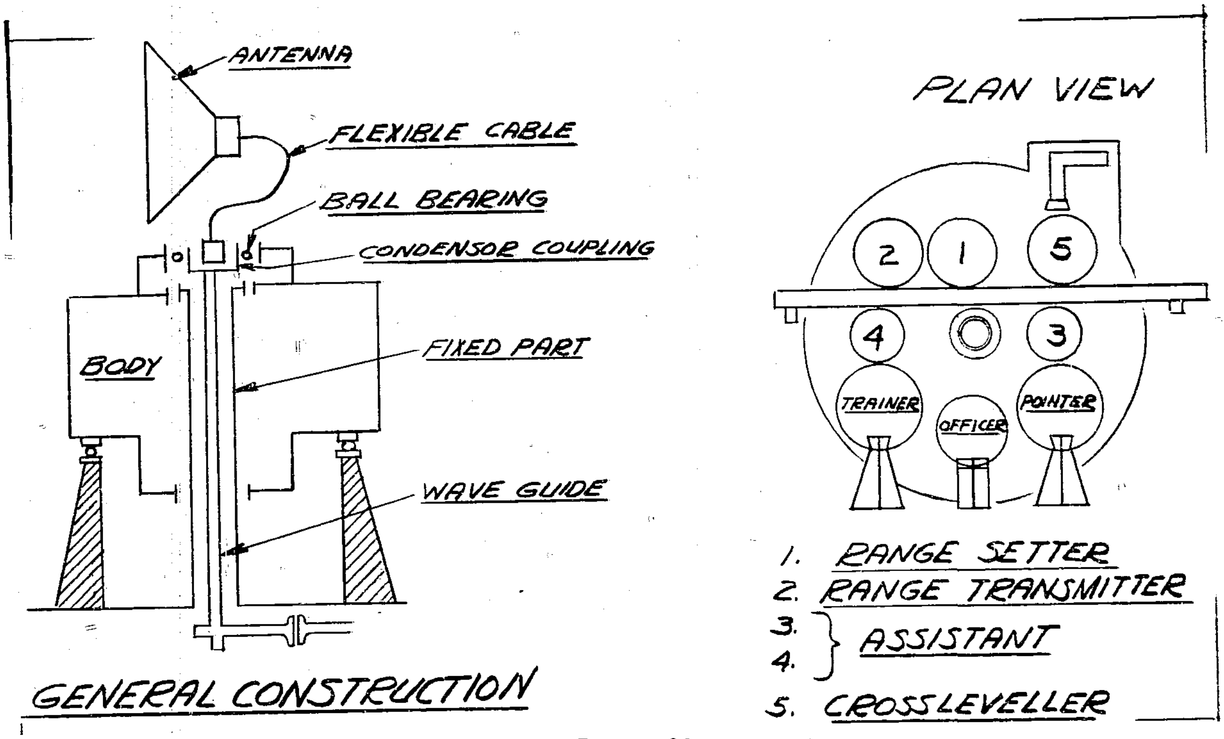


Figure 36

GENERAL ARRANGEMENT OF DENTAN HOIBAN TYPE V

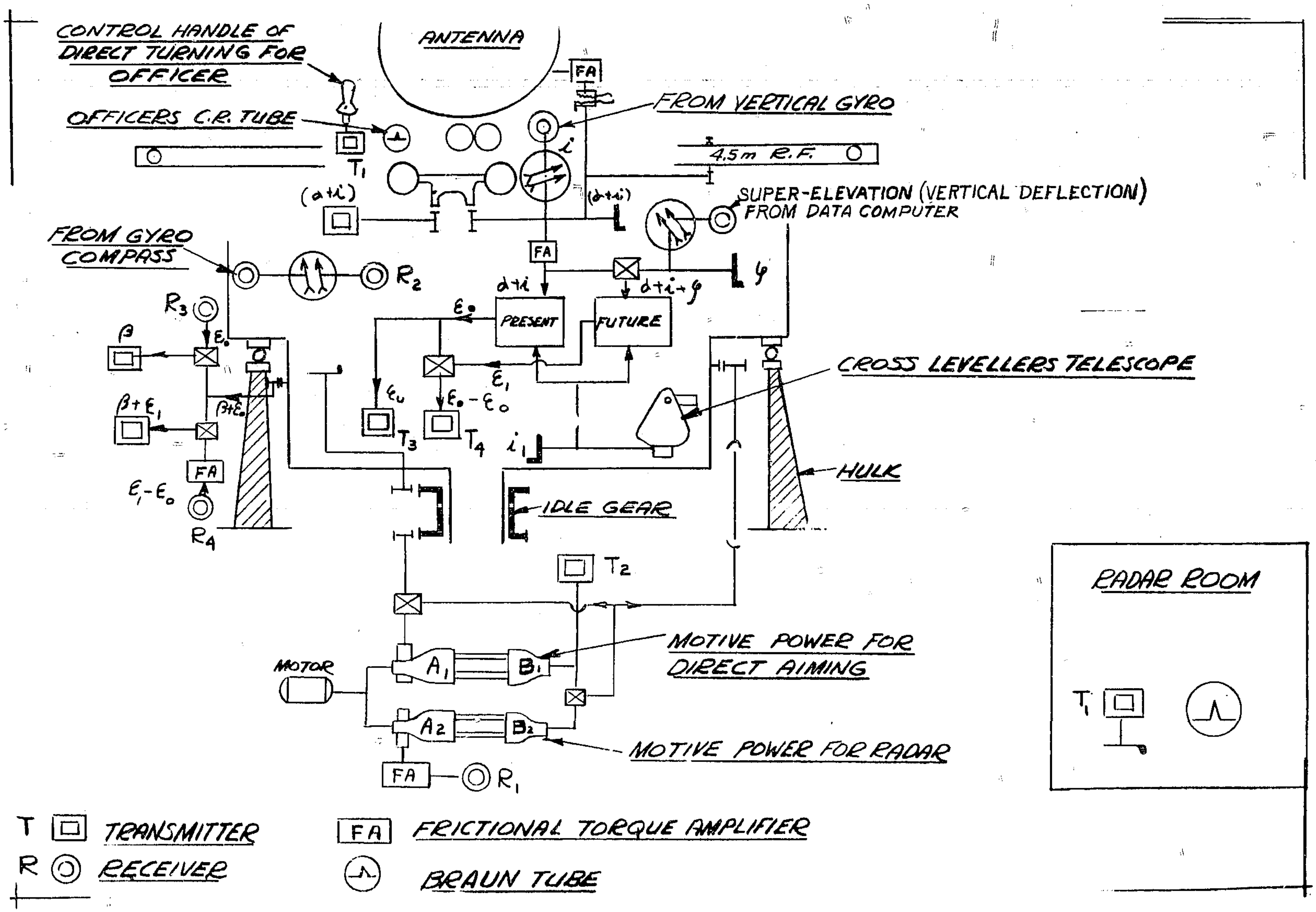


Figure 27

SCHEMATIC DIAGRAM OF DENTAN HOIBAN TYPE V

The first two are received through a selector switch by R_1 on the sensitive side of the training gear. The layer rotates his handwheel in terms of $\alpha - i$, which is angle of sight plus roll in the line of sight or director setting. This quantity, added to vertical deflection (in H.A.) and superelevation, enters the mechanism box for "future" position (i.e. gun) data. Only the director setting feeds into the "present" box. Both boxes are fed with cross-roll and their outputs are ε_o and ε_1. These, in turn, are transmitted to receivers R_3 and R_4 so as to obtain transmission of β (target bearing) and $\beta + \varepsilon_1$ (future target bearing).

J. A Simple Sine Wave Mechanism

1. General. It is believed that this mechanism may be entirely Japanese, but if not, so far as is known, it is not found elsewhere in British, American or German fire control. It is the invention of Mr. MIZUNO of the NIPPON KOGAKU KOGYO. Mr. MIZUNO was lost at sea in a submarine on his way to Germany in 1943. This mechanism is suitable for solving sines only within certain limits and, therefore, its application is strictly limited. It is to be found in the Type 94 Computer (KOSHA SOCHI), so the mechansim can be further examined and analysed in the U.S.A. The mathematics of the scheme is presented below.

2. Description. This simple mechanism consists of two regular spur gear wheels mounted eccentrically. One drives, the other is driven.

Let these two spur gears of pitch diameter 2a mesh with each other but with an eccentricity of e and whose relation, therefore, can be shown as:

$$\phi = \theta + \frac{e}{a}\sin\theta + \tfrac{1}{2}\left(\frac{e}{a}\right)^2 \sin 2\theta + \ldots \quad (1)$$

where ϕ = uniform rotational angle of the driver

and θ = non-uniform rotational angle of the driven.

The radius of each spur wheel being "a", let O_1 and P_1 be the centers of the gears, and O and P be the rotational centers as in Figure 38.

Let A be rotated by an angle θ, then O_1 traces out a path to O_2 and P_1 to P_2 and the positions of the gears change from AB to A'B', then:

$$O_2P_2 = 2a \text{ and } OP = a - e + a + e = 2a$$

Then we obtain the following relationships:

$$O_2P_2 \cos\delta - PP_2 \cos\phi + OO_2 \cos\theta = OP \quad \text{i.e.}$$

$$2a \cos\delta \cdot e(\cos\phi - \cos\theta) = 2a$$

$$\therefore \cos\delta = 1 + \frac{e}{2a}(\cos\phi - \cos\theta) \quad (2)$$

and $OO_2 \sin\theta + PP_2 \sin\phi = O_2P_2 \sin\delta$, i.e.

$$e(\sin\theta + \sin\phi) = 2a \sin\delta$$

$$\therefore \sin\delta = \frac{e}{2a}(\sin\theta + \sin\phi) \quad (3)$$

By squaring and adding we obtain:

$$1 = 1 + \frac{e}{2a}(\cos\phi - \cos\theta) + \frac{e^2}{4a^2}(2 - 2\cos\phi\cos\theta + 2\sin\theta\sin\phi)$$

$$\cos\phi - \cos\theta = \frac{-e}{2a}[1 - \cos(\phi + \theta)]$$

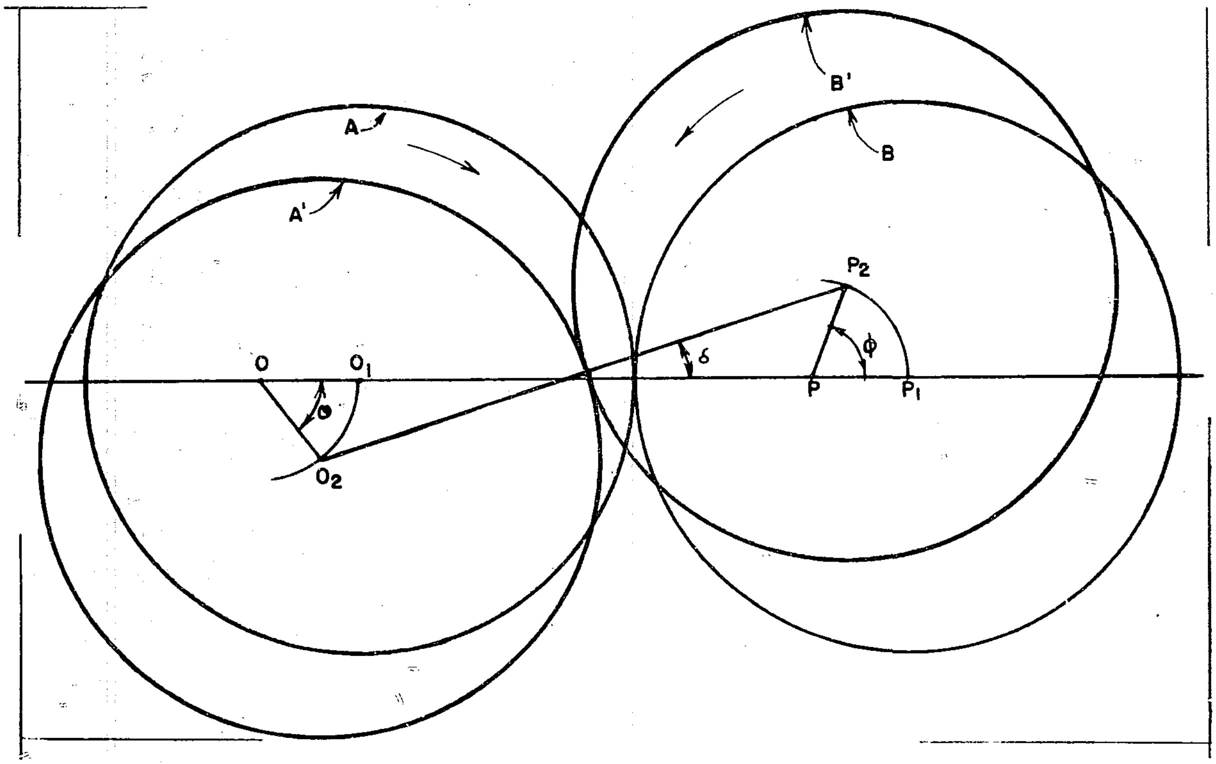


Figure 38
SIMPLE SINE WAVE MECHANISM

Putting $\phi = \theta + \Delta\theta$ and neglecting higher terms we get:

$$\cos\theta - \Delta\theta\sin\theta - \cos\theta = \frac{-e}{2a}(1 - \cos 2\phi - \Delta\theta\sin 2\theta)$$

$$= \frac{-e}{2a}(2\sin^2\theta - \Delta\theta\sin 2\theta)$$

therefore

$$\therefore \Delta\theta\left(1 - \frac{e\sin 2\theta}{2a\sin\theta}\right) = \frac{e}{a}\sin\theta$$

Thus we get

$$\Delta\theta = \frac{e}{a}\sin\theta\left(1 + \frac{e}{2a}\frac{\sin 2\theta}{\sin\theta}\right) + \ldots\ldots$$

$$= \frac{e}{a}\sin\theta + \tfrac{1}{2}\left(\frac{e}{a}\right)^2\sin 2\theta + \ldots\ldots$$

Neglecting the higher terms, therefore, we can say that:

$$\phi = \theta + \frac{e}{a}\sin\theta \quad \ldots\ldots\ldots\ldots \quad (4)$$

3. Mechanical Application. If we wish to get $\sin\sigma$ from σ we substitute $\theta = m\sigma$ where m is a constant. Then:

$$\phi = m\sigma + \frac{e}{a}\sin m\sigma \quad \ldots\ldots\ldots\ldots \quad (5)$$

This must be equal to $n\sin\sigma$ so that we put $n\sin\sigma = m\sigma + \frac{e}{a}\sin m\sigma$ where n is a constant.

But as this cannot be true for all values of σ we assume that

$$\sigma = \sigma_1$$

so that $n \sin \sigma_1 = m\sigma_1 + \frac{e}{a} \sin m\sigma_1$ .... (6)

If we determine m, e, and a; we can find n from this equation. Generally speaking, however, if σm be the maximum value of σ and $-\sigma n$ is the maximum value of negative deflection we have to give the following limit:

$m(\sigma m + \sigma n) = 2K\pi \qquad 0<K<1$ .... (7)

If a value of k is assumed, σm and σn being known, m is determined and from (6) for values of "e" we obtain values of n. From equation (5) values of ϕ are calculated for all values of e and the acceptable error found for the relation $\phi = n \sin \sigma$ The most suitable "e" can then be selected.

For the best results the maximum value of "e" is about 2mm when "a" is 50mm.

PART II

A. Short Range H.A. Director Type 95 (SHAGEKI SOCHI)

1. General. The Type 95 short range H.A. director system was the standard one in use by the Japanese Navy.

It is based on the "course and speed" principle and originally copied from the French "Le Preiur" sight.

It is the only system which was associated with a remote controlled mount and this was the 25mm MG.

The most usual kind of installation was three twin-gun mounts controlled by one director, but sometimes there were two triple gun mounts instead. In all cases of multiple mountings, the elevation and training motors were interconnected by selsyns to prevent the motors getting out of step.

A full description of the Ward-Leonard Remote Power Control is given in NavTechJap Report, "Japanese Fire Control", Index No. 0-29, but the following remarks are relevant.

2. Description. The control officer has a scooter control which has two pairs of vibrating contacts; one for elevating and one for training; these contacts are vibrated by means of an eccentric cam.

If the scooter control is moved, one side of the pairs of contacts will complete the circuit for a longer time than the other and the generator will be thereby excited so that the motors will be driven at high or low speed accordingly and in the appropriate direction. Figure 39 shows this arrangement.

The maximum target speed that could be set in this system was 600 kilometers/hour. When the demand for handling higher speed targets was made, the only satisfactory solution which could be supplied was the addition of an etched ring sight in the control officer's telescope. (See Figure 40.)

This ring sight provided for 900, 800 and 700 km/hr target speeds.

3. Remarks. Since there were no drawings or descriptions of this system, the above has been obtained through interrogations. It appears that the Navy could not procure the necessary manufacturing capacity to fulfill its requirements and decided, therefore, to simplify this equipment which then

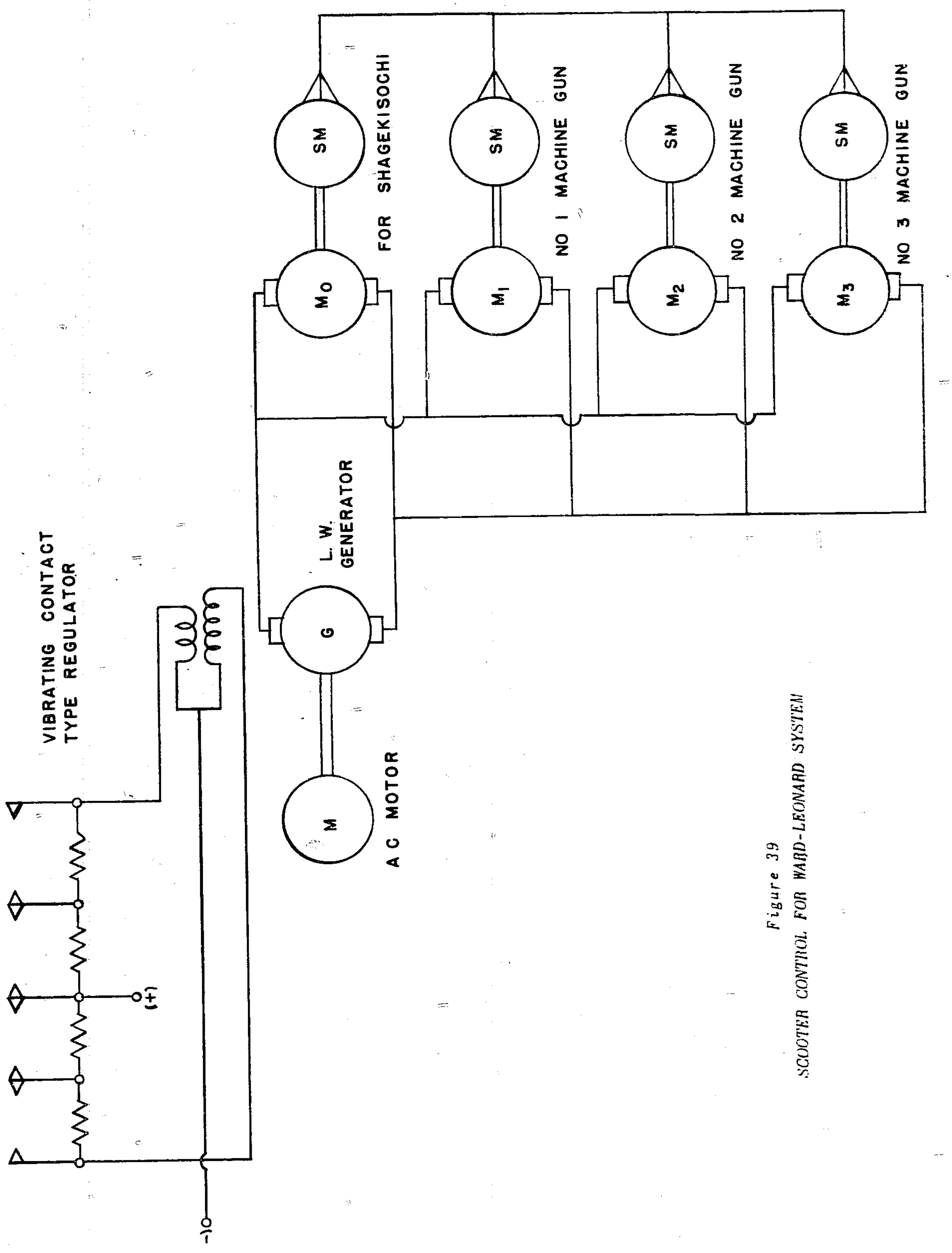


Figure 39
SCOOTER CONTROL FOR WARD-LEONARD SYSTEM

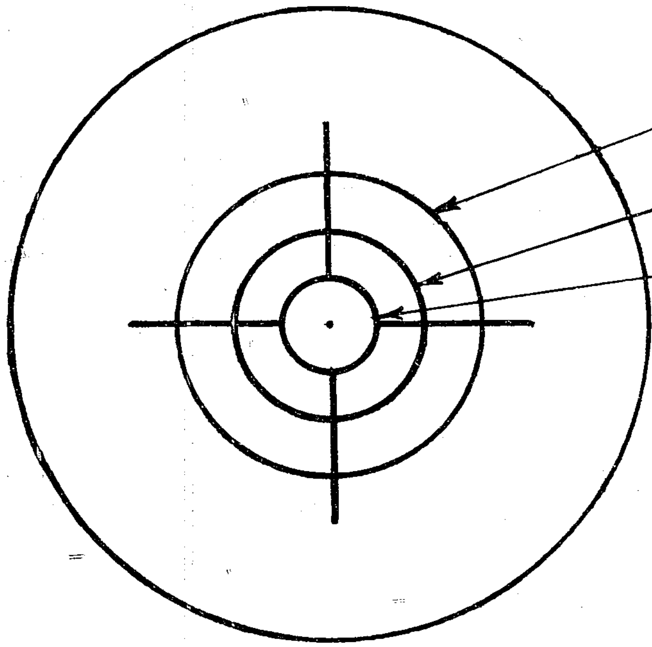


Figure 40

RING SIGHT IN TELESCOPE OF KOSHA SHAGEKI SOCHI

became known as the Type 4 Mod 3 and is described in the next section.

It is curious that the Japanese Navy took no steps at all to design any other form of sight based on more advanced principles or which were tachymetric.

B. Simplified Short Range H.A. Director System (Type 4 Mod 3) (KOSHA SHAGEKI SOCHI)

1. General. The illustrations of Enclosure (F) show the equipment which resulted from the requirements outlined in the remarks on the Type 95 Director System (see Part II, Section A). The greater simplicity of manufacture did much to hasten the more extensive fitting to ships of short range directors and the use of it on land. It was stated that the successful development of a ½ hp friction type torque amplifier also contributed to the popularity of the Type 4.

This sight was intended for the control of:

a. 25mm Machine Gun Mounts.

b. 12cm Multiple Rocket Guns.

It was also used as the main director in small modern destroyers having one single and one twin 12.7cm gun, and as the auxiliary director for land use (also for Type 98, 10cm and 12cm guns).

The basic differences from the Type 95 are as follows:

a. Tracking was manual.

b. No anti-log cam was installed as on the Type 95, but instead a graphical method was used. (Deflection multiplied by ballistic quantity is obtained graphically instead of mechnically and superelevation is not set automatically but must be separately.)

2. Description. This Type 4 Mod 3 sight consists of five main sections:

a. Elevating gear.

b. Traversing mechanism. (When used on land, a response differential for training is provided.)

c. Dummy target with its mechanical linkages.

d. Fuze setting equipment.

e. Vertical and lateral spotting correction gear.

3. Limits of Operation.

a. Angle of Elevation: + 80°

Angle of Depression: - 15°

b. Transmission Speeds

Elevation:	Coarse	90°/rev
	Fine	10°/rev
Training:	Coarse	360°/rev
	Fine	20°/rev
Fuze:	Coarse	50 secs/rev
	Fine	5 secs/rev

(Note: One revolution of the elevation handwheel elevates sight 3°.)

c. Range

H.A. 10cm gun .... 2000 to 14,000 meters
12-12.7cm guns .... 2000 to 10,000 meters
L.A. 10cm gun .... 100 to 13,000 meters
12-12.7cm .... 100 to 10,000 meters

d. Target

Diving angle .... to 90°
Climbing angle .... to 30°
Course .... 0 to 360°
Speed .... 0 to 400 knots

e. Training Limit: 2 revolutions each way (total 4)

f. Deflection spotting, lateral and vertical:160 mils.

g. Fuze

10cm gun .... 0 to 38 seconds
12cm gun .... 0 to 28 seconds
12.7cm gun .... 0 to 35 seconds

(Spotting correction from 0 to 8 seconds.)

h. Working circle: 2 meters

i. Weight: 295 kg (without shockproof mounting)

j. Personnel:

(1) Control officer

(2) Tracker

(3) Range setter

(4) Fuze operator

(5) Spotter

4. Functional Description (See Figure 1(F) in Enclosure (F). The rotating head B can be trained on pedestal A and the training angle is obtained from the gear D which rotates on the fixed gear C attached to the mount A. The lateral deflection from the spotting knob is added differentially and the total gun train is transmitted by the gun training transmitter.

Fuze time is obtained by rotating handwheel G to follow indicator H on the range curve on the time of flight drum and this is then transmitted by the fuze transmitter. The elevation portion of the sight with its telescope L is connected to gear J attached to the gear box I and the open sight K.

Target course is set by aligning the dummy airplane with the fuselage of the target (there is a mechanical response differential so that director training does not affect target bearing).

Vertical and lateral deflections are outputs of the dummy airplane linkage. Vertical spotting correction is added to the vertical deflection and gun elevation is obtained.

Superelevation is obtained by rotating nut O until the correct range mark is reached.

Target speed is set on the target speed bar U against the curves T.

5. Design Considerations. Correct gun training and elevation occurs when future elevation is 30° with a 12cm gun and 40° with a 12.7cm gun. In Figure 41 the situation is represented graphically.

If OAB and OPM are similar triangles

$$\frac{OM}{OB} = \frac{PM}{AB} \quad \dots\dots (1)$$

If OBB' and OMN are similar triangles

$$\frac{OM}{OB'} = \frac{NM}{B'B} = \frac{OM}{OB} \quad \dots\dots (2)$$

From (1) and (2) we get $PM = \frac{ON \cdot AB}{OB'} = L\frac{VT}{R'_1}$ ....(3)

In order to get the burst to occur at B, the superelevation ϕ (i.e. drop of projectile during flight) must be considered; the target speed curve can be drawn by calculations of the quantity $L\frac{VT}{R'}$.

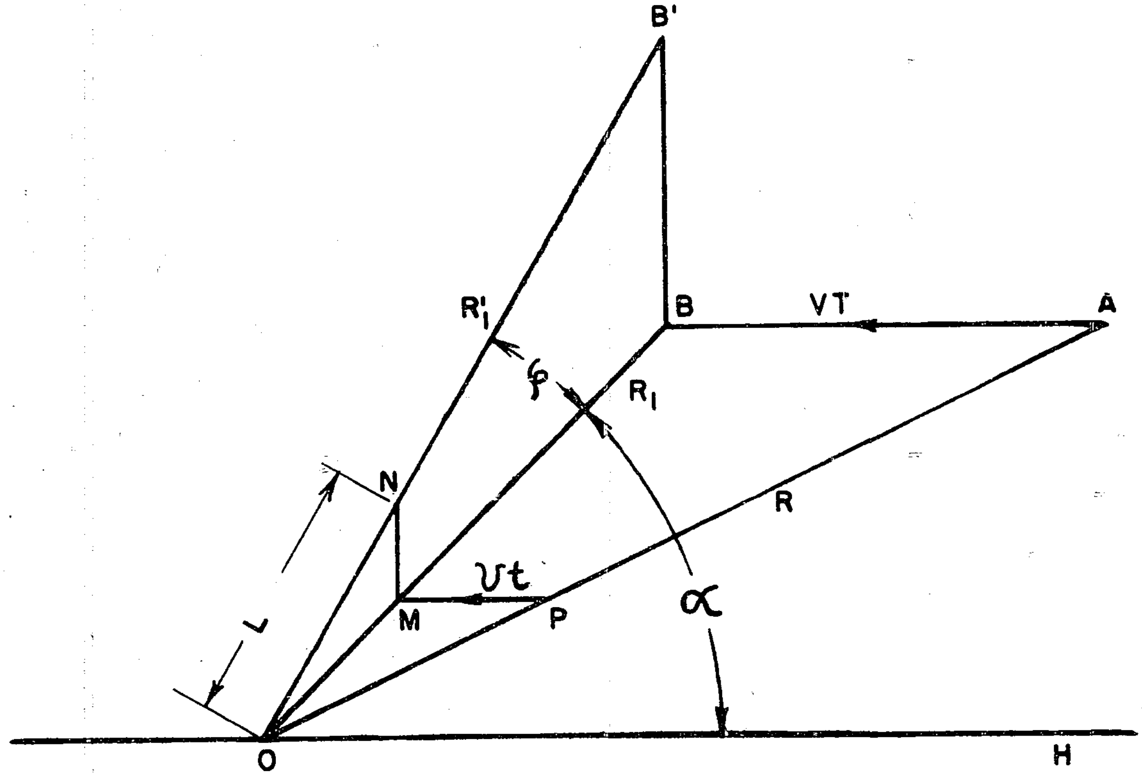


Figure 41
VECTOR DIAGRAM FOR DIRECTOR TYPE 4 MOD 3

The value $L\ T/R_1$ will also be determined if the future range R_1 and future angle α are fixed. (The error resulting from these assumptions increases considerably at over 6000 meters). The superelevation scale is obtained by making the scale of the superelevation linear; this admits of only one angle at which superelevation is exactly correct. In Figure 42 NM is at right angles to OH. Then in the similar triangles NMS and ONR we have:

$$\angle MNS = \angle MOR \doteq \angle \alpha$$

and $$ON \sin \phi = NM \cos \alpha,$$

therefore $$\therefore NM = \frac{ON \sin \phi}{\cos \alpha} = \frac{L \sin \phi}{\cos \alpha}$$

Fuze time is obtained from range and height. The height of the cylinder is 60mm (diameter) and one revolution indicates 110°; length is 2.5mm, equivalent to one second.

For L.A. fire, range can be set by the L.A. range dial on the vertical deflection dial.

For night L.A. fire, a spirit level is used instead of the open sight so that a rough stabilization can be effected. The training angle is obtained under these circumstances from 12cm binoculars.

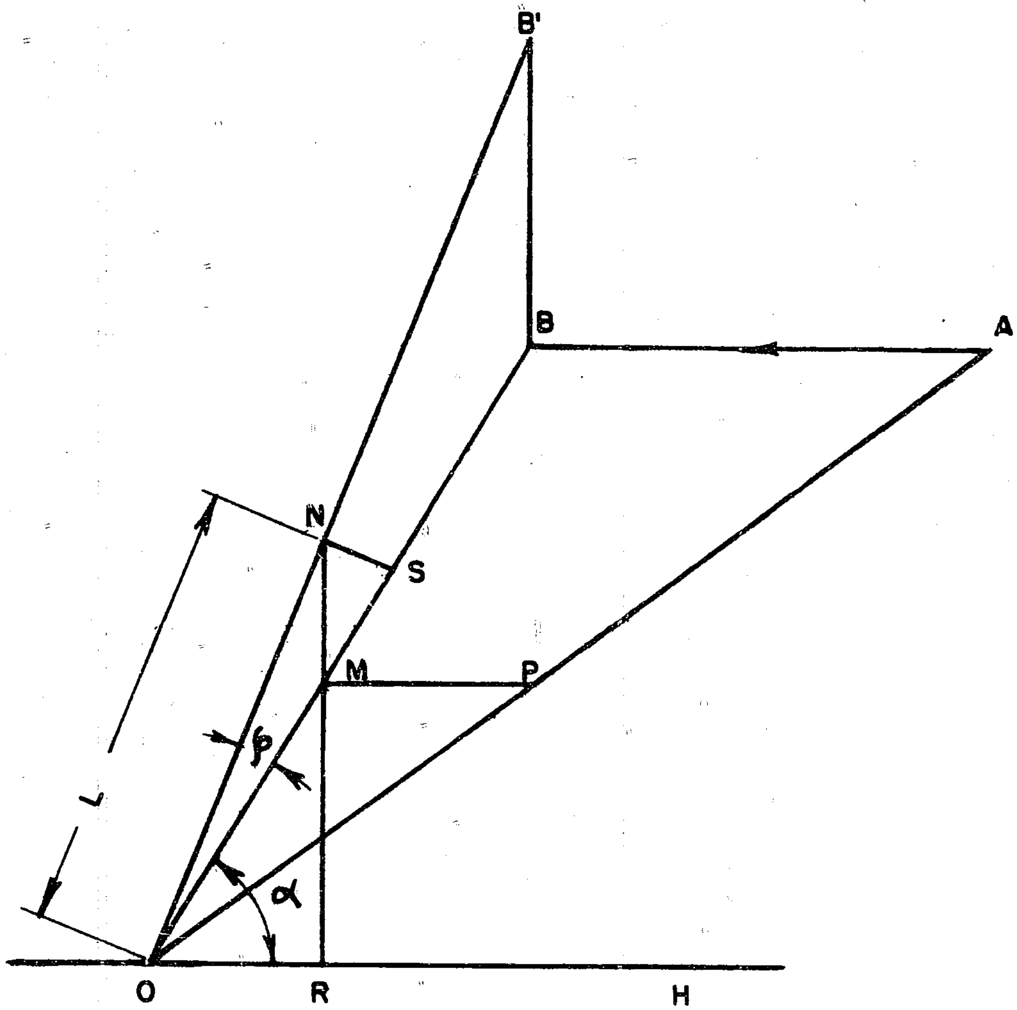


Figure 42
VECTOR DIAGRAM KOSHA SHAGEKI SOCHI

ENCLOSURE (A)

LIST OF FIRE CONTROL EQUIPMENT SHIPPED TO OIL, INDIANHEAD, MD.

NavTechJap Equipment No.	Item
JE50-3004	Type 94 Fuze Time Computer (Nippon Optical)
05	Type 94 Vertical Deflection Resolver (Nippon Optical)
07	Type 94 Parallax Converter (Nippon Optical)
08	Type 94 Fuze Time Computer (Nippon Optical)
09	Type 94 Vertical Deflection Resolver (Nippon Optical)
10	Type 94 Lateral Deflection Resolver (Nippon Optical)
11	Type III Land Use AA Computer (Nippon Optical)
12	Type 94 AA Director (Nippon Optical)
13	Pointer's Optical Sighting Bracket (Nippon Optical)
14	Layer's Optical Sighting Bracket (Nippon Optical)
15	Cross-Leveller's Sight (Nippon Optical)
JE21-3405	Type 91 Mod 2 AA Director (YOKOSUKA)

ENCLOSURE (B)

LIST OF FIRE CONTROL DOCUMENTS SHIPPED TO WDC VIA ATIS

NavTechJap Document No.	Item	ATIS No.
ND21-3429	Fire Control Tests - FUSO (Battleship)	3945
3430	Fire Control Tests - SUZUYA (Cruiser)	3946
3434	AA Defense for Naval Vessels	3950
3435	Type 94 AA Director - Adjustments	3951
ND21-3440 to ND21-3440-47	Type 94 Director-Computer for 12.7cm Twin Gun	3934
- 1	Second Level of Computer	
- 2	"(DR/dt) (T)" Calculator	
- 3	First Level of Computer	
- 4	Elevation Transmitter	
- 5	Everyday Correction	
- 6	Roll Receiver	
- 7	Bearing Receiver	
- 8	Compass Receiver	
- 9	Elevation Receiver	
-10	Third Level	
-11	Cross Leveller's Sight	
-12	Pointer's Telescope	
-13	"T" Transmitter	
-14	Leveller's Telescope	
-15	Everyday Correction	
-16	Compass Card	
ND50-3440-17	Fourth Level	
-18	Second Level (Middle Plate)	
-19	Trainer's Telescope	
-20	Vertical Deflection	
-21	Lateral Deflection $\cos(\alpha - \sigma)/\cos \alpha$ cam	
-22	Lateral Deflection	
-23	Plot	
-24	Plot	
-25	Own Speed Correction	
-26	"T" Cam	
-27	Axis Converter	
-28	Parallax Correction	
-29	Parallax Correction	
-30	Time of Flight Clock	
-31	"(DR/dt) (T)" Calculator	
-32	Super Elevation	
-33	Rate Mechanism No. 1	
-34	Rate Mechanism No. 2	
-35	Rate Mechanism No. 3	
-36	Rate Mechanism No. 4	
-37	Director No. 1	
-38	Director No. 2	
-39	Director No. 3	
-40	Director No. 4	
-41	Director No. 5	
-42	Bearing Transmitter	
-43	Bearing Transmitter	

ENCLOSURE (B), continued

NavTechJap Document No.	Item	ATIS No.
ND50-3440-44	Bearing Transmitter (Calculation)	
-45	Bearing Transmitter	
-46	Elevation Transmitter	
-47	Notes on Assembling Computer	
ND21-3441 to ND21-3441-55	Type 92 L.A. Data Computer for 36cm and 40cm Guns	3935
- 1	General	
- 2	Plot	
- 3	Plot	
- 4	Plot	
- 5	Lateral Deflection Dial	
- 6	Range Rate Dial	
- 7	Plot	
- 8	Range Receiver	
- 9	Own Speed Resolver	
-10	Own Speed Resolver	
-11	General Plan View	
-12	Bearing Rate Dial	
-13	Target Speed Resolver	
-14	Own Speed Resolver	
-15	Wind Speed Dial	
-16	Time of Flight Dial	
-17	Bearing Gear Train	
-18	Compass Card	
-19	Own Speed Resolver	
-20	Plot	
-21	Plot	
-22	Rate Mechanism	
-23	Range Averager	
-24	Plot	
-25	Deflection Transmitter	
-26	Time of Flight Mechanism	
-27	Target and Own Speed	
-28	Deflection due to Target Speed	
-29	Bearing Gear Train	
-30	Rate Mechanism	
-31	Starter	
-32	Range Transmitter	
-33	Dip Correction Gear	
-34	Compass Card	
-35	Bearing Dial	
-36	Range Receiver	
-37	Bearing Gear Train	
-38	Bearing Dial	
-39	Deflection Calculator due to Wind Speed	
-40	Bearing and Range Rate Dial	
-41	Target and Own Speed Dial	
-42	Plot	
-43	Rate Mechanism	
-44	Range Dial	
-45	Future Range Dial	
-46	Range Correction Dial	
-47	Manuel Gear Train	
-48	Manuel Gear Train	
-49	Future Range Dial	

ENCLOSURE (B), continued

NavTechJap Document No.	Item	ATIS No.
ND21-3441-50	Range Difference due to Own Speed	
-51	Target and Own Speed Dial	
-52	Range Difference due to Target Speed	
-53	Plot	
-54	Rate Mechanism	
-55	Wind Velocity Dial	
ND21-3442- 1 to ND21-3442-19	Blueprints: Type 92 L.A. Computer for 20cm Gun	3936
- 1	Wind Velocity Dial	
- 2	Bearing Dial	
- 3	Range Difference due to Own Speed	
- 4	Range Difference due to Target Speed	
- 5	Own Speed Deflection	
- 6	Target Speed Deflection	
- 7	Range Dial	
- 8	Future Range Correction Dial	
- 9	Own Speed Dial	
-10	Target Speed Dial	
-11	Dip Correction Gear	
-12	Plot	
-13	Plot	
-14	Plot	
-15	Wind Velocity Deflection	
-16	Drift	
-17	Future Range Dial	
-18	Plot	
-19	Compass Card	
ND21-3443- 1 to ND21-3443-24	Type 91 AA Director	3937
- 1	Mounting	
- 2	Pointer's Telescope	
- 3	Trainer's Telescope	
- 4	Leveller's Telescope	
- 5	Cross Leveller's Telescope	
- 6	Vertical Cross Roll Correction	
- 7	Parallax Correction	
- 8	Roll Converter	
- 9	Lateral Deflection No. 1	
-10	Lateral Deflection No. 2	
-11	Time of Flight Calculator	
-12	Vertical and Lateral Deflection Calculator	
-13	Vertical Deflection Calculator	
-14	Vertical Deflection Calculator	
-15	Parallax Calculator	
-16	Drift Calculator	
-17	Future Range Calculator No. 1	
-18	Future Range Calculator No. 2	
-19	Range Rate Calculator	
-20	Compass Card	
-21	Cross Roll Correction Gear	
-22	Wind Correction Gear	
-23	Super Elevation Gear	
-24	General Arrangement of Calculator	

ENCLOSURE (B), continued

NavTechJap Document No.	Item	ATIS No.
ND21-3444- 1 to ND21-3444- 8	Type 95 AA Director (For Ground Use)	3938
- 1	General Arrangement of Communication Wires	
- 2	General Arrangement of Communication Wires	
- 3	First Level	
- 4	Second Level	
- 5	Third Level	
- 6	Fourth Level	
- 7	Fifth Level	
- 8	Sixth Level	
ND21-3445- 1 to ND21-3445-21	Type 94 Mod 1 L.A. Director	3939
- 1	Firing and Illuminating Circuits (NAGATO)	
- 2	Bearing Gear Train (NAGATO)	
- 3	Cross Leveller's Corrections (NAGATO)	
- 4	Elevation Gear Train (NAGATO)	
- 5	Bearing Gear Train (CHIKUMA)	
- 6	Cross Leveling Correction (CHIKUMA)	
- 7	Elevation Gear Train (CHIKUMA)	
- 8	Bearing Gear Train (MOGAMI)	
- 9	Cross Leveling Correction (MOGAMI)	
-10	Elevation Gear Train (MOGAMI)	
-11	Firing and Illuminating Circuits Secondary Battery (HIEI)	
-12	Range and Deflection Receivers Secondary Battery (HIEI)	
-13	Bearing Gear Train Secondary Battery (HIEI)	
-14	Bearing Gear Train Secondary Battery (HIEI)	
-15	Cross Leveling Correction Secondary Battery (HIEI)	
-16	Bearing Gear Train Secondary Battery (HIEI)	
-17	Bearing Gear Train (MUTSU Secondary Battery)	
-18	Elevation Gear Train (MUTSU Secondary Battery)	
-19	General Arrangement	
-20	General Arrangement (HIEI Secondary Battery)	
-21	Cross Leveling (MUTSU Secondary Battery)	
ND21-3446- 1 to ND21-3446- 4	Type 94 Mod 3 L.A. Director	3940
- 1	General Arrangement of Tower	
- 2	Training Gear Train	
- 3	Elevation Gear Train	
- 4	General View	
ND21-3447- 1 to ND21-3447-26	Type 94 L.A. Data Computer (BIODOBAN)	3941
- 1	Component Resolver	
- 2	Plan View Upper Part	
- 3	Deflection Dial	
- 4	Plan View of Lower Parts	
- 5	Plan View of Upper Part	
- 6	Super Elevation Correction Gear	

ENCLOSURE (B), continued

NavTechJap Document No.	Item	ATIS No.
ND21-3447- 7	Future Range Dial	
- 8	General Gear Train	
- 9	Plan View of Lower Part	
-10	General Calculator	
-11	Deflection and Own Speed Dial	
-12	Transmitter Gear Train	
-13	Plan View of Transmitters	
-14	Bearing Dial	
-15	Motive Power	
-16	Range Rate Dial	
-17	Differential Selsyn	
-18	Plan View of Upper Part	
-19	Plan View of Upper Part	
-20	Super Elevation Correction Gear	
-21	Future Range Dial	
-22	General View	
-23	Plan View of Lower Part	
-24	Plan View of Lower Part of Calculator	
-25	Plan View of Upper Part of Calculator	
ND21-3448- 1 to ND21-3448- 7	Electrical AA Data Computer	3942
- 1	General View of Deflection Follow-up Device	
- 2	Target Angle Setter	
- 3	Schematic Diagram of Electrical Lines	
- 4	Schematic Diagram of Unit	
- 5	Target Velocity Setter	
- 6	Schematic Diagram - General	
- 7	Deflection Calculator	
ND21-3452	Simplified AA Computer Type 2 (1942)	3959
3479	AA Firing Data Converter of Type 94 Mod 1 Spotting Instrument	
3480-1	Mechanical Play and Transmission Efficiency of Destroyer Director - First Report	3988
3480-2	Mechanical Play and Efficiency Transmission of Destroyer Director - Second Report	
3481	General Description of Type 91 AA Director Sight	3989
3482	AA Deflection Table (7cm Type 88 Army Gun)	3990
3483	AA Deflection Table (12.7cm 40 cal 8cm 40 cal Gun)	3991
ND50-3006-1	DENTAN HOIBAN Type 5 GA	3907
-2	DENTAN HOIBAN Type 5 GA	
3007	SHAGEKIBAN Type 98, Brief Description	3908
3020-1	Schematic Diagram KOSHA SOCHI Type 91	3893
-2	Schematic Diagram (Gear Train) KOSHA SOCHI Type 91	

ENCLOSURE (B), continued

NavTechJap Document No.	Item	ATIS No.
ND50-3020-3	Schematic Diagram (Perspective) KOSHA SOCHI Type 91	
3021-1	Notes SHAGEKIBAN Type 94	3894
-2	Description with Diagram SHAGEKIBAN Type 94	
-3	Adjustments and Lining up	
3022-1	Schematic Diagram BIODOBAN Type 94	3895
-2	General Construction	
3023	Machine Gun Sight (SHAGEKISOCHI) Type 94	3896
3024	Schematic Diagrams KOSHA SOCHI Type 95	3897
3025	Handbook Complete KOSHA SOCHI Type 2	3898
3026	Schematic Diagram KOSHA SHAGEKIBAN Type 3	3961

ENCLOSURE (C)

FIRE CONTROL EQUIPMENT CARRIED BY PRINCIPAL JAPANESE NAVAL VESSELS

Ship	Main Battery	Secondary Battery	AA Battery	Remarks
YAMATO Class	45cm Type 98 HOIBAN 45cm Type 98 SHAGEKIBAN	15.5cm Type 98 HOIBAN Type 98 SHAGEKIBAN	12.7 Type 94 40 cal KOSHA SOCHI	
NAGATO Class	40cm Type 94 HOIBAN Type 92 SHAGEKIBAN	14cm Type 94 HOIBAN Type 94 SHAGEKIBAN	12.7 Type 94 40 cal KOSHA SOCHI	
FUSO, KI-RISHIMA Class	36cm Type 94 HOIBAN Type 92 SHAGEKIBAN	15cm Type 94 HOIBAN Type 94 SHAGEKIBAN	12.7 Type 94 40 cal KOSHA SOCHI	
Heavy Cruiser (over 7,000 tons)	20cm Type 94 HOIBAN Type 92 SHAGEKIBAN		12.7 Type 94 40 cal KOSHA SOCHI	Among them (AA gun 12cm)
Light Cruiser	14cm Type 94 HOIBAN Type 94 SHAGEKIBAN			
Aircraft Carrier	12.7 Type 94 KOSHA SOCHI 40 cal			Among them (AA gun 10cm Type 98)
Destroyer	12.7 HOIBAN Old Type and 50 BIODOBAN Type 94 cal			L.A.
	12.7 HOIBAN Type 94 and 50 BIODOBAN Type 94 cal			L.A
	12.7 HOIBAN Type 2 and 50 BIODOBAN Type 2 cal			H.A.&L.A.
	10cm KOSHA SOCHI Type 94 Type 98			H.A.&L.A.

ENCLOSURE (D)

TYPE 94 ANTIAIRCRAFT DIRECTOR EQUIPMENT (KYUYONSHIKI KOSHA SOCHI)

Prepared by Nippon Kogakukogyo K.K., TOKYO
(Japan Optical Industry Co.)

I. GENERAL DESCRIPTION

A. Type

Angular velocity type, for indirect firing, composed of three main parts - Director, Computer and Gunhouse.

1. Pre-war type for use on a ship, "KYUYONSHIKI KOSHA SOCHI"

2. Mid-war type for use on a ship, "KYUYONSHIKI KOSHA SOCHI" KAI ICHI (Revised type)

3. Mid-war type for use on land, "SANSHIKI RIKUYO KOSHA SOCHI ICHI GATA"

These three types are the same in general principle, but differ in details.

B. General

The director is a sighting or directing instrument for use on a ship or on land. It measures the present values of elevation angle α, training angle β and range R (and lateral and vertical inclination angles i and i_1) and continuously transmits these to the computer.

The computer calculates mechanically the necessary firing data - total elevation, deflection angles and fuze setting time - from above mentioned present data and transmits them to the gunhouses.

The equations solved are as follows

$$R_1 = R + \frac{dR}{dt} T$$ by recording method

$$\sin\theta = \frac{R}{R_1} T \frac{d\alpha}{dt} - (1 - \cos\delta)\sin\alpha\sin(\alpha + \sigma)$$ by balancing wheel

$$\sin\delta = \frac{R}{R_1} T \frac{d\beta}{dt} \frac{\cos\alpha}{\cos(\alpha+\sigma)} \sin\alpha\sin(\alpha+\sigma)$$ by balancing wheel

$$\phi = \phi(T, \alpha + \sigma)$$

$$R_1 = R_1(T, \alpha + \sigma)$$ by functional gears, multiplicator, camoid.

Inherent speed correction $= -V\sin(\beta + Cp + \delta)\dfrac{f(T)}{f(\alpha + \beta)}$

Parallax correction $= B\sin(\beta + Cp + \delta)\dfrac{f(T)}{f(\alpha + \theta)}$ by functional gears and proportion mechanisms.

For the correction of rolling and pitching of ships, a so-called "co-ordinate - convertor", an optical model of co-ordinates, is used. The output data are transmitted to the gunhouse being corrected by correction devices.

The types of guns, controlled are 10cm AA gun with mechanical fuse, 8cm AA gun with mechanical fuse and 12.7cm AA gun with mechanical fuse.

ENCLOSURE (D), continued

The types of ships on which it is fitted are battleships, aircraft carriers, cruisers, and destroyers.

II. PRINCIPAL DATA OF DIRECTOR

A. Director

Name	Notation	Transmitter	Range	Notes
Present Range	R	Pow. Selsyn	1.5 to 20 km	for Computer
Height	H		0 to 9.5 km	for Reference
Elevation	$\alpha - i$	Dif. Selsyn	-15° to $+90^\circ$	for Gunhouse
Elevation	α	Pow. Selsyn	0° to 90°	for Computer
Training Angle	β+Cp	Pow. Selsyn	$\pm 220^\circ$	for Computer
Vertical Inclination	i	Pow. Selsyn	$\pm 15^\circ$	for Computer
Lateral Inclination	i_1	Pow. Selsyn	$\pm 10^\circ$	for Computer
Vertical Correction	S_1		$\pm$ 200 m	for Gunhouses
Lateral Correction	S_2		$\pm$ 200 m	for Gunhouses

B. Rangefinder and Telescopes

Name	Magnification	Field	Pupil	Objective
4.5 m AA Rangefinder	12, 24	3°, 1.5°	4;2 mm	48 mm
Sighting Telescope for elevation	8	7.5°	5	40 mm
Sighting Telescope for training	8	7.5°	5	40 mm
Sighting Telescope for vertical inclination	8	7.5°	5	40 mm
Sighting Telescope for lateral inclination	8	7.5°	5	40 mm

C. Personnel

1. Director officer
2. Vertical pointer (α)
3. Lateral pointer (β + Cp)
4. Vertical inclination pointer (i)
5. Lateral inclination pointer (i_1)
6. Range observer (R)
7. Range transmitter
8. Spotter
9. Runner
10. Assistants

ENCLOSURE (D), continued

D. Summary

Total weight: 3,500 tons, approximately.

Training motor: Electric motor -5 hp at 100 or 220 volts DC or 4 kilowatts at 220 or 440 volts AC.

Hydraulic gear: Jonney's gear. (K 2.5)

Oscillation damper: For the sake of convenience in sighting an oscillation damper is installed.

III. PRINCIPAL DATA OF COMPUTER

A. List of Input Data

Name	Notations	Receiver	Range	Notes
Present range	R	Pow. Selsyn	1 to 20 km	From Director
Range change rate	$\frac{dR}{dt}$	Set by hand	± 500 kt	By aligning range marks on the range change rate chart
Spotting	S_R	Hand input	± 3,000 m	Spotting by observation
Range correction	ΔR	Hand input	± 3,000 m	Weather latitude correction & C
Time of flight	T	Set by hand	1 to 43 sec	By aligning optical slit in range marks on the range change v. chart
Fuse correction	Tc	Hand input	± 10 sec	
Elevation	α	Pow. Selsyn	0 to 90°	From Director
Training	β+ Cp	Pow. Selsyn	no limit	From Director
Compass	Cp	Hand input Selsyn repeater	no limit	From Main Compass
Vertical inclination	i	Pow. Selsyn	± 10°	From Director
Lateral inclination	i_1	Pow. Selsyn	± 15°	From Director
Correction for target on the level	$\Delta\phi$	Hand input	1 to 43 sec	By time of flight correction
Inherent speed corr.	ω	Hand input	± 5° 30'	Follow the pointer dial
Parallax correction	n	Hand input	±4°	Follow the pointer dial

ENCLOSURE (D), continued

Name	Notation	Receiver	Range	Notes
Vertical total corr.		Hand input	30°	Co-ordinate converter
Lateral total corr.		Hand input	45°	Cor-ordinate converter

B. List of Output Data

Name	Notation	Transmitter	Range	Notes
Fuse	$= T + Tc$	Selsyn	1 to 43 sec	For Gun
Vertical total corr.		Differential Selsyn		For Gun
Lateral total corr.		Differential Selsyn		For Gun

C. Personnel

1. Computer officer.

2. Range and range change rate setter. By operating the handwheels of time of flight and range change rate, the optical slit line is aligned to the range marks on the range change rate chart.

3. Vertical deflection setter. Operating the vertical deflection handwheel stops the balancing wheel of the vertical deflection dial.

4. Lateral deflection setter. Operating the lateral deflection handwheel stops the balancing wheel of the lateral deflection dial.

5. Compass receiver. By operating the compass handle the pointer follows the compass repeater.

6. Vertical inclination correction setter.

7. Lateral inclination correction setter. Both No. 6 and 7 operating their handwheels set the mark "0" of the "Optical Co-ordinate Converter" to the fixed mark.

8. Correction Setter No. 1. Correction for fuse setting and for level target.

9. Correction Setter No. 2. Correction for parallax and for inherent speed.

D. Summary

Total weight 2,000 kg, approximately.

Constant speed electric motor, 100 or 220V, DC, 1/4 hp, 4,000 RPM.

Dimensions and external appearance are shown in annexed figures.

ENCLOSURE (D), continued

IV. PRINCIPLE OF COMPUTATION

Assumption:

Target speed is constant.

Target does not change its course.

Notation:

See Data List (paragraph III) and Figure 1(D)

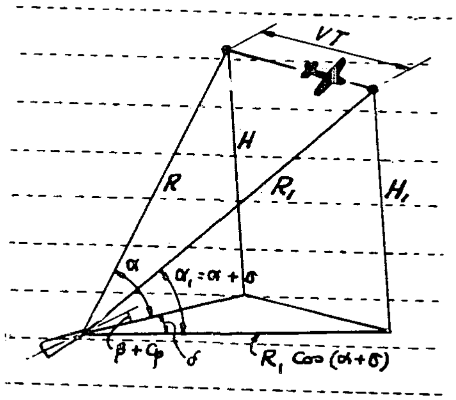


Figure 1(D)
TYPE 94 COMPUTER
DIAGRAM OF PROBLEM

Fundamental equations:

$$R_1 \sin(\alpha + \sigma) - R \sin\alpha = \frac{d}{dt} R \sin(\alpha + \sigma) \cdot T$$

$$R_1 \cos(\alpha + \sigma) \sin\delta = R \cos \frac{d\beta}{dt} T$$

$$R_1 \cos(\alpha + \sigma) \cos\delta - R \cos\alpha = \frac{d}{dt} R \cos(\alpha + \sigma) \cdot T$$

$$R_1 = R + \frac{dR}{dt} T + R_1 \{(1 - \cos\delta) \cos\alpha \cos(\alpha + \sigma) + 1 - \cos\sigma\}$$

$$\sin\delta = \frac{R \cos\alpha}{R_1 \cos \alpha + \sigma} \frac{d\beta}{dt} T$$

$$\sin\sigma = \frac{R}{R_1} \frac{d\alpha}{dt} T - (1 - \cos\delta) \sin\alpha \sin(\alpha + \sigma)$$

Time of flight T is a function of future range R_1 and future elevation. Therefore,

$$R_1 = f(T, \alpha + \sigma)$$

Superelevation is also

$$\phi = \phi_1 (R_1, \alpha + \sigma)$$
$$= \phi(T, \alpha + \sigma)$$

Inherent speed correction ω is given by

$$\omega = - V \sin(\beta + Cp + \delta) f(R_1, \alpha + \sigma)$$

$$= - V \sin(\beta + Cp + \delta) \frac{f(T)}{f(\alpha + \sigma)}$$

where V is inherent speed and the calculation is carried out assuming V is 30 knots. Therefore, when V is 24, for example, the correction value must be multiplied by 24/30, i.e. 0.8. This multiplication is accomplished by change gears.

ENCLOSURE (D), continued

Parallax correction n

$$n = B \sin(\beta + Cp + \delta)/R_1 \cos(\alpha + \sigma)$$

$$n = B \sin(\beta + Cp + \delta) \frac{f(T)}{f(\alpha + \sigma)}$$

B is the base length (distance between director and the gunhouse) and the calculation is carried out assuming B = 40 m. Therefore, for other base lengths change gears are used for multiplication.

The mechanics of the computer and arrangement of its parts are shown in Figures 1(D) to 4(D).

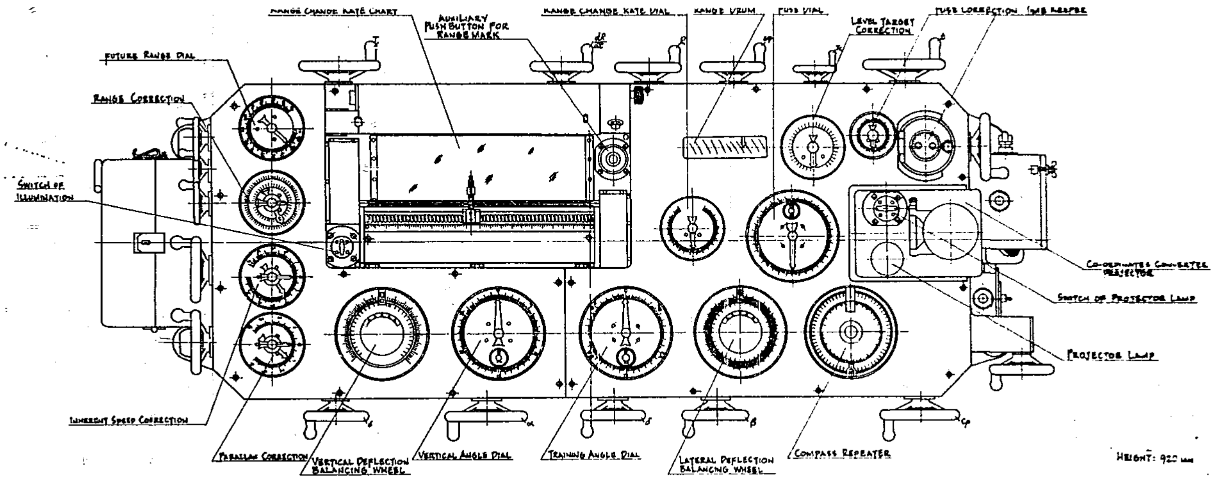


Figure 2(D)
TYPE 94 COMPUTER
ARRANGEMENT OF CONTROLS AND POINTERS

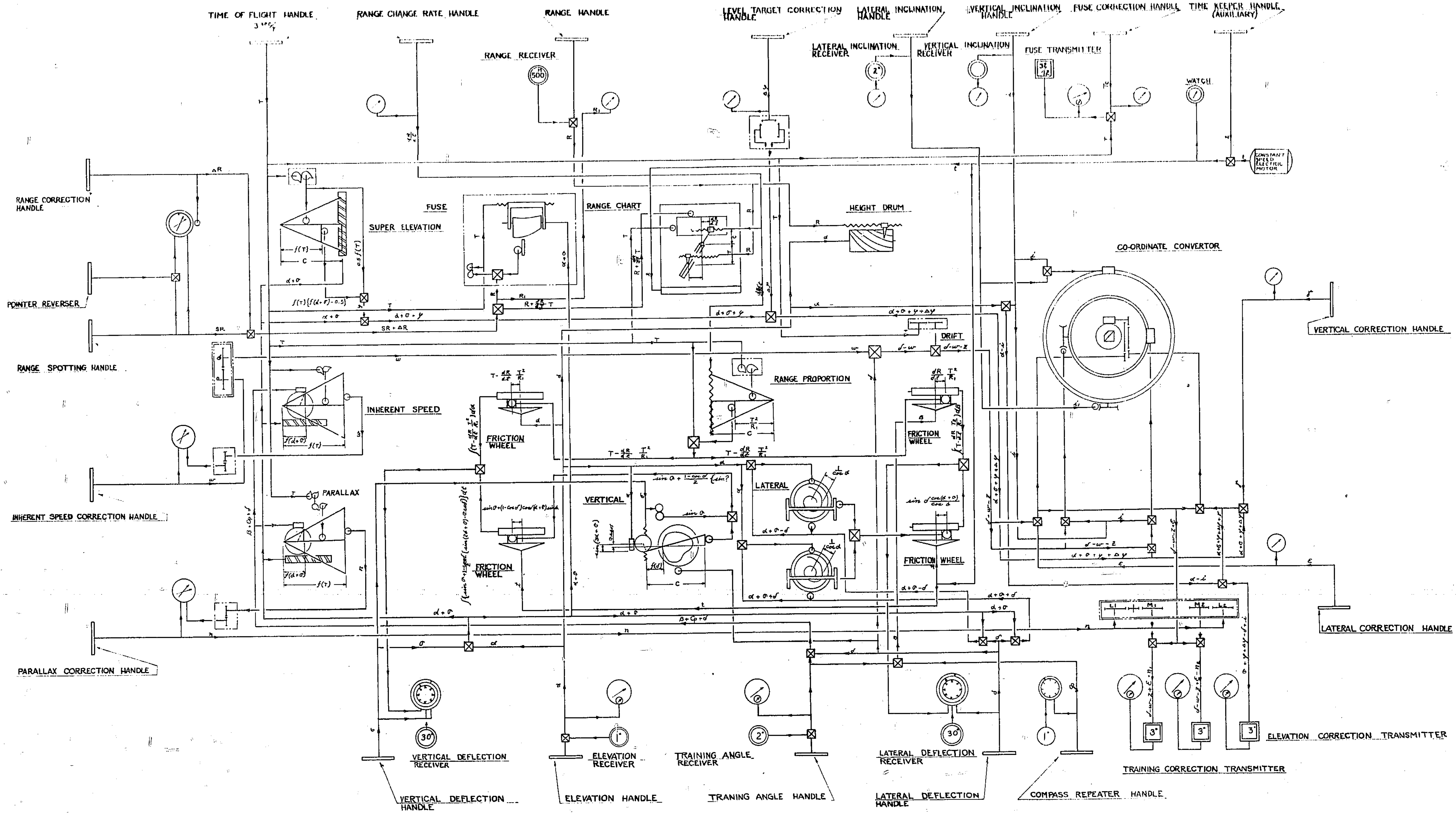


Figure 3(D)
TYPE 94 COMPUTER
SCHEMATIC DIAGRAM

ENCLOSURE (D), continued

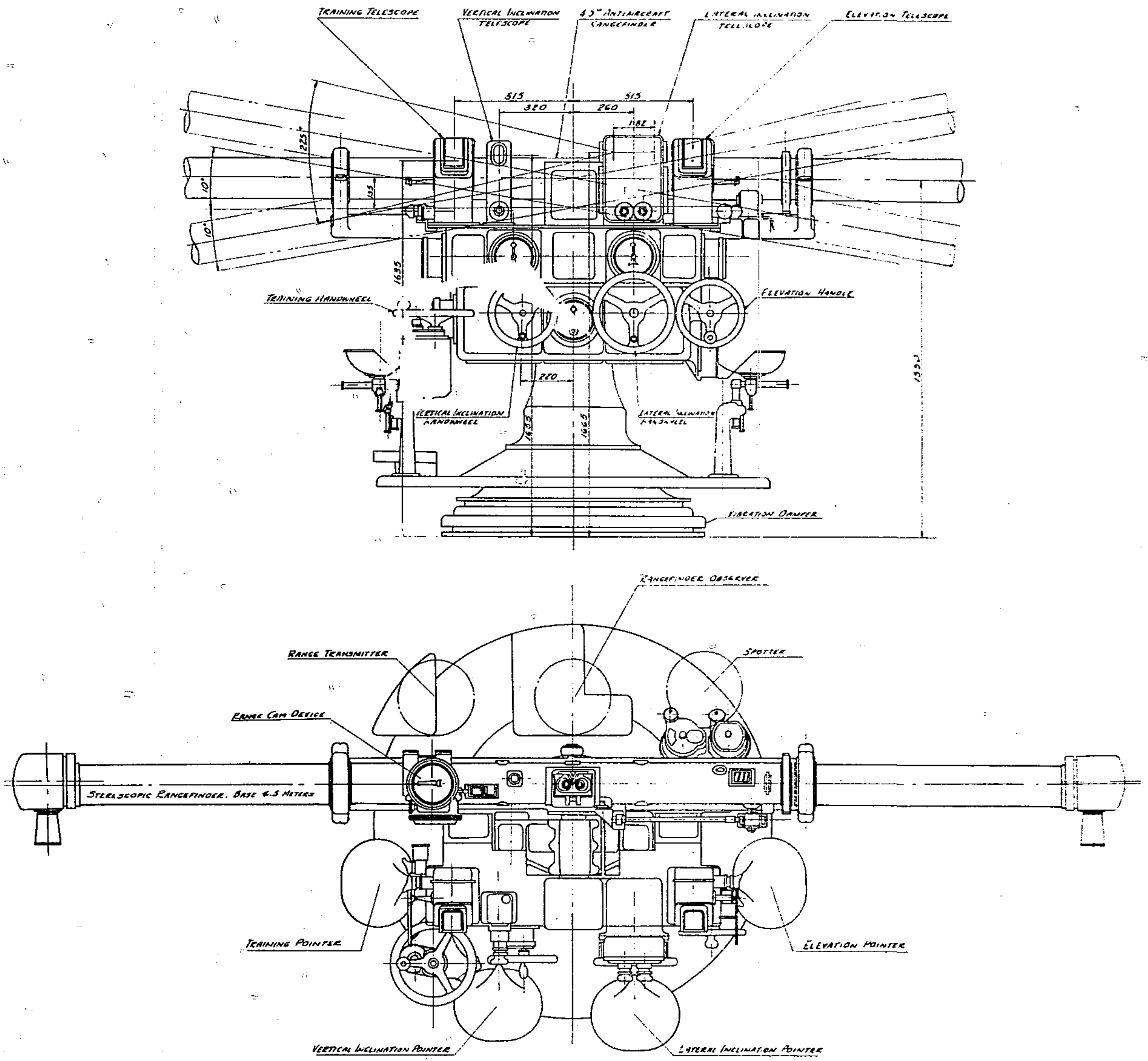


Figure 4(D)
TYPE 94 COMPUTER
DRAWING OF PLAN AND SIDE VIEWS

ENCLOSURE (E)

TYPE 94 DIRECTOR MODIFICATION I
GENERAL DESCRIPTION OF DESIGN

Prepared by Ichiro MIZUMO
Kawasaki First Designing Section
Nippon Optical Company

12 January 1944

A. Introduction

After the outbreak of the China incident it was necessary to increase suddenly the number of AA directors aboard ships, and considerable progress was made. However, it was apparent that Japanese optical concerns previously engaged in the manufacture of AA directors could not meet the demands and so plans were made for their manufacture at navy yards as well.

Then, when the Greater East Asia War commenced, an urgent need for increasing the number of shipboard AA directors arose. Thereupon plans for the immediate construction of AA directors and increased production were advanced by Tech. Lt. Comdr. SUGANUMA of the Navy Technical Department, Tech. Lt. Comdr. ICHII of the Kure Navy Yard, and others. Furthermore under the leadership of Comdr. NAKAYAMA of the Navy Technical Department, opinions of personnel who used the equipment were considered and the following plan was formulated by integrating their ideas with those of personnel from the Naval General Staff, the Yokosuka Gunnery School, and the Tateyama Gunnery School, which manufactured the AA directors. An outline of requirements for AA directors to be used aboard newly constructed vessels follows:

1. To be capable of conducting pointer fire and spot firing.
2. To be capable of firing by estimating target course and target speed.
3. To be capable also of angular velocity type firing.
4. To make feasible target course and target speed type firing and the conduct of pointer fire by sight base only.
5. To be capable of being produced in quantity.
6. Easy to repair and easy to interchange parts.
7. To be capable of being easily assembled by anyone with simple instruction.
8. To make night firing possible.
9. To make possible indirect fire at planes flying in and out of clouds.
10. Easy target designation from commander to AA director.
11. Suited to a hypothetical vertical angle of 25 degrees, hypothetical horizontal angle of 45 degrees, and target speed of 500 knots.
12. To show a tolerance of about 10 minutes.
13. To reduce calculator error to less than 100 meters in direct fire.
14. To use multiple communications.

ENCLOSURE (E), continued

15. Equipped with range receiver, elevation receiver, lateral angle re-ce[illegible]er (using radar).

16. Top turning speed of 18°/sec.

17. Planned so as to leave a simplified target shelf and rangekeeper.

18. It must not use a ball-bearing the housing of which is less than 1/8".

The above requirements have many variations and digressions. It is almost impossible to satisfy them all. For that reason the "Type 3 AA Director" was designed at Kure Naval Yard as a concrete plan which was comparatively satisfactory in view of the above aims. Furthermore, taking into account the many uses to which it had been put, plans and designs were executed by the Nippon Optical Industry which resulted in improving the "Type 94 AA Director" and more closely satisfying the above aims.

B. <u>Essentials of the Type 94 Improved AA Director</u>

In order to effect a greater production of the Type 94 AA Director the following policy was laid down with the aim of simplification.

1. Although planned construction to modify air pressure and difference in muzzle velocity has been stopped, it has been decided to modify the firing range in the future.

2. The time of flight clock is to be eliminated.

3. Corrections of the conveying angles will be by a manual crank. Correction of gun spacing will be by altering the gear ratio.

4. Range not to be recorded, but to be represented by an outline in flight.

5. Wind corrections will not be made. Drift correction (and own speed correction) only will be made (as heretofore). Own speed will be by altering the gear ratio to standard speed.

6. The range handwheel to be discarded and the time delay handwheel to be substituted.

7. As heretofore, no predicting interval correction will be effected. However, the time delay correction scale and the range scale will be brought closely together and the predicting interval correction will be reduced to an average.

8. It will be possible to set the range measurement by altitude and angle of sight, and by curved line cylinder tracking.

9. The angle indicated by the commander's glasses will enter the left lens of the tracking binoculars and by tracking this, the AA director may be controlled by the commander.

10. The binoculars will not be fitted with simple illuminators.

11. Using target course and target speed, simple predicting calculations will be carried out where the commander is, and the predicted angle will be sent to the rangekeeper by means of communications equipment. At the rangekeeper this will be used in tracking and be transmitted to the guns.

ENCLOSURE (E), continued

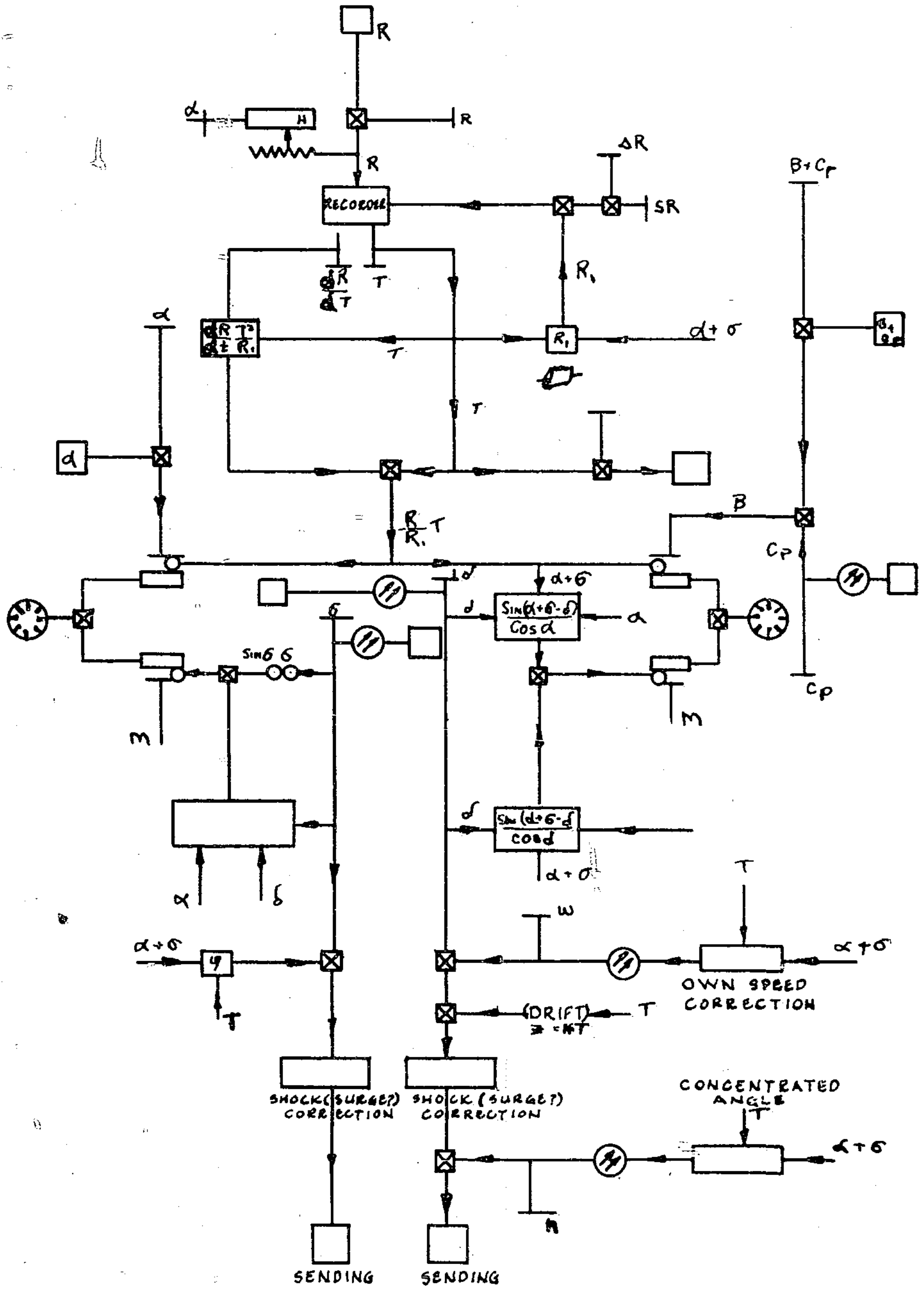


Figure 1(E)
TYPE 94 MOD 1 DIRECTOR
BLOCK DIAGRAM

ENCLOSURE (E), continued

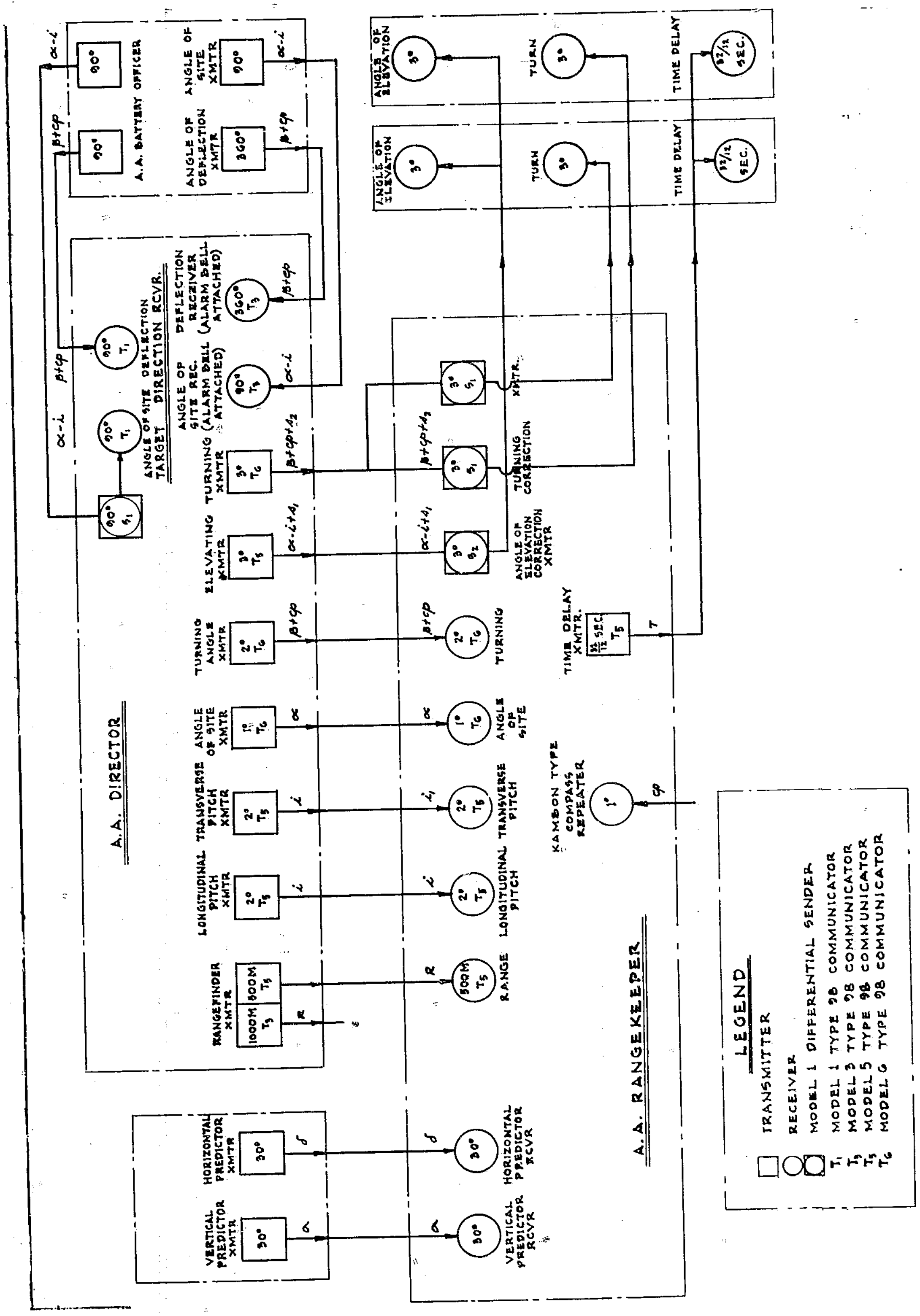


Figure 2(E)
TYPE 94 MOD 1 DIRECTOR
COMMUNICATION CONNECTIONS

ENCLOSURE (E), continued

In item 9 above the communications equipment which transmits the angle indicated by the commander's glasses and the simple calculator mentioned in item 11 are manufactured at the navy yard (s). The rest of the equipment is manufactured by the Nippon Optical Co., Inc.

In accordance with the above, the rangekeeper and communications systems are shown in Figure 1(E) and Figure 2(E).

C. Basic Theory

Referring to Figure 3(E), with O as firing position, take the front of the sight as the vertical plane and the level surface as the horizontal plane. Make as the projection of the firing point the aiming point which is in the vertical plane of P Q and the horizontal plane of $P_0 Q_0$. However, a fixed coordinating surface is made on the firing panel. This is equal to $Q_0 Q_0$. $O_0 Q_1$

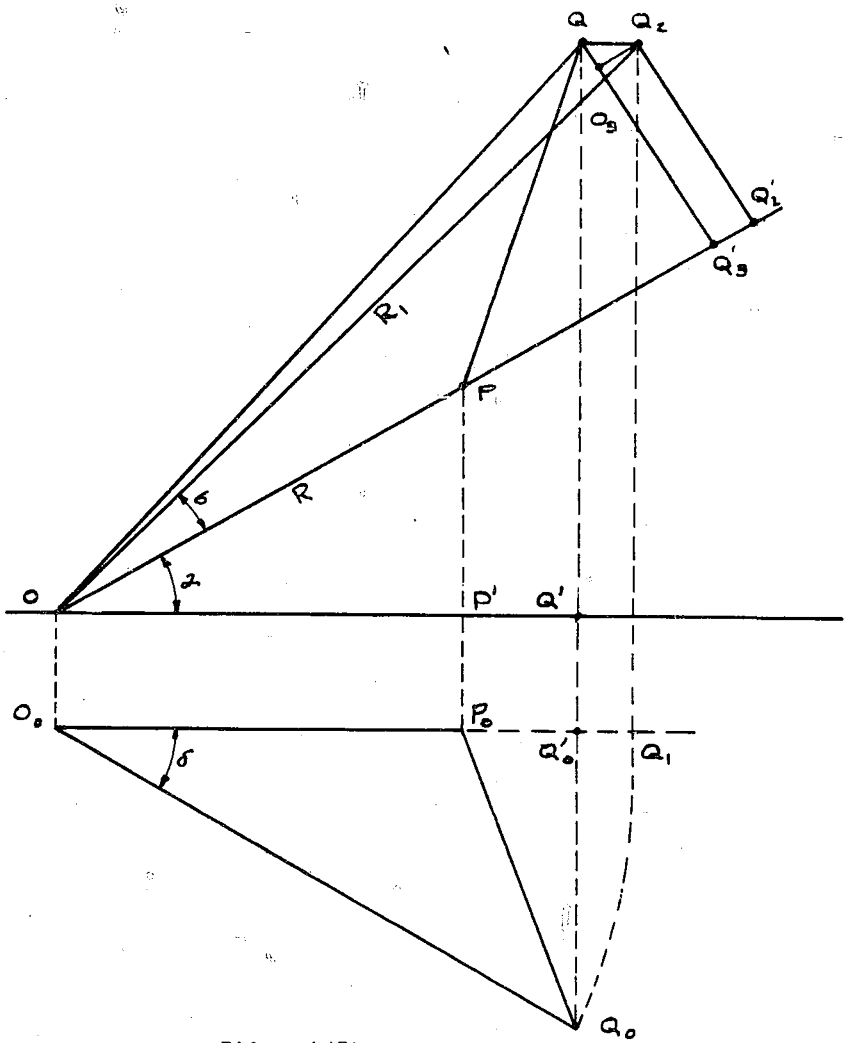


Figure 3(E)
TYPE 94 MOD 1 DIRECTOR
DIAGRAM OF PROBLEM

ENCLOSURE (E), continued

and the extension $O_0 P_0$ coincide at Q_1. A perpendicular is dropped from Q_1 and it coincides with the horizontal line drawn on the horizontal surface from Q at Q_2. Then a perpendicular line is dropped from Q_2 to OP and coincides with its extension at Q'_2. Next the perpendicular line QQ'_3 is dropped from Q to OQ'_2 and the perpendicular line $Q_2 Q_3$ is dropped from Q_2 at QQ_1. The distance from O to the aiming point and to the firing point are R and R_1 respectively. The angles formed by the horizontal surface with the aiming point and the firing point are α and $\alpha + \sigma_1$, respectively.

$$OP = R$$
$$OQ_2 = R_1$$
$$O_0P_0 = R \cos \alpha$$
$$O_0Q_0 = R_1 \cos (\alpha + \sigma)$$
$$QQ'_0 = R \cos (\alpha + \sigma) \sin \delta$$
$$QQ_2 = Q_1Q'_0 = R \cos (\alpha + \sigma) (1 - \cos \delta)$$
$$Q_2Q_3 = Q'_2Q'_3 = QQ_2 \cos \alpha = R_1 \cos (\alpha + \sigma) (1 - \cos \delta) \cos \alpha$$
$$QQ_3 = QQ_2 \sin \alpha \; R_1 \cos (\alpha + \sigma) (\cos \delta) \sin \alpha$$
$$OQ_2 = OQ_2 \cos \sigma = R_1 \cos \sigma$$
$$Q_2Q'_3 = OQ_2 \sin \sigma = R_1 \sin \sigma$$

If the firing panel moves in a direct line with uniform speed, and the target moves into the path of the shell in a direct line at uniform speed, then

$$PQ'_3 = \frac{dB}{dt} T$$
$$QQ'_2 = \frac{R \, d\alpha}{dt} T$$
$$Q_0O'_0 = R \cos \alpha \frac{dB}{dt} T$$
$$T = f \, [R_1, (\alpha + \sigma)]$$

On the other hand.

$$PQ'_3 = OQ'_2 - OP - Q'_2Q'_3$$
$$= R \cos \sigma - R - R_1 \cos (\alpha + \sigma) (1 - \cos \delta) \sin \alpha$$
$$QQ'_3 = QQ_3 + Q_3Q'_3 = QQ_3 + Q_2Q'_2$$
$$= R_1 \cos (\alpha + \sigma) (1 - \cos \delta) \sin \alpha + R_1 \sin \sigma$$
$$Q_0Q^1_0 = R_1 \cos (\alpha + \sigma) \sin \delta$$

Ergo - if all three sides are equal to preceding we may say (T is time of flight) that:

$$\frac{dR}{dt} T = R_1 \cos \sigma - R - R_1 \cos (\alpha + \sigma) (1 - \cos \delta) \sin \alpha$$
$$R \frac{d\alpha}{dt} T = R_1 \cos (\alpha + \sigma) (1 - \cos \delta) \sin \sigma + R_1 \sin \sigma$$

ENCLOSURE (E), continued

$$R \cos \alpha \frac{dB}{dt} T = R_1 \cos (\alpha + \sigma) \sin \delta$$

Then, if we differentiate these -

$$R_1 = R + \frac{dR}{dt} T + R_1 \left\{ (1 - \cos \sigma) + \cos \alpha \cos (\alpha + \sigma) (1 - \cos \delta) \right\} \ldots\ldots \text{(C1)}$$

$$\frac{d\alpha}{dt} \frac{R}{R_1} T = \sin \sigma + \sin \alpha \cos (\alpha + \sigma) (1 - \cos \delta) \ldots\ldots \text{(C2)}$$

$$\frac{dB}{dt} \frac{R}{R_1} T = \frac{\cos (\alpha + \sigma)}{\cos \alpha} \sin \delta \ldots\ldots \text{(C3)}$$

That is to say that equations (C1), (C2), and (C3) are the basic methods of calculating for angular velocity.

D. <u>Range</u>

Concerning the range of Type 94 AA Director if we simplify the mechanics and let

$$R_1 = R + \frac{dR}{dt} T \ldots\ldots \text{(D1)}$$

there should be an error of

$$R_1 \left\{ (1 - \cos \sigma) + \cos \alpha (\alpha + \sigma) (1 - \cos \delta) \right\}$$

First, consider the area covering R and R_1: if we call the angle formed by R and R_1 at its top surface λ it is evident from Figure 4(E) that since

$$R_1 = R + \frac{dR}{dt} T + R_1 (1 - \cos \lambda) \ldots\ldots \text{(D2)}$$

the difference between equations (D1) and (D2) will be $R_1 (1 - \cos \lambda)$. If we compare this to equation (C1) we have

$$R_1 (1 - \cos \lambda) = R_1 \left\{ (1 - \cos \sigma) + \cos \alpha \cos (\alpha + \sigma) (1 - \cos \delta) \right. \ldots\ldots \text{(D3)}$$

Let θ represent target course and V target speed on the surface under consideration then (see Figure 4(E)

$$\sin \lambda = \frac{VT \sin \theta}{R_1} \ldots\ldots \text{(D4)}$$

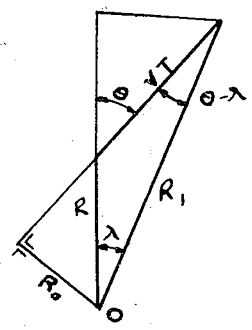


Figure 4(E)
TYPE 94 MOD 1 DIRECTOR
DIAGRAM FOR ANALYSIS OF PROBLEM

ENCLOSURE (E), continued

$$\cos\lambda = \sqrt{1-\sin^2\lambda} = \sqrt{1-\left[\frac{VT\sin\theta}{R_1}\right]^2} = 1 - \tfrac{1}{2}\left(\frac{VT\sin\theta}{R_1}\right)^2 - 1/8\left(\frac{VT\sin\theta}{R_1}\right)^4 \dots$$

$$1-\cos\lambda = \tfrac{1}{2}\left(\frac{VT\sin\theta}{R_1}\right)^2 + 1/8\left(\frac{VT\sin\theta}{R_1}\right)^4 \dots$$

Therefore, we know that in general $(1-\cos\lambda)$ is proportional to the rate of target speed. Therefore, when the rate of target speed is low, $(1-\cos\lambda)$ is extremely small. But when the target speed is great, the problem is more difficult. Making R_0 the perpendicular dropped from the line of target course (see Figure 4(E).

$$R_1\sin(\theta-\lambda) = R_0$$

$$\sin(\theta-\lambda) = \frac{R_0}{R_1} \dots\dots (D5)$$

From equation (D4)

$$\sin\lambda = \frac{VT\sin\theta}{R_1} = \frac{VT}{R_1}\sin\{(\theta-\lambda)+\lambda\}$$

$$= \frac{VT}{R_1}\{(\sin\theta-\lambda)\cos\lambda + \cos(\theta-\lambda)\sin\lambda\}$$

$$\therefore \sin\lambda\left\{1-\frac{VT}{R_1}\cos(\theta-\lambda)\right\} = \cos\lambda\,\frac{VT}{R_1}\sin(\theta-\lambda)$$

$$\tan\lambda = \frac{\frac{VT}{R_1}\sin(\theta-\lambda)}{1-\frac{VT}{R_1}\cos(\theta-\lambda)} \dots\dots (D6)$$

From this the gunnery rules are determined. In equation (D5) if we assume R_0, R_1 must follow, and we derive $(\theta-\lambda)$. In equation (D6) then when we assume V we derive λ and consequently we can calculate $R_1(1-\cos\lambda)$. In actuality, though we determined the gunnery rules, we leave only determined R, since $T = f[R_1(\alpha+\sigma)]$ and T has not been derived. However in the foregoing problem, since $(1-\cos\lambda)$ was proportional to $(T)^2/(R_1)^2$ and if we choose the maximum value for T and calculate on the same R_1, we derive the maximum for $(1-\cos\lambda)$. Then, in making the gunnery rules, when we have a 10cm gun, $R_1 \leq 10{,}000$ m or $T_{\alpha+\sigma=0}$ is assumed to be the maximum T. Furthermore, since $R_1 > 10{,}000$ m or $T_{\alpha+\sigma=0}$ is in general the average value of T, we substitute $T_{\alpha+\sigma=0}$ for the sake of convenience, and continue calculations. Since V = 200 m/s and R_0 is 1000 to 8000 m, the result is identical with Figure 5(E).

However, when we consider it further, we cannot presume $R_1(1-\cos\lambda)$.

Thus $$R_1 = R + \frac{dR}{dt}T + R_1(1-\cos\lambda) \dots\dots (D7)$$

but $$T = f[R_1(\alpha+\sigma)]$$

$$R_1 = P + \frac{dP}{dt}T \dots\dots (D6)$$

but $$T' = f[R_1(\alpha+\sigma)]$$

Moreover

$$R_1 = R_1 + \Delta R$$

$$T' = T + \frac{dT}{dR}\Delta R$$

ENCLOSURE (E), continued

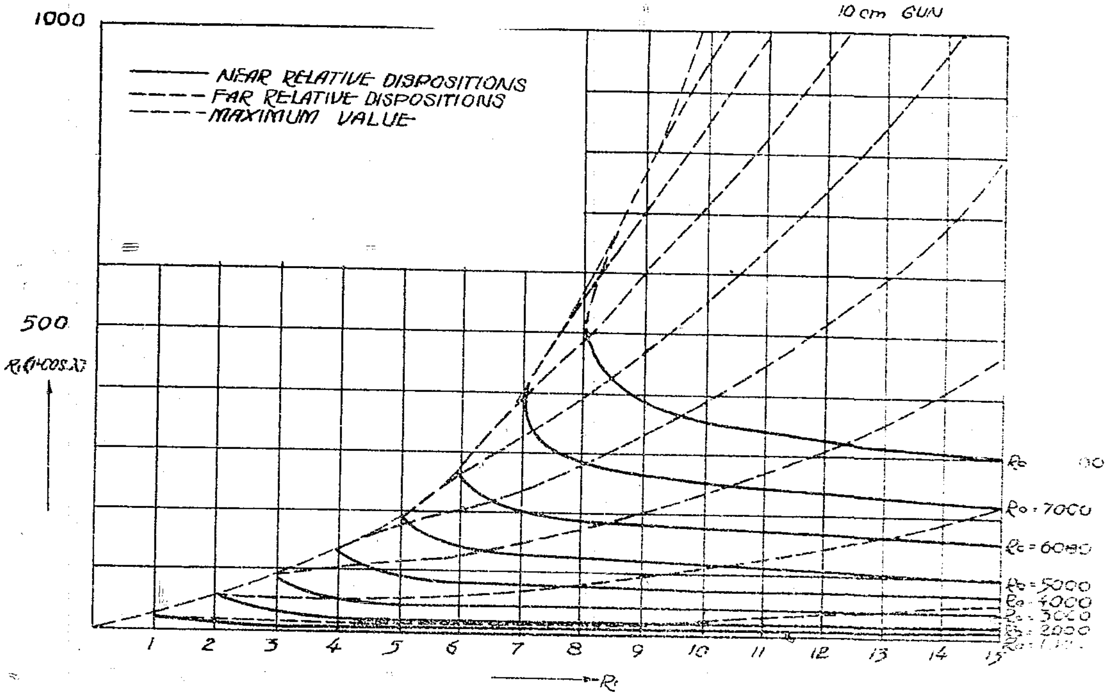


Figure 5(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* $R_1(1 - \cos\lambda)$

Therefore equation (D8) is

$$R_1+\Delta R_1 = R + \frac{dR}{dT}\left(T + \frac{dt}{dR_1}\Delta R_1\right) = R\frac{dR}{dt}T + \frac{dP}{dt}\frac{dT}{dR}\Delta R_1 \quad \ldots\ldots \text{(D9)}$$

When we complete equation (D7) from (D9)

$$\Delta R_1 = -R_1(1-\cos\lambda) + \frac{dR}{dt}\frac{dT}{dR_1}\Delta R_1$$

$$\Delta R_1 = \frac{-R_1(1-\cos\lambda)}{1 - \frac{dR}{dt}\frac{dT}{dR_1}} \quad \ldots\ldots \text{(D10)}$$

Moreover

$$\frac{dR}{dt} = V\cos\theta$$

Since we have calculated θ from equations (D5) and (D6), we can calculate dR/dt . Therefore, when we discover dT/dR_1 from the firing table, we can determine ΔR_1 by using the previous $R_1(1 - \cos\sigma)$.

When this is determined we have the diagram in Figure 6(E). This is for the most part, identical with the foregoing diagram in Figure 5(E) but when the relative position is near, the error is small even though it is dependent upon

ENCLOSURE (E), continued

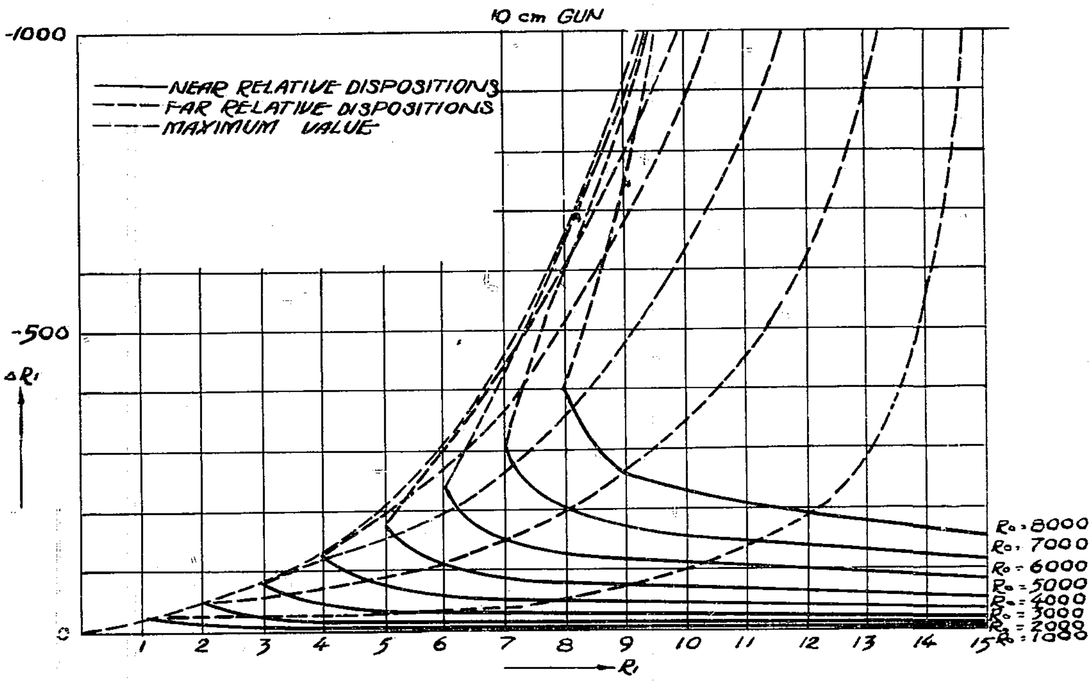


Figure 6(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* ΔR_1

method in equation (D8) . However, when the relative position is distant, the errors may be great if one uses that method. The denominator of equation (D10) contains

$$\frac{dR}{dt}\frac{dT}{dR_1} = \frac{\frac{dR}{dt}}{\frac{dR_1}{dT}} = \frac{\text{Target speed}}{\text{Residual speed of shell.}}$$

Since V of the target speed is great and the above proportion amounts to more than 1, the shell cannot hit the target. Consequently when the relative position is distant, errors are great. Even so, firing at a target with a great relative speed and with a distant relative position is almost impossible, so we do not consider such cases. If it is a problem with only a small relative distance, we use the method of equation (D8) and we may say that we can gain our object. Although we have derived $\Delta R/dt$ in the above calculations, it is a restatement of Figure 7(E). With this we can find out how to complete $dR/dt = -V$ when there is small relative distance.

E. Range Ratio

The formula for firing distance as shown in equation (D1) is correct though we used method of equation (D8), but the result is influenced by R/R_1 T which was used in the basic methods of equations (C8) and (C3). Let us consider this next:

$$R_1 = R + \frac{dR}{dt} T \quad R_1 (1 - \cos \lambda)$$

ENCLOSURE (E), continued

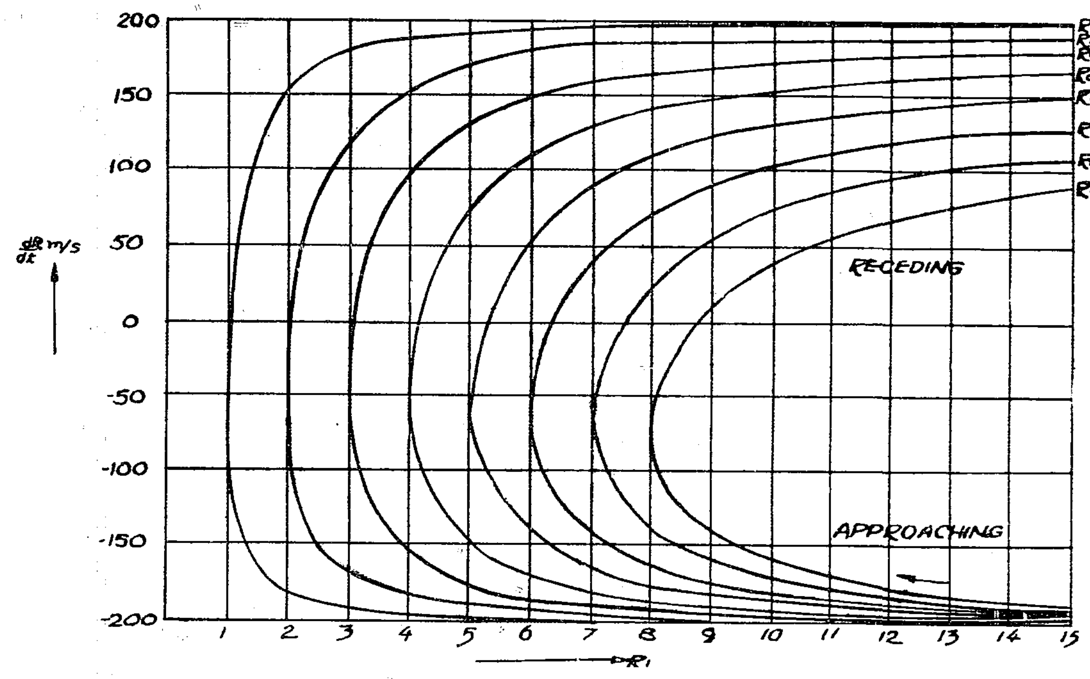


Figure 7(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* dR/dt

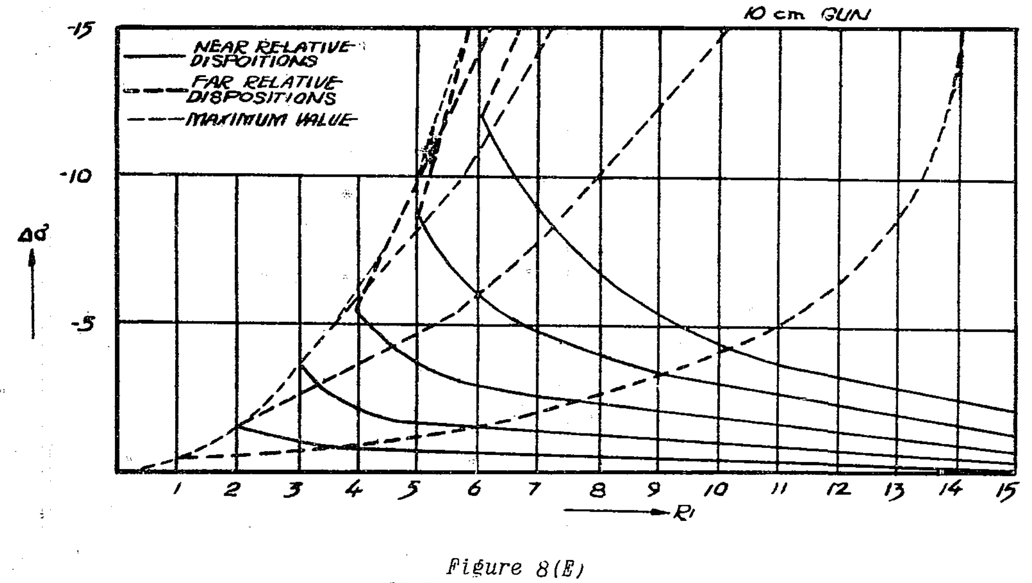


Figure 8(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* $\Delta\sigma$

ENCLOSURE (E), continued

$$R_1 = R + \frac{dT}{dt} T'$$

$$\Delta\left(\frac{R}{R_1}T\right) = \frac{R}{R_1'}T' - \frac{R}{R_1}T$$

$$= \frac{\Delta\left(\frac{R}{R_1}T\right)}{\frac{RT}{R_1}} = \frac{\frac{R}{R_1}T' - \frac{R}{R_1}T}{\frac{R}{R_1}T} = \frac{R_1}{R_1'}\frac{T'}{T} - 1 = \frac{R_1}{R_1 + \Delta R_1}\frac{T + \Delta T}{T} - 1 =$$

$$= \frac{1}{\left(1 + \frac{\Delta R_1}{R_1}\right)}\left(1 + \frac{\Delta T}{T}\right) - 1 = \left(1 - \frac{\Delta R_1}{R_1}\right)\left(1 + \frac{\Delta T}{T}\right) = \left(\frac{\Delta R_1}{R_1} + \frac{\Delta T}{T}\right)$$

Therefore:

$$\Delta T = T' - T = \frac{dT}{dR_1} \cdot \Delta R_1$$

$$\frac{\Delta T}{T} = \frac{dT}{dR_1}\frac{R_1}{T}\frac{\Delta R_1}{R_1}$$

$$\frac{\Delta\left(\frac{R}{R_1}T\right)}{\frac{R}{R_1}T} = \frac{\Delta R_1}{R_1} + \frac{dT}{dR_1}\frac{R_1}{T}\frac{\Delta R_1}{R_1} = \frac{\Delta R_1}{R_1}\left(\frac{dT}{dR_1}\frac{R_1}{T} - 1\right) \qquad \text{(E1)}$$

In order to consider the error of σ or δ dependent on $\Delta(R/R_1 \cdot T)$, and to calculate them singly, let us follow equation (C2) as closely as possible.

$$\sigma = \frac{d\alpha}{dt}\frac{R}{R_1}T$$

$$\Delta\sigma = \frac{d\alpha}{dt}\Delta\left(\frac{R}{R_1}T\right)$$

$$\frac{\Delta\sigma}{\sigma} = \frac{\Delta\left(\frac{R}{R_1}T\right)}{\frac{R}{R_1}T} \qquad \text{(E2)}$$

$$\Delta\delta = \varepsilon\,\frac{\Delta\left(\frac{R}{R_1}T\right)}{\frac{R}{R_1}T} \qquad \text{(E3)}$$

Now σ = 10 degrees. In calculating $\Delta\sigma$ using the foregoing result as well as equations (E1) and (E2), we get the diagram in Figure 8(E). Accordingly, we may say that the near relative position is for the most part correct when dependent on this. Now in actuality σ is not fixed and when the relative position is distant, σ is small, while when the range is close, σ increases. The error changes when the relative distance is great but it is now calculated without regard for this change. If it depends on both δ and equation (E3), we may treat it as the result of the diagram in Figure 8(E) without alteration.

ENCLOSURE (F), continued

F. Computer for Range Ratio

The calculator of range ratio is correct even though formula (D8) was used and was determined from equation (F1). But that formula was used, so let us then solve it in the following manner:

$$R_1 = R + \frac{dR}{dt} T \qquad \text{(F1)}$$

$$\frac{R}{R_1} T = \frac{R_1 - \frac{dR}{dt} T}{R_1} = T - \frac{dR}{dt} \frac{T^2}{R_1} \qquad \text{(F2)}$$

In these formulae, if we take the difference between T^2/R_1 and T for gunnery rules, we have diagrams Figures 9(E) and 11(E). As we discover in the diagrams we can make

$$\frac{T^2}{R_1} = f(T) \qquad \text{(F3)}$$

This is shown in the diagrams. However, in such a case how great an error is created in R/R_1 T ? This must be determined.

$$\Delta\left(\frac{R}{R_1} T\right) = \left\{ -\frac{dR}{dt} f(T) \right\} - \left\{ T - \frac{dR}{dt} \frac{T^2}{R_1} \right\}$$

$$= \frac{dR}{dt} \left\{ \text{etc.} \right. \qquad \text{(F4)}$$

However, when we consider the influence exercised by $\Delta(R/R_1 \cdot T)$ on σ and δ, equations (E2) and (E3) can be used without alteration.

$$\Delta\sigma = \sigma \frac{\Delta\left(\frac{R}{R_1} T\right)}{\left(\frac{R}{R_1} T\right)} \qquad \text{(F5)}$$

$$\Delta\delta = \delta \frac{\Delta\left(\frac{R}{R_1} T\right)}{\left(\frac{R}{R_1} T\right)} \qquad \text{(F6)}$$

We discovered in (F4) that $\Delta(R/R \cdot T)$ is the function of dR/dt, but as shown in paragraph D, dR/dt is generally equal to the target speed when the relative position is near. To simplify, we may say that:

$$\frac{dR}{dt} \doteq -200\text{m/sec}$$

We calculated $\Delta\sigma$ in paragraph E, finding $\Delta\sigma$ when $\sigma = 10^\circ$. When we apply the result to the gunnery rules, we get the diagram in Figure 12(E). One would suppose that the error for an 8cm gun would be fairly large, but this is accepted in order to leave a common $f(T)$ for both the 8cm and 12cm guns for convenience sake in converting gunnery rules. Naturally, if we consider them separately there is a degree of difference between the 10cm and 12cm guns.

ENCLOSURE (E), continued

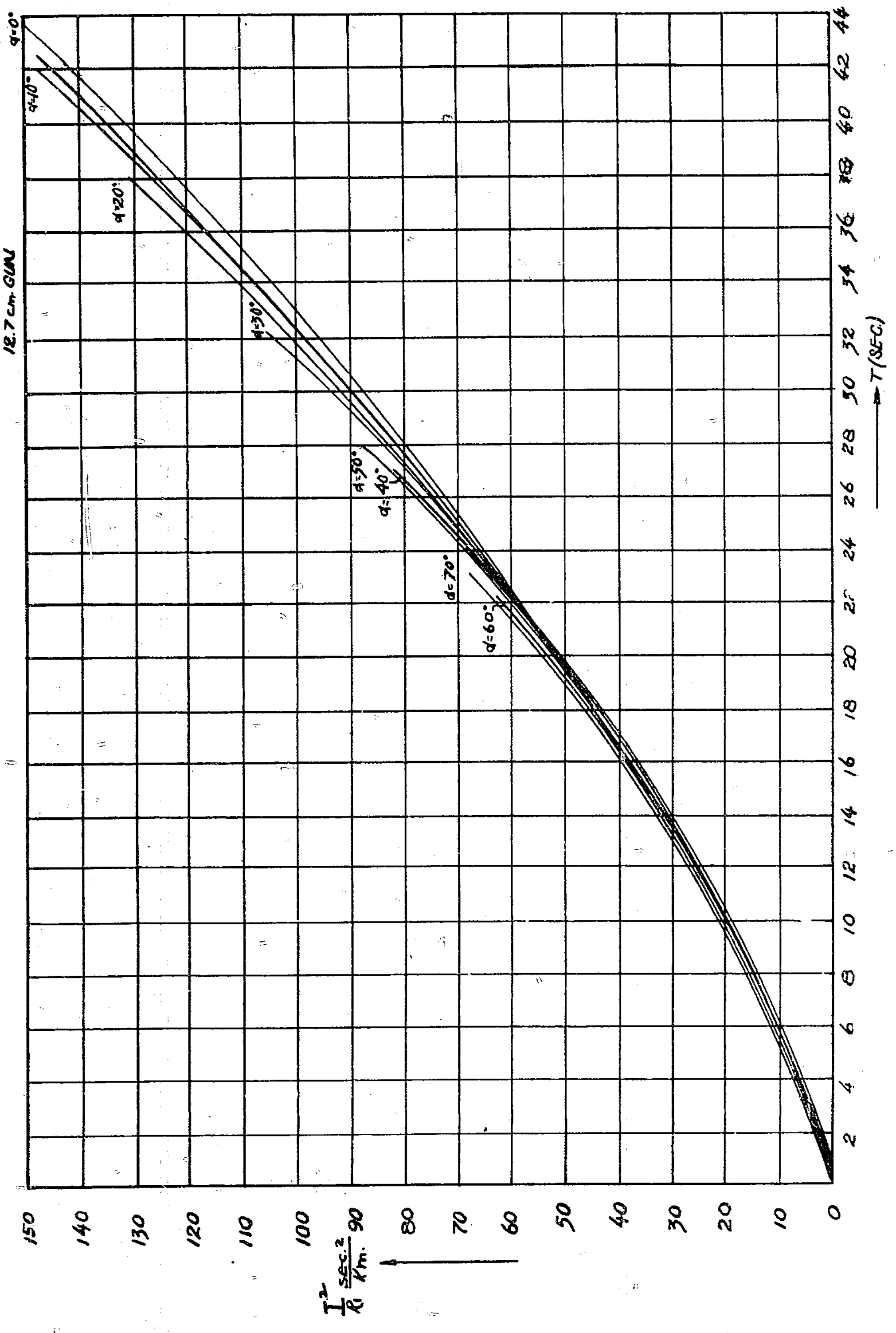


Figure 9(E)
TYPE 94 MOD 1 DIRECTOR
T vs. T^2/R_1

ENCLOSURE (E), continued

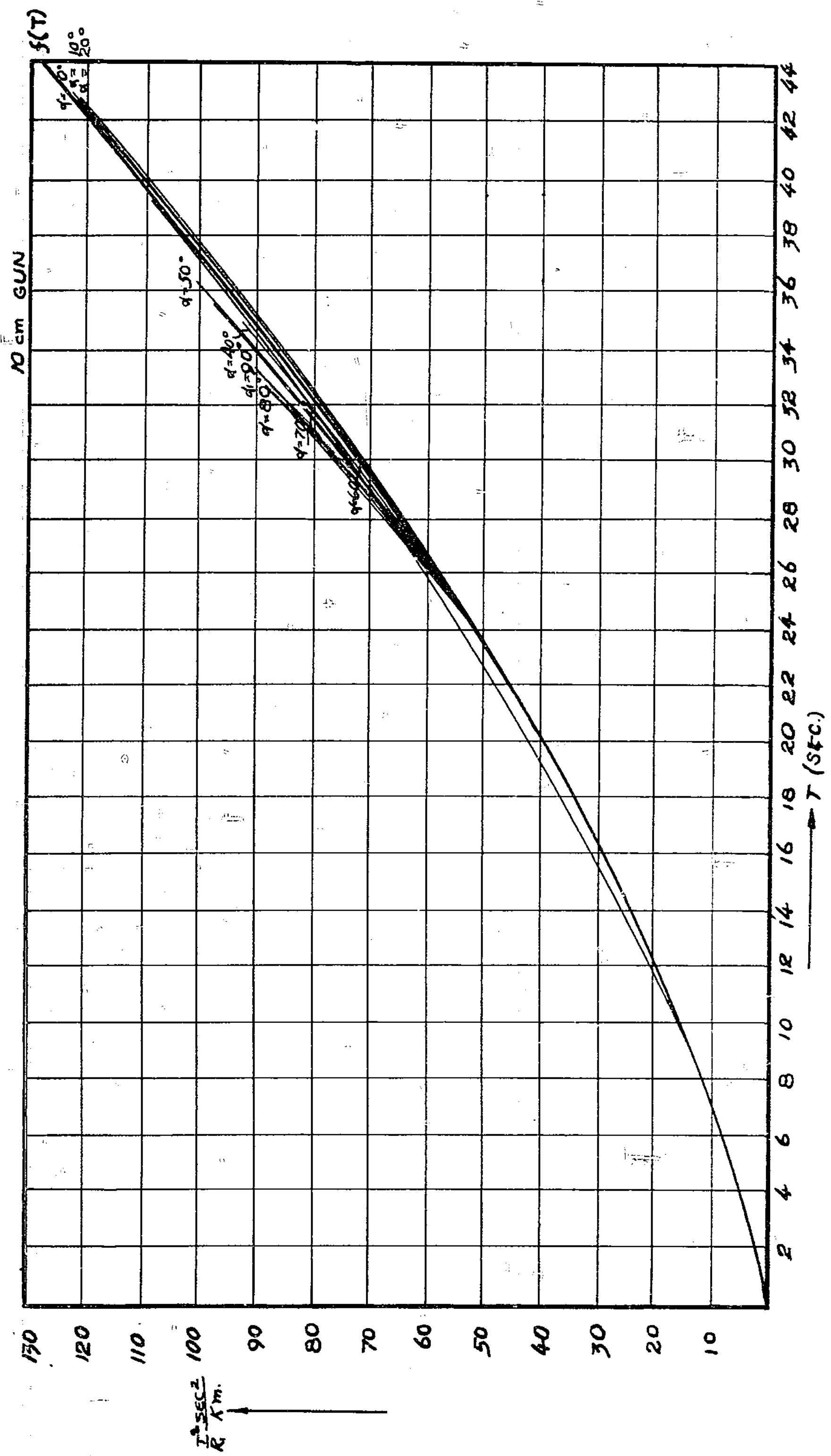


Figure 10(E)
TYPE 94 MOD 1 DIRECTOR
T vs. T^2/R_1

ENCLOSURE (E), continued

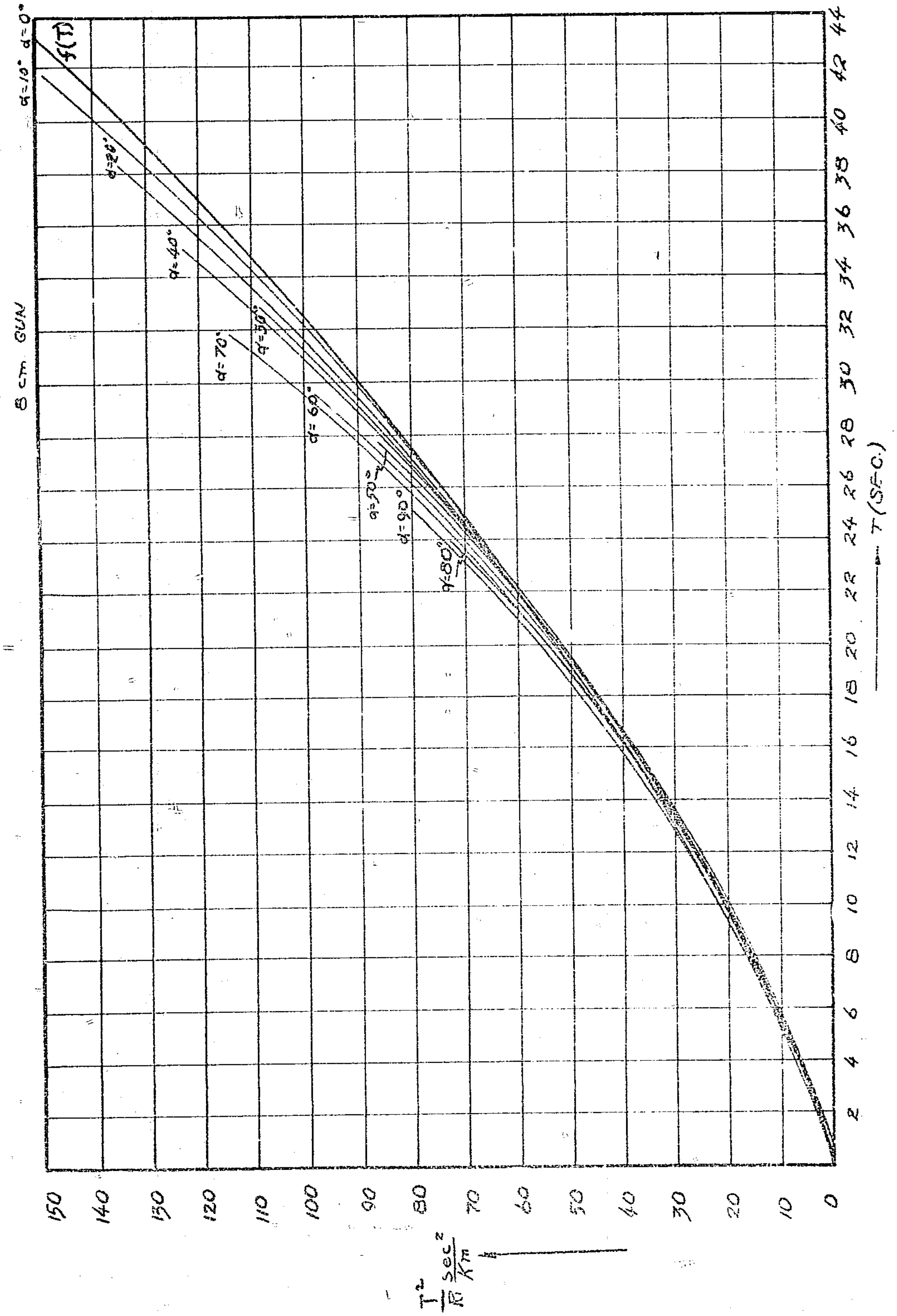


FIGURE 11(E)
TYPE 9, MOD 1 DIRECTOR
T vs. T^2/R_1

ENCLOSURE (E), continued

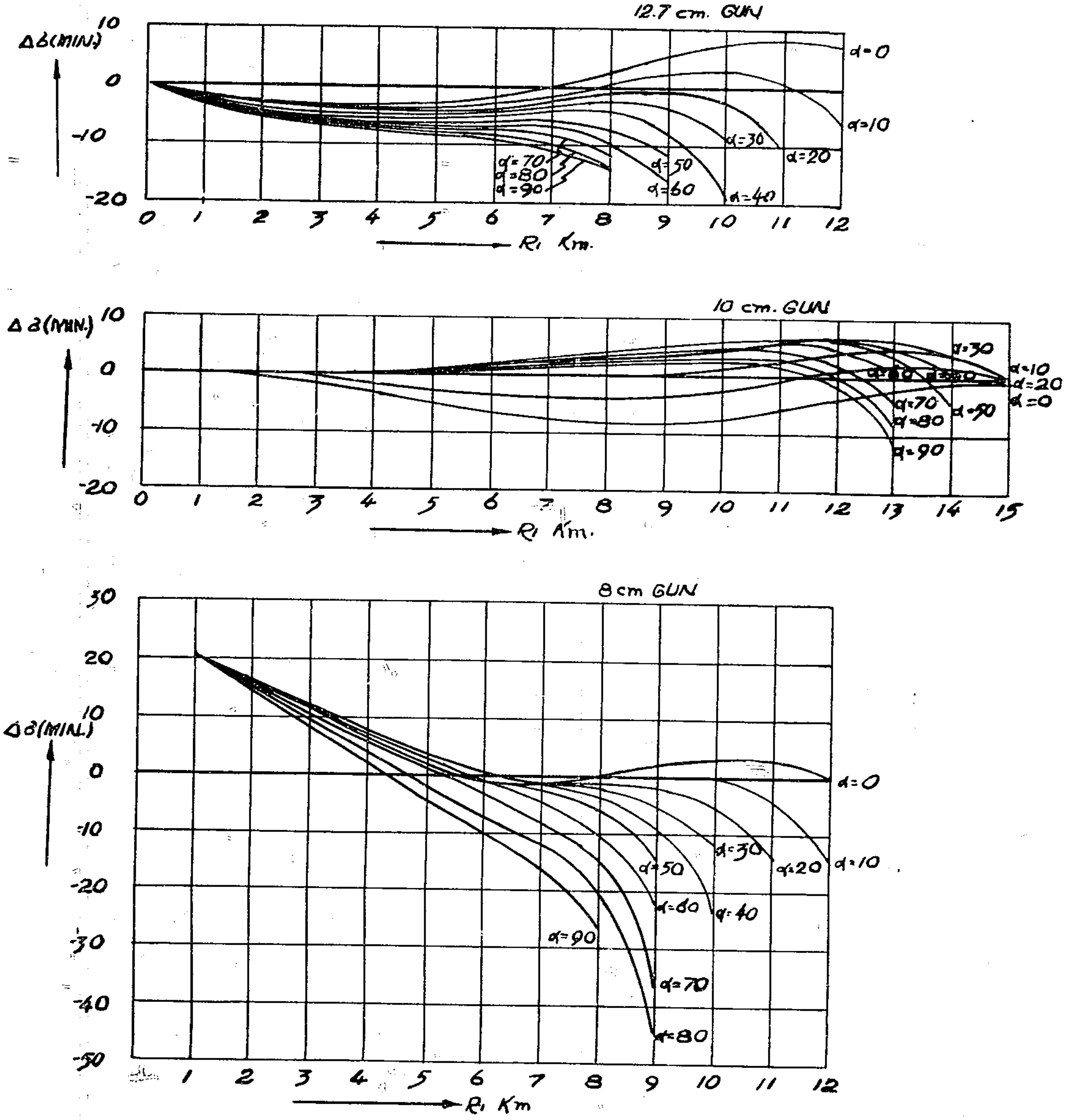


Figure 12(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* $\Delta\sigma$

ENCLOSURE (E), continued

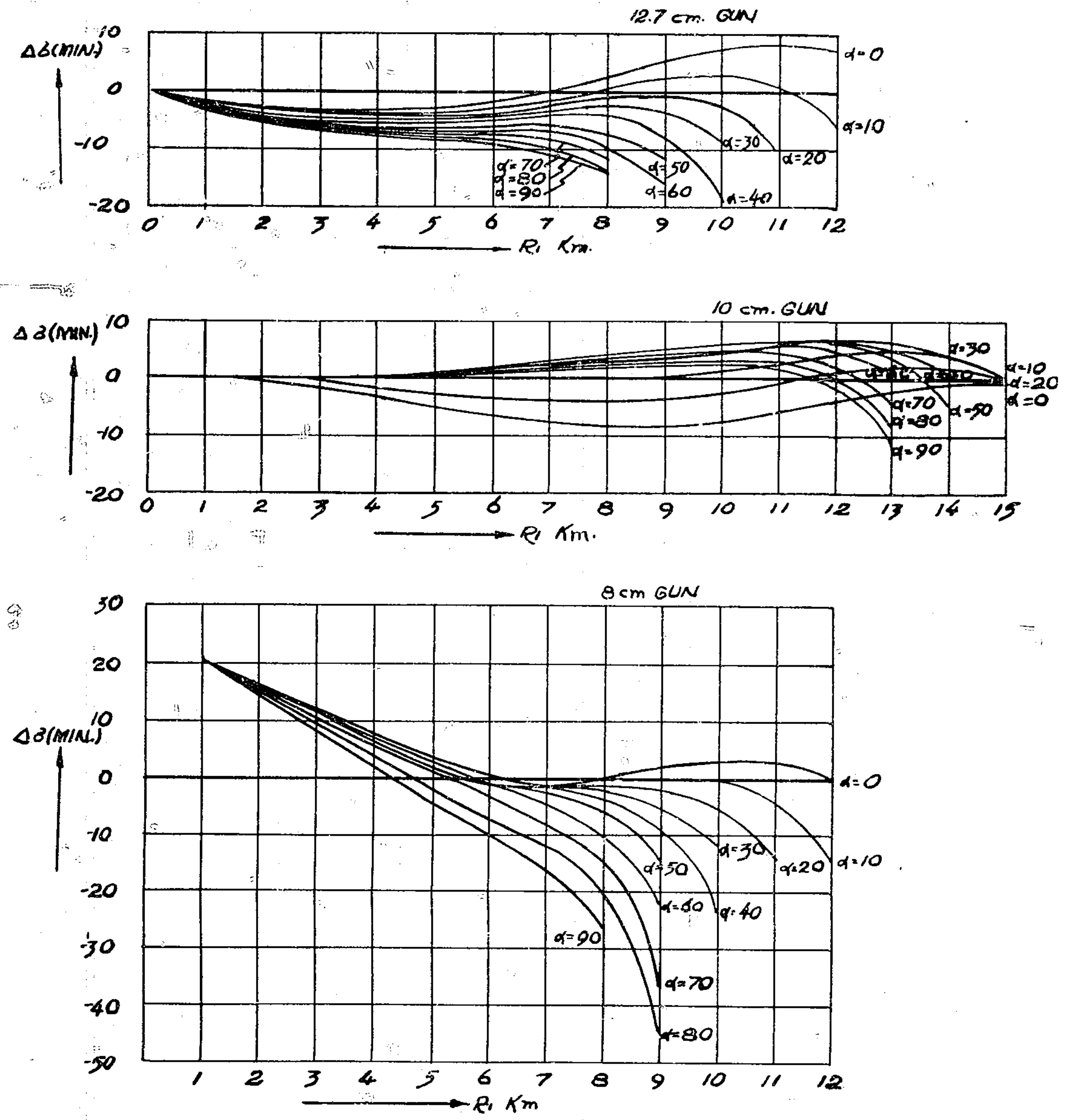


Figure 12(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* $\Delta\sigma$

G. Computer for Time of Flight

Time of flight is the function of firing distance and angle of elevation.

$$T = f(R_1, \alpha_1) \quad \text{(G1)}$$

However, since $\alpha_1 = \alpha + \sigma R_1$ must obviously be a function of T and α_1

$$\text{e.g. } R_1 = f(T_1, \alpha_1) \quad \text{(G2)}$$

To consider it another way, we have the diagrams in Figures 12(E) to 15(E) showing it for each type of gun. The fact we find immediately from the diagrams is that the influence of α_1 on R_1 in Figure 13(E) is less than the influence of α_1 on T, therefore,

$$R_1 = f_1(T) + f_2(T_1\ \alpha_1) \quad \text{(G3)}$$

In this case we must cube it. $f_1(T,\alpha)$ will become relatively small compared to $f_1(T)$. This is because the final product of the cubing is comparatively small and it is advantageous to be able to calculate accurately the greater part of T considered on the firing table. Figures 13(E) to 15(E) show $f_1(T)$ whose functional form is derived by a functioning setting gear (KANSU HAGURUMA) for T in the same manner as T/R_1 was derived. The function setting gear is changed depending on the type of gun, and conversion for gun types is easily made. Even so, $f_1(T)$ remains the same for both 12.7cm and 8cm guns as in the case of T/R_1. In other words, instead of operating the firing range ring and the range change ring as heretofore, when one wishes to operate the mechanism which determines the firing range, rate of range change and the desired R (i.e. the range controller), one operates the time of flight ring and the range change ring and the answer is correct. To put it another way--if one wants to manipulate the firing range handle one degree, and then determine the time of flight from this, the mechanism is much simpler.

H. Computer for Angle of Superelevation

The angle of superelevation is the function of R_1 and α_1, and the time of flight is also the function of R and α_1.

$$\zeta = f_\zeta(R_1, \alpha_1)$$

$$T = f_T(R_1, \alpha_1)$$

If we determine R from both of these formulae we get

$$\zeta = f(T_1, \alpha_1) \quad \text{(H1)}$$

When we look into the details of this form of the function there is relatively a small degree of error, and we can profit as follows:

$$\zeta = f(T)\ f(\alpha + \sigma) \quad \text{(H2)}$$

When we solve for $f(T)$ by applying (H2) to each type of gun we get

$$\zeta_{12.7} = f_{12.7}(T)\ f(\alpha + \sigma) \quad \text{(H3)}$$

$$\zeta_{10} = f_{10}(T)\ f(\alpha + \sigma) \quad \text{(H4)}$$

$$\zeta_8 = f_8(T)\ f(\alpha + \sigma) \quad \text{(H5)}$$

ENCLOSURE (E), continued

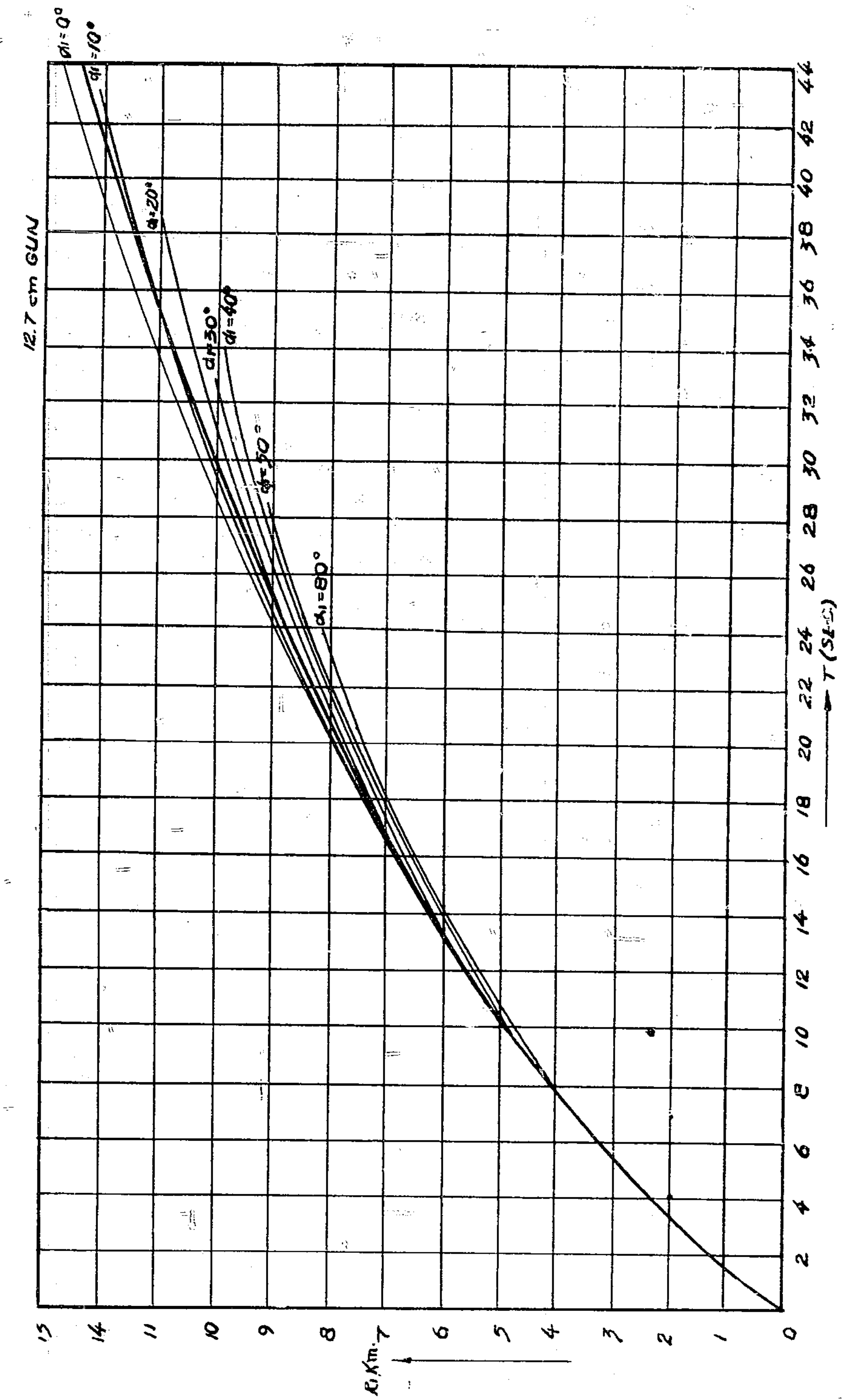


Figure 13(E)
TYPE 94 MOD 1 DIRECTOR
T vs. R_1

ENCLOSURE (E), continued

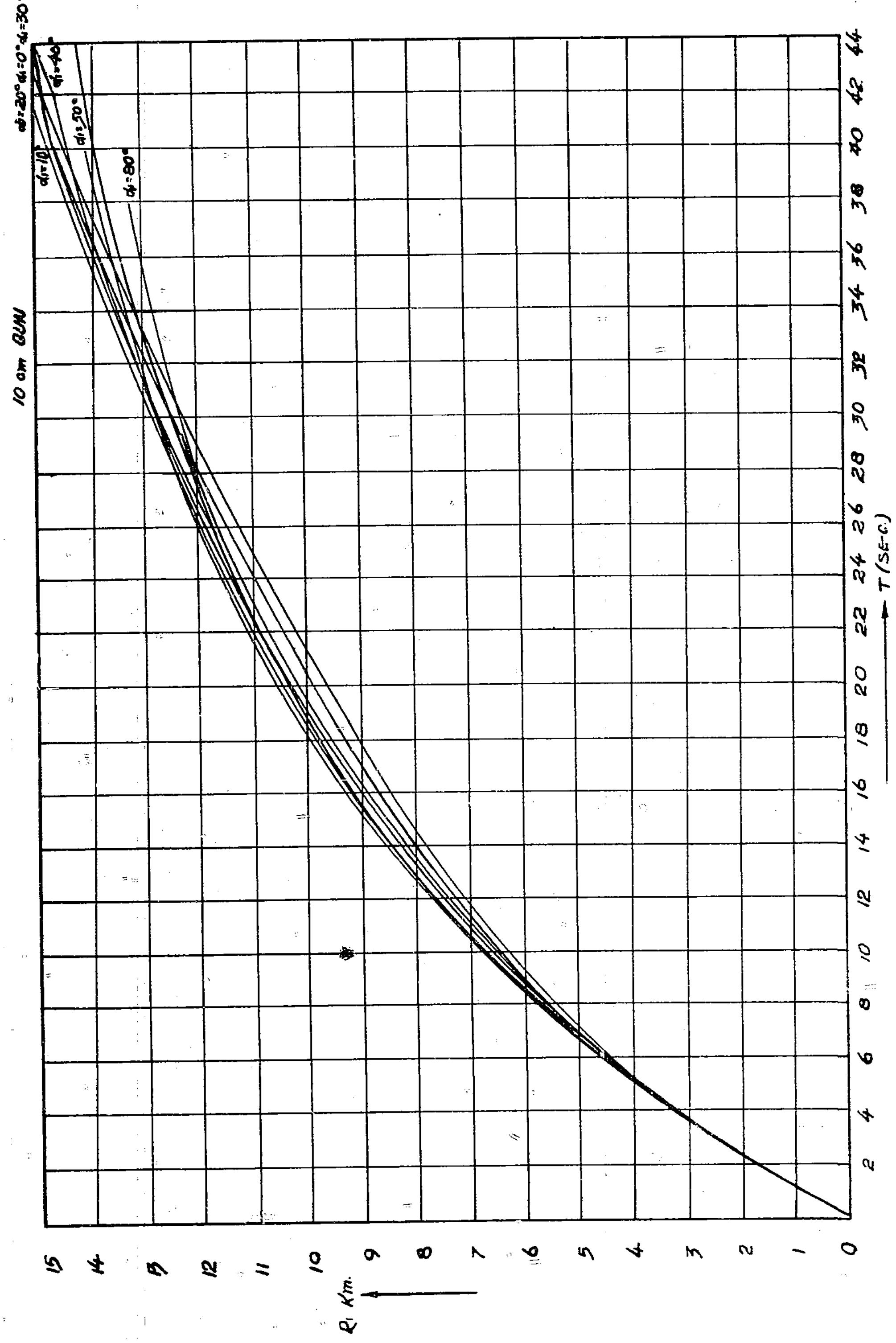


Figure 14(E)
TYPE 34 MOD 1 DIRECTOR
T vs. R_1

ENCLOSURE (E), continued

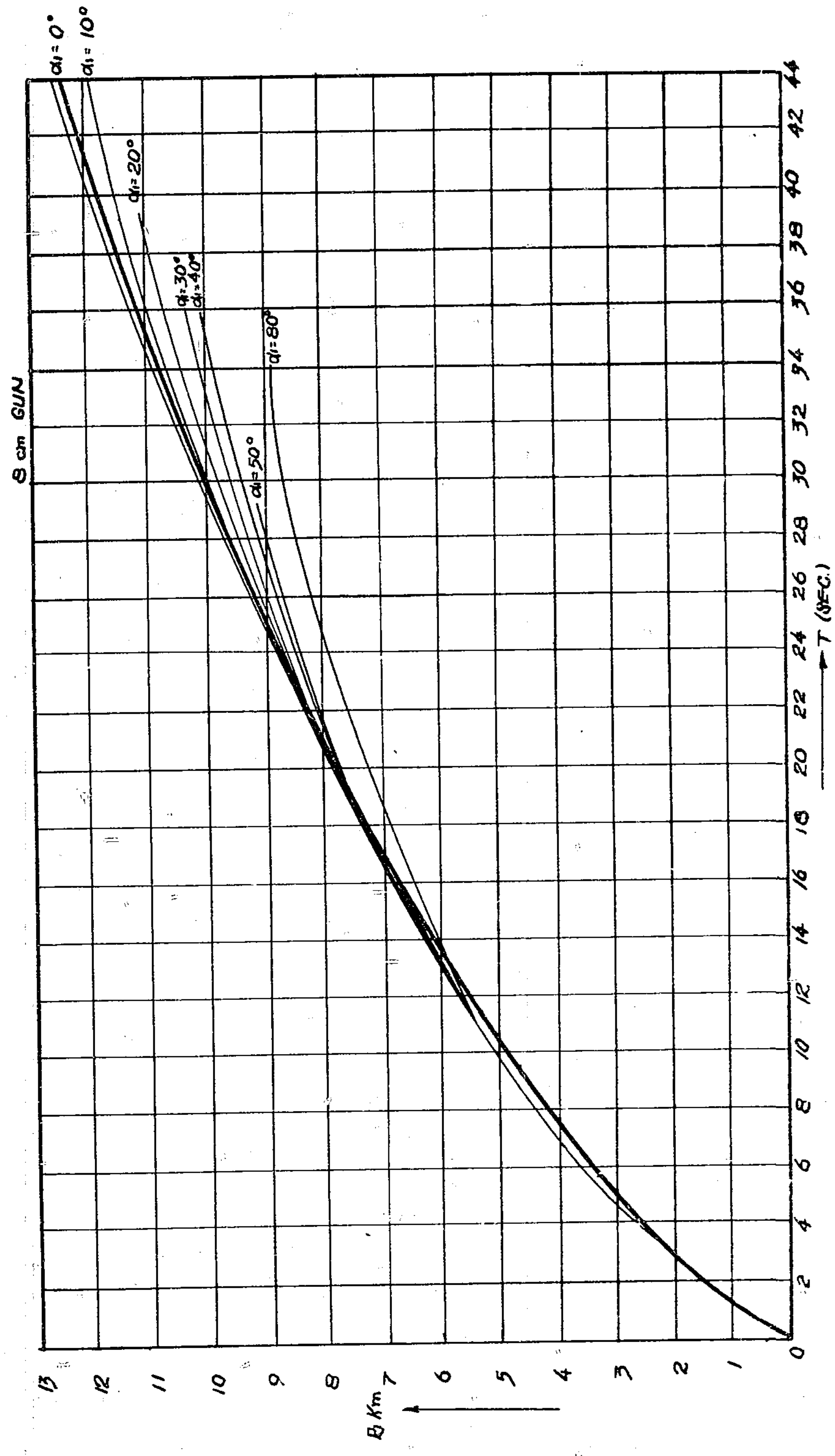


Figure 15(E)
TYPE 94 MOD 1 DIRECTOR
T vs. R_1

ENCLOSURE (E), continued

In all these, $f(\alpha + \sigma)$ is applied to each type of gun, and it is determined in a common manner. Consequently, if we handle it simply by applying only $f(T)$ to the function setting gear, conversions for gun types will be easy.

The superelevation angle tables dependent in the above formulae (H3) and (H5) follow. The error curves are shown in Figures 16(E) to 18(E). Moreover, it was derived from the machine that

$$\zeta = f(T) f(\alpha + \sigma)$$

$$= 0.5 f(T) + f(T) \{ f(\alpha + \sigma) - 0.5 \}$$

Since this is similar to

$$\frac{R}{R_1} T = T - \frac{T^2}{R_1} \frac{dR}{dt}$$

it is identical with the computer for range ratio.

I. <u>Firing Table, Computer Charts for Time of Flight and for Angle of Superelevation</u>

When the computer mentioned in paragraphs G and H is set to determine the firing table, accurate calculations for the entire firing table are necessarily possible. That is, only points within the scope of the firing table formulae can be accurately calculated by the computer. Points outside the scope will have comparatively large errors with the machine. See Figures 19(E) to 21(E).

J. <u>Vertical Prediction Computer</u>

The calculations of the vertical prediction is dependant on the basic formulae (C2).

$$\frac{d\alpha}{dt} \frac{R}{R_1} T = \sin \sigma + \sin \alpha \cos (\alpha + \sigma) \quad (1 - \cos \delta) \quad \ldots\ldots\ldots\ldots \text{(J1)}$$

In this formula, let us first consider solving $\sin \alpha$ singly. When the second gear is geared eccentrically with one side as the main wheel and the other as an attendant wheel, the relation between their angles of rotation is as follows

$$\phi = \theta \frac{e}{\rho a} \sin \theta + \left(\frac{e}{a}\right) \tfrac{1}{2} \sin^2 \theta + \ldots\ldots\ldots\ldots \text{(J2)}$$

where

- θ angle of rotation of main wheel (radians)
- ϕ angle of rotation of attendant wheel (radians)
- a diameter of gear pitch
- e eccentricity

and since we derive $\sin \sigma$ from $\sigma \ldots\ldots \theta = \cos \sigma$

If so, then $\phi = f(\theta) = f(\sin \sigma)$

In these when we choose $\sin \theta$ (a/e) correctly, $\phi = n \sin \sigma$

At this point the amount or error is extremely small. Moreover $\sigma = \pm 300$ and m and n are comparatively constant.

Next, let us consider the second term of equation (J1)

$$\sin \alpha \cos (\alpha + \sigma) (1 - \cos \delta) = \tfrac{1}{2} \{ \sin (2\alpha + \sigma) - \sin \sigma \} (1 - \cos \delta) \ldots\ldots \text{(J3)}$$

ENCLOSURE (E), continued

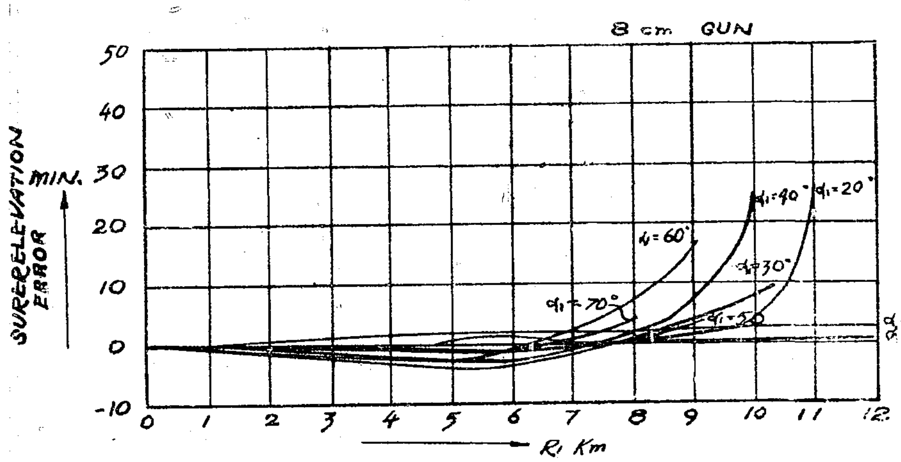


Figure 16(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs. SUPERELEVATION ERROR*

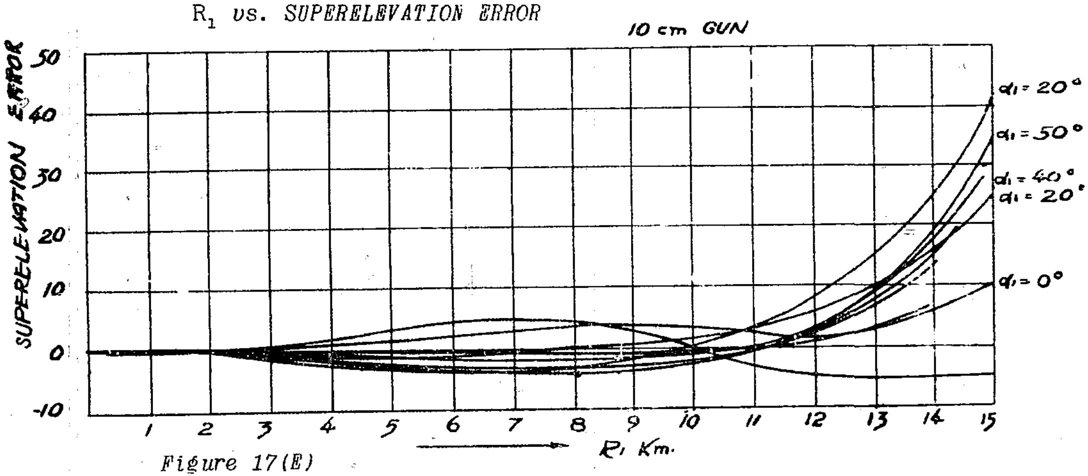


Figure 17(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs. SUPERELEVATION ERROR*

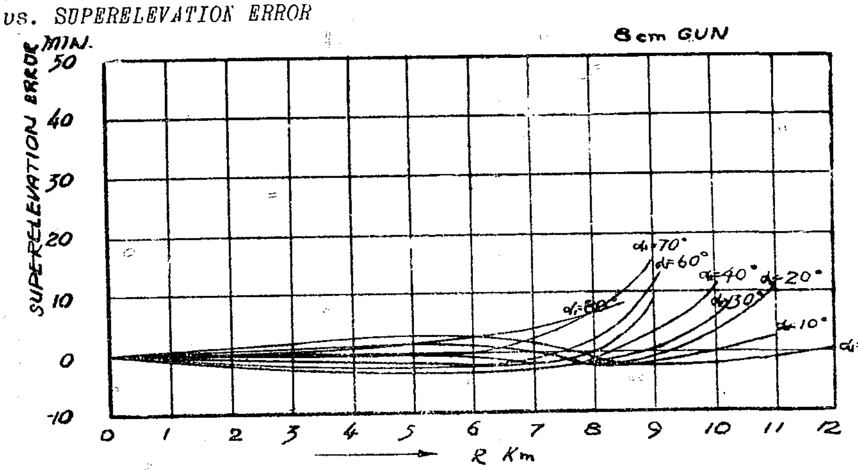


Figure 18(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs. SUPERELEVATION ERROR*

ENCLOSURE (E), continued

Table I(E)
SUPERELEVATION ANGLE

12.7 cm Gun

R_1		$a + \sigma$								
		0°	10°	20°	30°	40°	50°	60°	70°	80°
1	Calculated amt.	0° 36.6	0° 36.4	0° 34.6	0° 32.8	0° 29.2	0° 23.2	0° 19.0	0° 13.0	0° 7.6
	Actual amt.	0° 36.6	0° 35.9	0° 34.4	0° 31.6	0° 27.9	0° 23.7	0° 18.6	0° 13.0	0° 7.1
	Error	0	-0.5	-0.2	-1.2	-1.3	+0.5	-0.4	0	-0.5
2	Calculated amt.	1° 19.7	1° 17.8	1° 14.8	1° 9.8	1° 2.2	0° 52.6	0° 40.6	0° 28.6	0° 15.4
	Actual amt.	1° 19.6	1° 18.3	1° 14.6	1° 8.7	1° 0.8	0° 51.3	0° 39.9	0° 27.6	0° 14.5
	Error	-0.1	+0.5	-0.2	-1.1	-1.4	-1.3	-0.7	-1.0	-0.9
3	Calculated amt.	2° 12.8	2° 9.4	2° 5.2	1° 58.0	1° 43.6	1° 27.4	1° 8.2	0° 47.2	0° 25.0
	Actual amt.	2° 12.8	2° 10.6	2° 4.6	1° 54.8	1° 41.8	1° 25.3	1° 6.7	0° 46.1	0° 23.9
	Error	0	+1.2	-0.6	-3.2	-1.8	-2.1	-1.5	-1.1	-1.1
4	Calculated amt.	3° 18.6	3° 15.4		2° 54.3	2° 33.4	2° 9.4	1° 41.2	1° 10.6	0° 37.0
	Actual amt.	3° 18.5	3° 15.9		2° 52.4	2° 33.1	2° 8.9	1° 40.5	1° 9.1	0° 35.6
	Error	-0.1	+0.5	-0.2	-1.9	-0.3	-0.5	-0.7	-1.5	-1.4
5	Calculated amt.	4° 39.9	4° 35.2	4° 25.6	4° 7.0	3° 39.4	3° 4.0	2° 22.6	1° 38.2	0° 52.0
	Actual amt.	4° 40.3	4° 37.4	4° 25.4	4° 5.1	3° 37.3	3° 2.7	2° 22.7	1° 38.2	0° 50.6
	Error	+0.4	+2.2	-0.2	-1.9	-2.1	-1.3	+0.1	0	-1.4
6	Calculated amt.	6° 19.3	6° 15.4	5° 59.8	5° 37.0	5° 0.4	4° 11.8	3° 16.6	2° 16.0	1° 8.8
	Actual amt.	6° 19.4	6° 17.0	6° 1.2	5° 33.6	4° 55.8	4° 9.2	3° 13.8	2° 14.4	1° 9.1
	Error	+0.1	+1.6	+1.4	-3.4	-4.6	-2.6	-2.8	-1.6	+0.3
7	Calculated amt.	8° 18.4	8° 16.0	7° 58.6	7° 25.6		5° 33.4	4° 20.4	2° 59.8	1° 32.8
	Actual amt.	8° 18.5	8° 17.9	7° 58.1	7° 22.7		5° 33.8	4° 22.4	3° 0.4	1° 33.7
	Error	+0.1	+1.9	-0.5	-2.9		+0.4	+2.0	+0.6	+0.9
8	Calculated amt.	10° 37.3	10° 38.2	10° 16.6	9° 34.0	8° 34.0	7° 15.4	5° 45.4	4° 0.4	2° 4.0
	Actual amt.	10 38.1	10° 40.2	10° 17.9	9° 35.2	8° 36.7	7° 21.8	5° 51.2	4° 5.2	2° 7.1
	Error	+0.8	+2.0	+1.3	+1.2	+2.7	+6.4	+5.8	+4.8	+3.1
9	Calculated amt.	13° 13.9	13° 23.2	13° 1.6	12° 16.6	11° 10.6	9° 34.6	7° 40.0		
	Actual amt.	13° 13.2	13° 26.4	13° 5.2	12° 21.7	11° 16.1	9° 48.5	7° 56.8		
	Error	-0.7	+3.2	+3.6	+5.1	+5.5	+3.9	+16.8		
10	Calculated amt.		16° 38.2	16° 33.4	16° 1.4	15° 2.2				
	Actual amt.		16° 40.4	16° 36.5	16° 9.9	15° 25.9				
	Error		+2.2	+3.1	+8.5	+23.7				
11	Calculated amt.	19° 45.1	20° 38.2	21° 21.4						
	Actual amt.	19° 46.3	20° 39.2	21° 35.9						
	Error	+1.2	+1.0	+24.5						
12	Calculated amt.	23° 58.7	26° 10.6							
	Actual amt.	24° 0.2	26° 14.6							
	Error	+1.5	+4.0							

ENCLOSURE (E), continued

Table II(E)
SUPERELEVATION ANGLE

10cm GUN

R_1		$\alpha + \sigma$ 0°	10°	20°	30°	40°	50°	60°	70°	80°
1	Calculated amt.	0° 22.1	0° 21.9	0° 21.2	0° 20.0	0° 18.2	0° 16.0	0° 13.3	0° 10.4	0° 7.3
	Actual amt.	0° 22.2	0° 21.9	0° 21.0	0° 19.6	0° 17.7	0° 15.5	0° 12.9	0° 10.1	0° 7.1
	Error	+0.1	0	− 0.2	-0.4	-0.5	-0.5	-0.4	-0.3	-0.2
2	Calculated amt.	0° 42.8	0° 42.5	0° 41.1	0° 38.6	0° 34.7	0° 29.8	0° 24.1	0° 17.7	0° 11.0
	Actual amt.	0° 43.6	0° 42.7	0° 40.8	0° 37.6	0° 33.5	0° 28.8	0° 23.2	0° 17.1	0° 10.7
	Error	+0.8	+0.2	-0.3	-1.0	-1.2	-1.0	-0.9	-0.6	-0.3
3	Calculated amt.	1° 7.8	1° 6.9	1° 4.5	1° 0.2	0° 53.8	0° 45.9	0° 36.6	0° 26.2	0° 15.3
	Actual amt.	1° 9.3	1° 7.4	1° 3.7	0° 58.6	0° 51.8	0° 44.0	0° 35.1	0° 25.3	0° 14.9
	Error	+1.5	+0.5	-0.8	-1.6	-2.0	-1.9	-1.5	-0.9	-0.4
4	Calculated amt.	1° 38.3	1° 36.3	1° 32.1	1° 25.4	1° 16.0	1° 4.6		0° 36.2	0° 20.3
	Actual amt	1° 40.4	1° 37.0	1° 31.2	1° 23.3	1° 13.3	1° 1.8		0° 34.9	0° 19.6
	Error	+2.1	+0.7	-0.9	-2.1	-2.7	-2.8		-1.3	-0.7
5	Calculated amt.	2° 15.6	2° 11.8	2° 5.2	1° 55.3	1° 42.1	1° 26.5	1° 8.4	0° 47.9	0° 26.2
	Actual amt.	3° 18.4	2° 13.0	2° 4.1	1° 52.2	1° 38.9	1° 23.2	1° 5.6	0° 46.3	0° 25.7
	Error	+2.8	+1.2	-1.1	-3.1	-3.2	-3.3	-2.8	-1.6	-0.5
6	Calculated amt.	3° 1.8	2° 55.3	2° 45.0	2° 30.8	2° 13.0	1° 52.1	1° 28.4	1° 1.7	0° 33.3
	Actual amt.	3° 6.2	2° 56.8	2° 43.4	2° 27.1	2° 9.1	1° 48.1	1° 25.2	0° 59.9	0° 32.5
	Error	+4.4	+1.5	-1.6	-3.7	-3.9	-4.0	-3.2	-1.8	-0.8
7	Calculated amt.	4° 1.5	3° 48.9	3° 32.8	3° 13.1	2° 49.5	2° 22.4	1° 52.0	1° 18.0	0° 41.7
	Actual amt.	4° 6.6	3° 51.8	3° 31.3	3° 9.4	2° 44.9	2° 18.0	1° 48.5	1° 15.9	0° 40.8
	Error	+5.1	+2.1	-1.5	-3.7	-4.6	-4.4	-3.5	-2.1	-0.9
8	Calculated	5° 18.4	4° 55.6	4° 31.2	4° 3.9	3° 32.9	2° 58.5	2° 20.1	1° 37.8	0° 52.1
	Actual amt.	5° 23.1	4° 58.7	4° 30.6	4° 0.6	3° 28.3	2° 54.2	2° 16.6	1° 35.3	0° 51.0
	Error	+4.7	+3.1	-0.6	-3.3	-4.6	-4.3	-3.5	-2.5	-1.1
9	Calculated amt.	6° 52.4	6° 18.0	5° 43.1		4° 25.5	3° 42.2	2° 54.5	2° 1.8	1° 4.9
	Actual amt.	6° 55.5	6° 21.9	5° 43.6		4° 22.1	3° 39.0	2° 51.5	1° 59.7	1° 3.6
	Error	+3.1	+3.9	+0.5		-3.4	-3.2	-3.0	-2.1	-1.3
10	Calculated amt.	8° 43.2	7° 57.9	7° 10.6	6° 20.8	5° 29.7	4° 35.6	3° 37.0	2° 31.4	1° 20.5
	Actual amt.	8° 43.7	8° 0.8	7° 12.2	6° 20.3	5° 28.4	4° 34.8	3° 35.3	2° 30.5	1° 19.7
	Error	+0.5	+2.9	+1.6	-0.5	-1.3	-0.8	-1.7	-0.9	-0.8
11	Calculated amt.	10° 50.1	9° 54.5		7° 51.9	6° 48.6	5° 42.3	4° 30.1	3° 8.8	1° 40.1
	Actual amt.	10° 47.6	9° 56.3		7° 55.4	6° 51.6	5° 45.2	4° 31.4	3° 10.4	1° 40.8
	Error	-2.5	+1.8		+3.5	+3.0	+2.9	+1.3	-1.6	-0.7
12	Calculated amt.	13° 12.7	12° 8.4	10° 57.8	9° 42.0	8° 26.6	7° 7.3	5° 39.0	3° 58.6	2° 6.6
	Actual amt.	13° 8.3	12° 9.5	11° 2.2	9° 49.8	8° 35.2	7° 14.6	5° 44.8	4° 3.8	2° 9.4
	Error	-4.4	+1.1	+4.4	+7.8	+8.6	+7.3	+5.8	+5.2	+2.8
13	Calculated amt.	15° 51.7	14° 41.0	13° 21.5	11° 56.4	10° 31.1	8° 59.4	7° 14.0	5° 11.8	2° 48.8
	Actual amt.	15° 46.8	14° 43.3	13° 30.1	12° 10.3	10° 46.6	9° 15.0	7° 27.7	5° 24.3	2° 55.7
	Error	-4.9	+2.3	+8.6	+13.9	+15.5	+15.6	+13.7	+12.5	+6.9
14	Calculated amt.	18° 48.3	17° 36.1	16° 12.6	14° 45.2	13° 21.2	11° 52.7	10° 27.2		
	Actual amt.	18° 44.2	17° 42.5	16° 29.1	15° 10.9	13° 50.0	12° 23.4	10° 58.2		
	Error	-4.1	+6.4	+16.5	+25.7	+28.8	+30.7	+31.0		
15	Calculated amt.	22° 4.7	21° 00	19° 47.0	18° 46.6					
	Actual amt.	21° 59.7	21° 10.1	20° 11.8	19° 27.1					
	Error	-5.0	+10.1	+24.8	+40.5					

ENCLOSURE (E), continued

Table III(E)
SUPERELEVATION ANGLE

8cm GUN

R_1		$\alpha + \sigma$								
		0°	10°	20°	30°	40°	50°	60°	70°	80°
1	Calculated amt.	0° 24.5	0° 24.2	0° 23.3	0° 21.9	0° 19.7	0° 17.1	0° 13.8	0° 9.9	0° 5.9
	Actual amt.	0° 24.8	0° 24.2	0° 23.3	0° 21.5	0° 19.2	0° 16.4	0° 13.1	0° 9.6	0° 5.9
	Error	+ 0.3	0	0	-0.4	- 0.5	- 0.7	- 0.7	- 0.3	0
2	Calculated amt.	0° 53.7	0° 53.1	0° 51.4	0° 48.0	0° 42.9	0° 36.6	0° 28.8	0° 20.2	0° 11.1
	Actual amt.	0° 55.0	0° 53.9	0° 51.3	0° 47.2	0° 41.8	0° 35.3	0° 27.9	0° 19.2	0° 11.0
	Error	+1.3	+ 0.8	- 0.1	- 0.8	- 1.1	- 1.3	- 0.9	- 0.5	- 0.1
3	Calculated amt.	1° 34.1	1° 33.0	1° 29.5	1° 23.0	1° 13.7		0° 48.9	0° 34.1	0° 18.0
	Actual amt.	1° 36.2	1° 33.1	1° 29.0	1° 21.8	1° 12.1		0° 47.6	0° 33.5	0° 18.1
	Error	+ 2.1	+ 0.9	- 0.5	- 1.2	- 1.6		- 1.3	- 0.6	+ 0.1
4	Calculated amt.	2° 30.9	2° 28.1	2° 21.5	2° 10.8	1° 55.9	1° 37.7	1° 16.6	0° 53.2	0° 27.4
	Actual amt.	2° 33.7	2° 29.7	2° 21.3	2° 9.3	1° 53.6	1° 34.9	1° 14.6	0° 52.3	0° 29.0
	Error	+ 2.8	+ 1.6	- 0.2	- 1.5	- 2.3	- 2.8	- 2.0	- 0.9	+ 1.6
5	Calculated amt.	3° 49.9	3° 44.7	3° 33.9	3° 16.5	2° 53.6	2° 25.9	1° 54.8	1° 19.5	0° 40.8
	Actual amt.	3° 53.2	3° 47.1	3° 33.8	3° 15.0	2° 50.9	2° 22.8	1° 52.2	1° 18.9	0° 42.2
	Error	+ 3.3	+ 2.4	- 0.1	- 1.5	- 2.7	- 3.1	- 2.6	- 0.6	+ 1.4
6	Calculated amt.	5° 34.2	5° 26.9	5° 10.5	4° 44.7	4° 11.5	3° 31.2	2° 46.6	1° 55.6	0° 59.5
	Actual amt.	5° 37.5	5° 28.4	5° 10.3	4° 43.1	4° 8.4	3° 28.6	2° 44.2	1° 56.3	1° 2.0
	Error	+ 3.3	+ 1.5	- 0.2	- 1.6	- 3.1	- 2.6	- 2.4	+ 0.7	+ 2.5
7	Calculated amt.	7° 42.4	7° 34.0	7° 12.2	6° 37.7	5° 52.3	4° 57.7	3° 55.7	2° 44.8	1° 25.4
	Actual amt.	7° 44.5	7° 34.4	7° 11.2	6° 35.6	5° 49.5	4° 55.5	3° 55.1	2° 47.0	1° 29.2
	Error	+ 2.1	+ 0.4	- 1.0	-2.1	- 2.8	- 2.2	- 0.6	+ 2.2	+ 3.8
8	Calculated amt.	10° 12.8	10° 5.6	9° 40.1	8° 58.1	8° 0.5	6° 51.1	5° 29.3	3° 53.4	2° 2.3
	Actual amt.	10° 12.9	10° 4.4	9° 38.4	8° 56.5	7° 59.1	6° 50.7	5° 31.5	3° 58.5	2° 8.7
	Error	+ 0.1	- 1.2	- 1.7	- 1.6	-1.4	- 0.4	+ 2.2	+ 5.1	+ 6.4
9	Calculated amt.	13° 6.6	13° 3.8		11° 54.1	10° 50.9	9° 30.1	7° 53.0	5° 49.3	3° 16.0
	Actual amt.	13° 4.7	13° 1.7		11° 55.0	10° 53.7	9° 36.0	8° 4.4	6° 4.8	3° 27.4
	Error	- 1.9	- 2.1		+ 0.9	+ 2.8	+ 5.9	+ 11.4	+ 15.5	+ 11.4
10	Calculated amt.	16° 27.4	16° 36.2	16° 24.8	15° 55.1	15° 19.3				
	Actual amt.	16° 25.3	16° 36.8	16° 27.9	16° 2.6	15° 31.7				
	Error	- 2.1	+ 0.6	+ 3.1	+ 7.5	+ 12.4				
11	Calculated amt.	20° 22.6	21° 1.7	21° 43.5						
	Actual amt.	20° 20.5	21° 3.8	21° 54.0						
	Error	- 2.1	+ 2.1	+ 10.5						

ENCLOSURE (E), continued

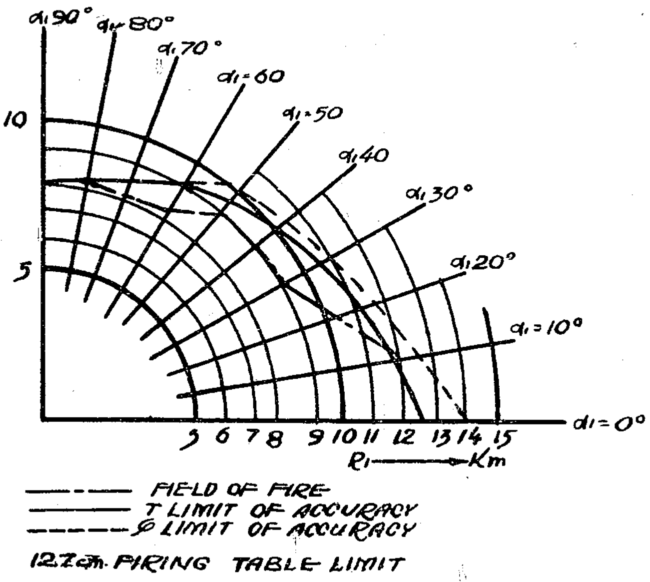


Figure 19(E)
TYPE 94 MOD 1 DIRECTOR
ACCURACY LIMITS

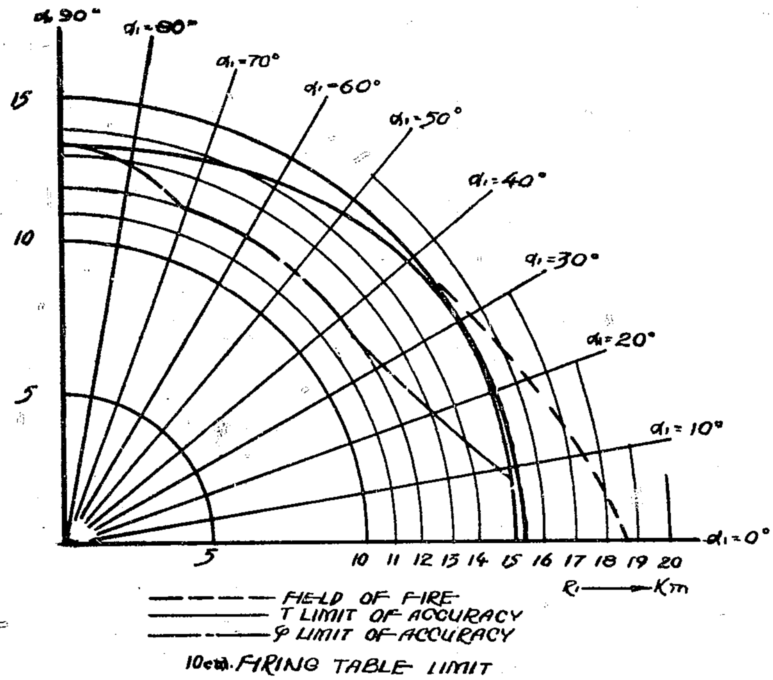


Figure 20(E)
TYPE 94 MOD 1 DIRECTOR
ACCURACY LIMITS

ENCLOSURE (E), continued

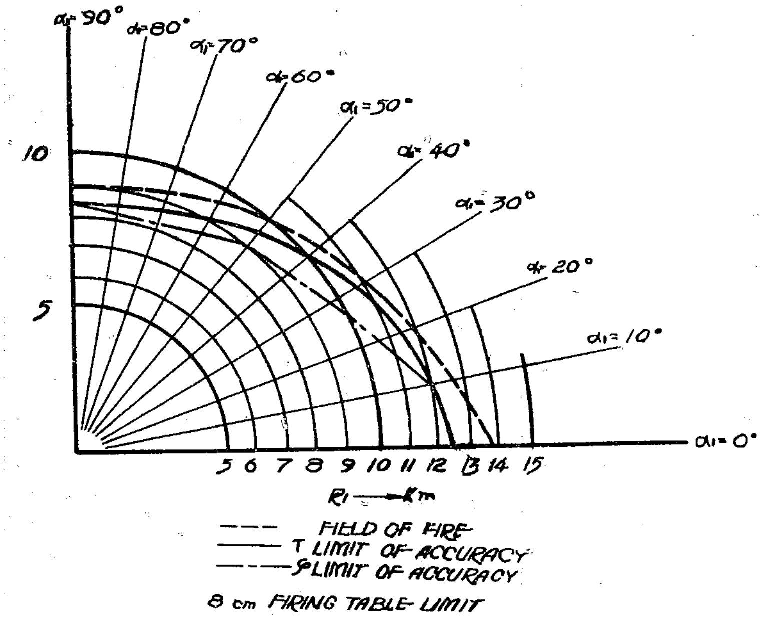


Figure 21(E)
TYPE 94 MOD 1 DIRECTOR
ACCURACY LIMITS

In these, when σ is within 30 degrees, and δ is within ± 450, the absolute value of equation (J3) is extremely small and so, even if we substitute σ for sin σ in formula (J3) the error will be small.

$$\sin \alpha \cos (\alpha + \sigma)(1 - \cos \delta) = \tfrac{1}{2}\left\{ \sin (2\alpha + \sigma) - \sigma_{rad} \right\}(1 - \cos \delta) \quad \text{......... (J4)}$$

When we use the final machine result of (J2) and formula (J3) even combining them with (J1) as follows, we may say that the error will probably be small.

$$\sin \sigma \,\theta \sin \alpha \cos (\alpha + \sigma)(1 - \cos \delta) = f(\sigma) + \tfrac{1}{2}\{\sin (2\alpha + \sigma) - \sigma_{rad})(1 - \cos \sigma) \quad \text{..... (J5)}$$

Whereupon, the amount of error of σ used in formula (J5) when calculated from $\Delta\sigma$ will be shown in table following and Figure 22(E).

K. <u>Horizontal Prediction Computer</u>

Basic formula for the calculation of horizontal prediction is

$$\frac{d\beta}{dt}\frac{R}{R_1}T = \frac{\cos (\alpha + \sigma)}{\cos \alpha} \sin \delta \quad \text{.. (K1)}$$

However, when we transpose this

$$\frac{\cos (\alpha + \sigma)}{\cos \alpha} \sin \delta = \tfrac{1}{2}\,\frac{1}{\cos \alpha}\left\{ \sin (\alpha + \sigma + \delta) - \sin (\alpha + \sigma - \delta) \right\}$$

$$= \tfrac{1}{2}\left\{ \frac{\sin (\alpha + \sigma + \delta)}{\cos \alpha} - \frac{\sin (\alpha + \sigma - \delta)}{\cos \alpha} \right\} \quad \text{.................(K2)}$$

ENCLOSURE (E), continued

Table IV(E)

δ	σ	Δ σ	δ	σ	Δ σ
	0°	0.00'		0°	0.00'
	5°	1.30'		5°	1.32'
	10°	1.33'		10°	1.54'
0°	15°	-0.34'	±30°	15°	0.37'
	20°	-2.80'		20°	-1.07'
	25°	-3.35'		25°	0.14'
	30°	2.57'		30°	8.84'
	0°	0.00'		0°	0.00'
	5°	1.30'		5°	1.35'
	10°	1.39'		10°	1.79'
±15°	15°	0.16'	±45°	15°	1.21'
	20°	2.36'		20°	0.98'
	25°	2.45'		25°	4.27'
	30°	4.16'		30°	16.32'

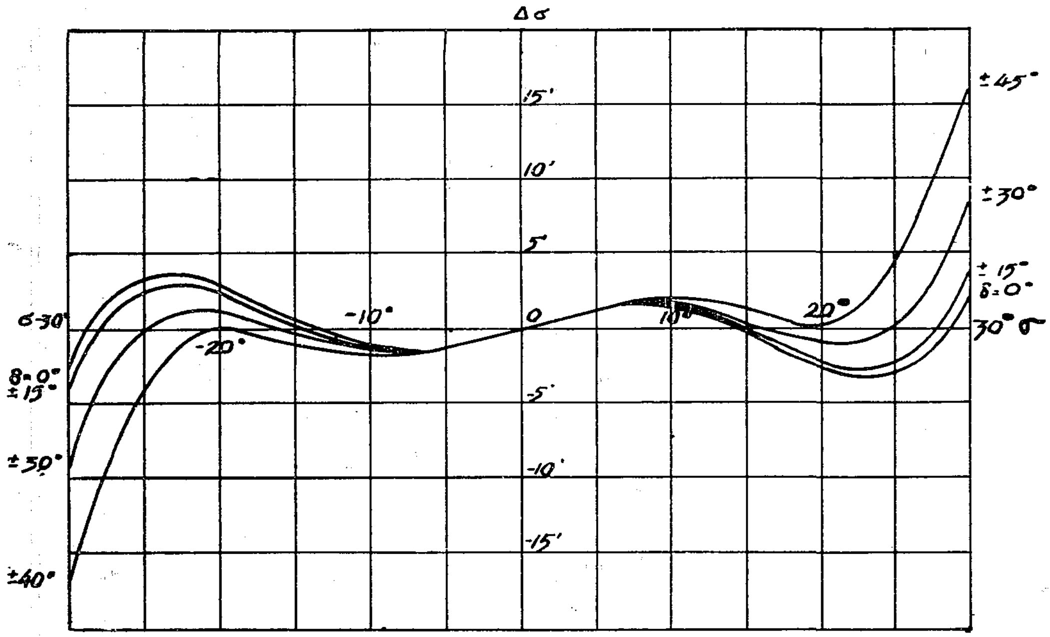


Figure 22(E)
ERROR CURVES FOR VERTICAL PREDICTION COMPUTER

ENCLOSURE (E), continued

In this, $\sin(\alpha+\sigma+\delta)/\cos\alpha$ and $\sin(\alpha+\sigma-\delta)/\cos\alpha$ have the same general form as the machine (calculation) only we substituted $\alpha-\sigma-\delta$ for $\alpha+\sigma+\delta$ Consequently, we can calculate the horizontal prediction with another computer of the same type. Thus, we can decrease the number of computers.

~~Since $\alpha = 0$ cannot be calculated mechanically,~~ we can get a correct calculation for σ only between 0 degrees and 75 degrees. When this is exceeded we can calculate more closely.

L. Deviation (Drift) Computer

The simplest formula for use with the deviation computer is $Z = a(T-b)$.

That is to say if we enter the deviation from this, T , the time of flight, by certain gear ratio can be added to the train as drift. For each type of gun this is as follows:

$$12.7\text{cm gun},\ Z = \frac{21}{11}(T-3)$$

$$10\text{cm gun},\ Z = 1.5\,(T-1)$$

$$8\text{cm gun},\ Z = 1.5\,(T-1)$$

Therefore, conversions for gun type can be easily made by changing the gear ratio. See following Tables V(E), VI(E) and VII(E) and Figures 23(E) to 25(E) for values in the firing table and values from the machine.

M. Angle Correcting and Speed Correcting Computer

In angle correction if we make B the distance between the position and the AA Director, then

$$n = \frac{B\sin(B + Cp + \delta)}{R_1\cos(\alpha+\sigma)} \quad \text{.......... (M1)}$$

However

$$\frac{1}{R_1\cos(\alpha+\sigma)} = \frac{f(T)}{f(\alpha+\sigma)} \quad \text{.......... (M2)}$$

In the above, when we solve $f(T)$ and $f(\alpha+\sigma)$

$$n = \left(\frac{V\sin(B + Cp + \delta)}{f(\alpha+\sigma)}\right)(f_n(T)) \quad \text{.......... (M3)}$$

On the other hand, we can most nearly express (own) speed error by

$$w = \left(\frac{V\sin(B + Cp + \delta)}{f(\alpha+\sigma)}\right)(fw(T)) \quad \text{.......... (M4)}$$

Moreover, we can use $f(\alpha+\sigma)$ as identical in both (M3) and (M4) . As a standard rule in (M3) , B = 40 m and in (M4) V = 30. The other B and V are made equal to the B and V of the ship by a previously determined gear ratio. If we calculate the constants by the computer, then

$$n = \frac{\sin(B + Cp + \delta)}{f(\alpha+\sigma)}\, f_n(T) \quad \text{.......... (M5)}$$

$$w = \frac{\sin(B + Cp + \delta)}{f(\alpha+\sigma)}\, f_w(T) \quad \text{.......... (M6)}$$

The computer is the same in all respects, for both n and w . Only $f_n(T)$ and $f_w(T)$ are interchanged. Moreover it is the same for each type of gun with only a change of gear ratio effected.

ENCLOSURE (E), continued

Table V(E)
AMOUNT OF DEVIATION (MINUTES)

12.7cm GUN

R_1		H_1 0000	1000	2000	3000	4000	5000	6000	7000
1	Calculated amt.	1.4							
	Actual amt	-2.9							
	Error	-4.3							
2	Calculated amt.	3.1	3.0						
	Actual amt.	0.2	0.5						
	Error	-2.9	-2.5						
3	Calculated amt.	5.3	5.2	5.2					
	Actual amt.	4.2	4.3	4.4					
	Error	-1.1	-0.9	-0.8					
4	Calculated amt.	8.2	8.3	7.9	8.4				
	Actual amt.	8.7	8.8	9.0	9.1				
	Error	+0.5	+0.5	+1.1	+0.7				
5	Calculated amt.	12.1	12.5	12.2	11.9	12.6			
	Actual amt.	13.9	14.1	14.2	14.3	14.5			
	Error	+1.8	+1.6	+2.0	+2.4	+1.9			
6	Calculated amt.	16.8	17.7	17.1	16.9	17.1	18.1		
	Actual amt.	19.7	20.0	20.1	20.3	20.5	20.7		
	Error	+2.9	+2.3	+3.0	+3.4	+3.4	+2.6		
7	Calculated amt.	22.9	24.8	24.1	23.7	23.6	24.3	26.9	
	Actual amt.	26.1	26.5	26.7	27.0	27.2	27.5	28.0	
	Error	+3.2	+1.7	+2.6	+3.3	+3.6	+3.2	+1.1	
8	Calculated amt.	30.2	32.2	32.8	32.4	32.3	33.3	35.0	40.7
	Actual amt.	32.9	33.5	34.0	34.3	34.6	35.2	35.9	36.9
	Error	+ 2.7	+ 1.3	+ 1.2	+ 1.9	+ 2.3	+ 1.9	+ 0.9	- 3.8
9	Calculated amt.	38.6	40.9	42.4	43.0	44.0	45.8	48.4	53.0
	Actual amt.	40.3	41.1	41.8	42.5	43.3	44.2	45.3	46.8
	Error	+ 1.7	+ 0.2	- 0.6	- 0.5	- 0.7	- 1.6	-3.1	- 6.2
10	Calculated amt.	48.9	51.8	54.2	56.6	59.2	63.5	69.7	81.7
	Actual amt.	48.4	49.6	50.7	52.0	53.5	55.4	58.2	62.1
	Error	- 0.5	- 2.2	- 3.5	- 4.6	- 5.7	- 8.1	- 11.5	- 19.6
11	Calculated amt.	61.2	65.3	69.3	74.1	81.8	97.7		
	Actual amt.	57.5	59.0	60.9	63.3	67.0	73.1		
	Error	- 3.7	- 6.3	- 8.4	-10.8	- 14.8	- 24.6		
12	Calculated amt.	76.2	82.1	90.3	105.3				
	Actual amt.	67.8	70.5	74.0	81.0				
	Error	- 8.4	- 11.6	- 16.3	- 24.3				

ENCLOSURE (E), continued

Table VI(E)
AMOUNT OF DEVIATION (MINUTES) 10cm GUN

R_1		$\alpha + \sigma$ 0°	10°	20°	30°	40°	50°	60°	70°	80°
1	Calculated amt.	0.4	0.7	0.9	1.0	1.1	1.1	1.2	1.2	1.2
	Actual amt.	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
	Error	-1.8	-2.1	-2.3	-2.4	-2.5	-2.5	-2.6	-2.6	-2.6
2	Calculated amt.	0.9	1.3	1.9	2.2	2.4	2.5	2.5	2.6	2.6
	Actual amt.	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Error	-0.5	-0.9	-1.5	-1.8	-2.0	-2.1	-2.1	-2.2	-2.2
3	Calculated amt.	1.5	2.6	3.2	3.6	3.9	4.2	4.3	4.4	4.5
	Actual amt.	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.4
	Error	+0.9	-0.2	-0.8	-1.3	-1.6	-1.9	-2.0	-2.1	-2.1
4	Calculated amt.	2.4	4.0	4.8	5.4	5.9	6.1		6.4	6.9
	Actual amt.	4.8	4.7	4.6	4.6	4.5	4.5		4.6	4.6
	Error	+2.4	+0.7	-0.2	-0.8	-1.4	-1.6		-1.8	-2.3
5	Calculated amt.	3.5	5.7	6.8	7.5	8.1	8.6	8.9	9.2	10.0
	Actual amt.	7.6	7.4	7.2	7.0	7.0	7.0	7.0	7.1	7.1
	Error	+4.1	+1.7	+0.4	-0.5	-1.1	-1.6	-1.9	-2.1	-2.9
6	Calculated amt.	5.0	7.9	9.3	10.2	10.9	11.5	12.0	12.5	14.1
	Actual amt.	10.8	10.4	10.1	9.9	9.8	9.7	9.8	9.9	10.0
	Error	+5.8	+2.5	+0.8	-0.2	-1.1	-1.8	-2.2	-2.6	-4.1
7	Calculated amt.	7.1	10.6	12.3	13.4	14.4	15.8	16.6	16.6	19.5
	Actual amt.	14.2	14.0	13.4	13.1	12.9	12.8	12.9	13.0	13.1
	Error	+7.1	+3.4	+1.1	-0.3	-1.5	-3.0	-3.7	-3.6	-6.4
8	Calculated amt.	9.9	14.0	16.0	17.3	18.3	19.4	20.4	21.8	26.8
	Actual amt.	19.1	18.1	17.3	16.7	16.4	16.4	16.4	16.6	16.8
	Error	+9.2	+4.1	+1.3	-0.6	-1.9	-3.0	-4.0	-5.2	-10.0
9	Calculated amt.	13.3	18.2	20.6		23.4	24.8	26.2	28.6	36.6
	Actual amt.	24.1	22.7	21.7		20.5	20.4	20.5	20.8	21.1
	Error	+10.8	+4.5	+1.1		-2.9	-4.4	-5.7	-7.8	-15.5
10	Calculated amt.	17.4	23.1	26.1	27.9	29.5	31.4	33.6	37.4	50.4
	Actual amt.	29.4	27.8	26.6	25.6	25.3	25.1	25.3	25.6	26.0
	Error	+12.0	+4.7	+0.5	-2.3	-4.2	-6.3	-8.3	-11.8	-24.4
11	Calculated amt.	22.1	28.7		34.7	36.9	39.6	42.8	49.4	70.5
	Actual amt.	35.0	33.6		30.9	30.5	30.5	30.8	31.3	31.9
	Error	+12.9	+4.9		-3.8	-6.4	-9.1	-12.0	-18.1	-38.6
12	Calculated amt.	27.4	35.1	39.5	42.7	46.0	49.7	55.1	66.2	101.4
	Actual amt.	41.0	39.1	37.7	36.8	36.6	36.8	37.4	38.3	39.2
	Error	+13.6	+4.0	-1.8	-5.9	-9.4	-12.9	-17.7	-27.9	-62.2
13	Calculated amt.	33.7	42.4	47.9	52.3	57.2	63.5	73.1	94.4	168.5
	Actual amt.	47.2	45.4	44.2	43.6	43.7	44.6	45.1	47.9	50.0
	Error	+13.5	+3.0	-3.7	-8.7	-3.5	-18.9	-28.0	-46.5	118.5
14	Calculated amt.	40.9	51.1	58.1	64.7	73.1	86.3	116.5		
	Actual amt.	53.8	52.3	51.5	51.7	53.0	55.8	61.8		
	Error	+12.9	+1.2	-6.6	-13.0	-20.1	-30.5	-54.7		
15	Calculated amt.	49.7	61.5	71.1	83.4					
	Actual amt.	60.9	60.0	60.1	62.6					
	Error	+11.2	-1.5	-11.0	-20.8					

ENCLOSURE (E), continued

Table VII(E)
AMOUNT OF DEVIATION
(MINUTES)

8cm GUN

R_1		α + σ								
		0°	10°	20°	30°	40°	50°	60°	70°	80°
1	Calculated amt.	1.4	1.4	1.7	1.4	1.4	1.7	1.4	1.0	2.0
	Actual amt.	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Error	-1.1	-1.1	-1.4	-1.1	-1.1	-1.4	-1.1	- 0.7	-1.7
2	Calculated amt.	3.0	2.7	3.0	3.0	3.0	3.0	3.0	3.4	5.1
	Actual amt.	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	Error	- 0.4	- 0.1	- 0.4	-0.4	-0.4	- 0.4	- 0.4	- 0.8	- 2.5
3	Calculated amt.	5.1	5.1	5.1	5.1	5.1		5.7	6.8	9.1
	Actual amt.	5.4	5.4	5.4	5.4	5.4		5.4	5.5	5.5
	Error	+ 0.3	+0.3	+0.3	+0.3	+ 0.3		- 0.3	-1.3	- 3.6
4	Calculated amt.	7.4	7.4	7.8	7.8	8.1	8.4	9.5	11.5	16.9
	Actual amt.	9.0	9.0	8.9	8.9	8.8	8.8	8.8	9.0	9.2
	Error	+ 1.6	+ 1.6	+1.1	+ 1.1	+ 0.7	+ 0.4	- 0.7	- 2.5	- 7.7
5	Calculated amt.	11.1	11.1	11.1	11.1	11.8	12.8	13.8	17.9	28.4
	Actual amt.	13.4	13.3	13.2	13.1	13.0	13.0	13.1	13.4	13.7
	Error	+ 2.3	+2.2	+2.1	+2.0	+ 1.2	+0.2	- 0.7	-4.5	-14.7
6	Calculated amt.	14.9	15.2	15.9	15.9	16.5	17.9	20.6	26.7	46.2
	Actual amt.	18.4	18.3	18.2	18.1	18.0	18.1	18.3	18.7	19.3
	Error	+3.5	+3.1	+2.3	+2.2	+1.5	+0.2	- 2.3	- 8.0	- 26.9
7	Calculated amt.	19.6	19.9	20.9	21.6	23.0	26.0	30.4	41.9	76.3
	Actual amt.	23.8	23.7	23.7	23.7	23.8	23.9	24.4	25.1	25.9
	Error	+ 4.2	+3.8	+2.8	+2.1	+0.8	- 2.1	- 6.0	- 16.8	- 50.4
8	Calculated amt.	24.6	25.7	27.3	28.7	32.1	36.1	45.6	66.5	128.6
	Actual amt.	29.5	29.6	29.8	30.1	30.4	31.0	31.9	33.2	34.6
	Error	+4.9	+ 3.9	+ 2.5	+ 1.4	-1.7	-5.1	-13.7	- 22.3	-94.0
9	Calculated amt.	31.1	33.1	35.8	39.2	44.2	54.7	75.6	122.9	285.2
	Actual amt.	35.7	36.2	36.8	37.6	38.6	40.2	42.7	46.2	50.3
	Error	+ 4.6	+ 3.1	+ 1.0	- 1.6	- 5.6	-14.5	-32.9	- 76.8	-234.9
10	Calculated amt.	38.1	41.9	47.3	55.0	70.5				
	Actual amt.	42.5	43.6	45.1	47.2	50.8				
	Error	+ 4.4	+ 1.7	- 2.2	- 7.8	-19.7				
11	Calculated amt.	47.6	54.7	65.1						
	Actual amt.	50.2	52.4	56.0						
	Error	+ 2.6	- 2.3	- 9.1						
12	Calculated amt.		71.2							
	Actual amt.		64.3							
	Error		- 6.9							

ENCLOSURE (E), continued

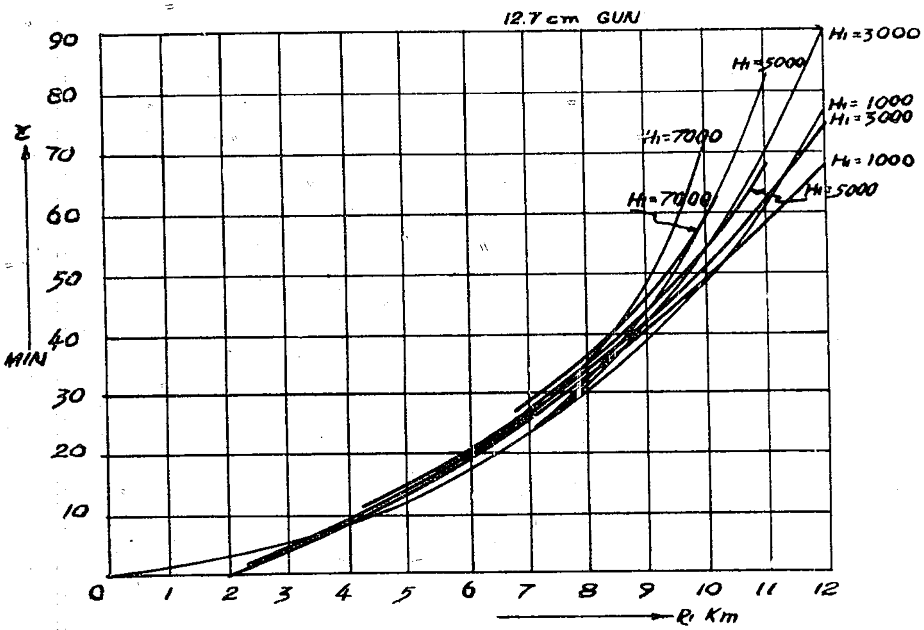


Figure 23(E)
DEVIATION CURVES

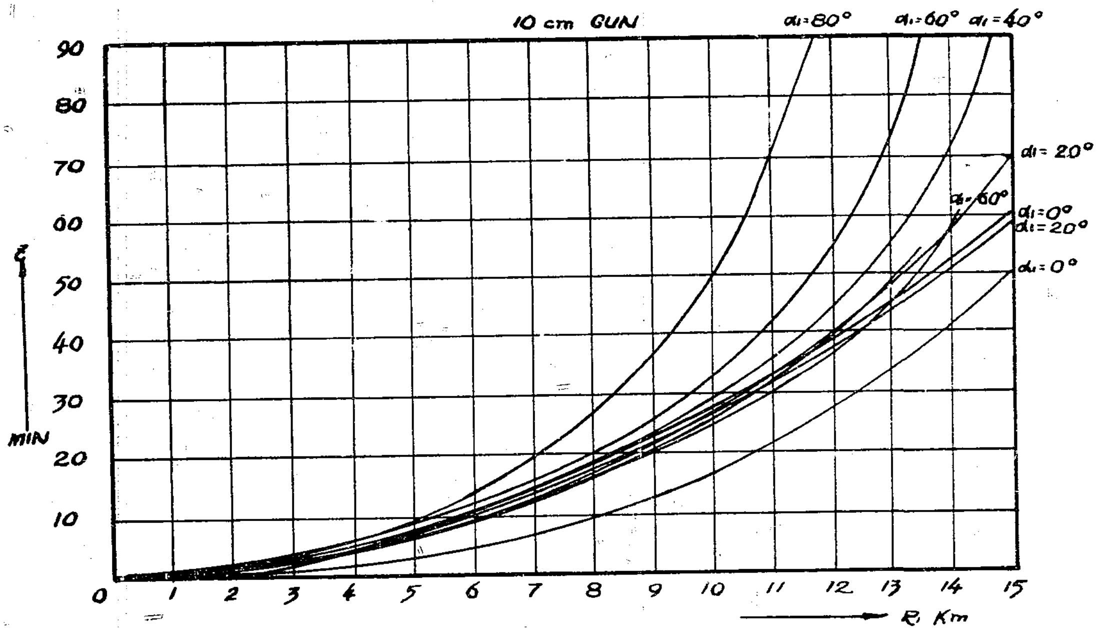


Figure 24(E)
DEVIATION CURVES

ENCLOSURE (E), continued

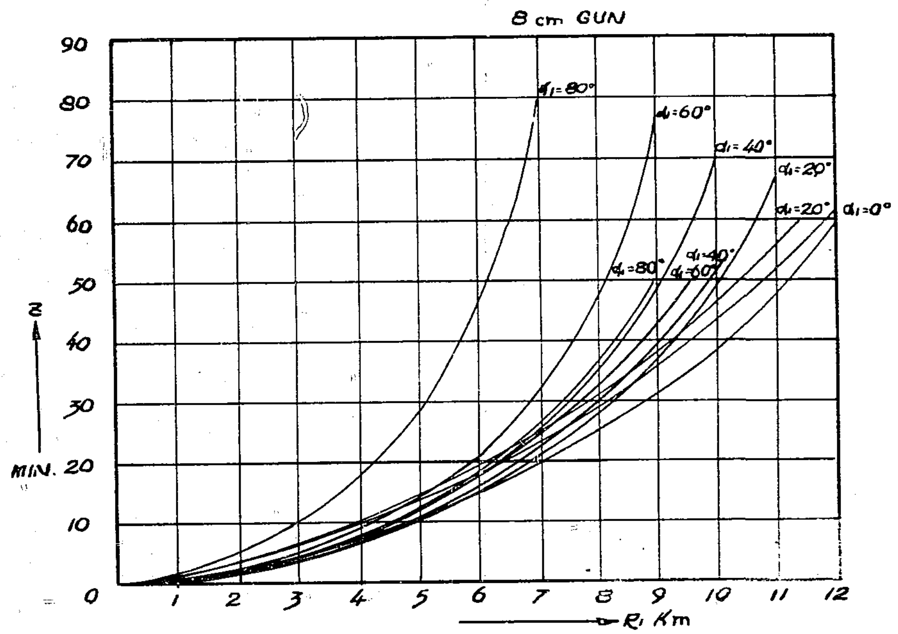


Figure 25(E)
DEVIATION CURVES

$$n_{12.7} = \frac{72}{56} n_{10} = 1.285\, n_{10}$$

$$n_{8} = \frac{170}{58} n_{10} = 1.205\, n_{10}$$

$$w_{12.7} = 1.2\, w_{10}$$

$$w_{8} = 1.5\, w_{10}$$

In these, the sub-numbers show the type of gun. Both n and w are standard for 10 cm gun. Accordingly the fixed values, on the firing table and computer values are as shown in Tables VIII(E), IX(E), X(E) and Figures 26(E) to 31(E).

N. Flat Trajectory Correcting Computer

Since there are some differences in the type of shell, weight of shell etc., between the AA shell (high-angle shell) and the flat trajectory shell, the trajectories will differ; there is a correction of angle of rear sight only depending on whether AA or flat trajectory fire is being carried out. Flat trajectories corrections are:

$$\Delta\zeta = \zeta_{FLAT}(R_1) - \zeta_{AA}(R_1)$$
$$= f(R_1)$$
$$= f(T)$$

ENCLOSURE (E), continued

Table VIII(E)
CONVERGING ANGLE 12.7cm GUN

R_1		α + σ							
		0	10	20	30	40	50	60	70
1	Calculated amt.	137.5	139.6	146.3	158.8	179.5	213.9	275.0	402.1
	Actual amt.	77.2	77.2	80.5	86.8	97.5	115.0	145.5	206.1
	Error	-60.3	-62.4	-65.8	-72.0	-82.0	-108.9	-129.5	-196.0
2	Calculated amt.	68.8	69.8	73.2	79.4	89.8	107.0	137.5	201.0
	Actual amt.	61.6	62.2	64.8	69.9	78.5	92.4	116.7	165.3
	Error	-7.2	-7.6	-8.4	-9.5	-11.3	-14.6	-20.8	-35.7
3	Calculated amt.	45.8	46.5	48.8	52.9	59.8	71.3	91.7	134.0
	Actual amt.	46.1	46.5	48.5	52.2	58.4	68.7	86.8	122.9
	Error	+0.3	-0.0	-0.3	-0.7	-1.4	-2.6	-4.9	-11.1
4	Calculated amt.	34.4	34.9		39.7	44.9	53.5	68.8	100.5
	Actual amt.	33.8	33.9		38.0	42.5	50.0	63.2	90.7
	Error	-0.6	-1.0		-1.7	-2.4	-3.5	-5.6	-9.8
5	Calculated amt.	27.5	27.9	29.3	31.8	35.9	42.8	55.0	80.4
	Actual amt.	26.8	27.0	28.1	30.2	33.8	39.7	50.1	70.9
	Error	-0.7	-0.9	-1.2	-1.6	-2.1	-3.1	-4.9	-9.5
6	Calculated amt.	22.9	23.3	24.4	26.5	29.9	35.7	45.8	67.0
	Actual amt.	22.5	22.6	23.5	[illegible]	28.2	33.1	41.7	59.2
	Error	-0.4	-0.7	-0.9	1.3	-1.7	-2.6	-4.1	-7.8
7	Calculated amt.	19.6	20.0	20.9	22.7		30.6	39.3	57.4
	Actual amt.	19.7	19.8	20.6	22.1		28.9	36.4	51.6
	Error	+0.1	-0.2	-0.3	-0.6		-1.7	-2.9	-5.8
8	Calculated amt.	17.2	17.2	18.3	19.9	22.4	26.7	34.4	50.3
	Actual amt.	17.7	17.8	18.9	19.7	22.0	25.8	32.4	45.2
	Error	+0.5	+0.3	+0.6	-0.2	-0.4	-0.9	-2.0	-5.1
9	Calculated amt.	15.3	15.5	16.3	17.6	20.0	23.8		
	Actual amt.	16.3	16.3	16.8	17.9	19.9	23.2		
	Error	+1.0	+0.8	+0.5	+0.3	-0.1	-0.6		
10	Calculated amt.		14.0	14.6	15.9				
	Actual amt.		15.1	15.5	16.3				
	Error		+1.1	+0.9	+0.4				
11	Calculated amt.	12.5	12.7	13.3					
	Actual amt.	14.2	14.1	14.3					
	Error	+1.7	+1.4	+1.0					
12	Calculated amt.	11.5	11.6						
	Actual amt.	13.4	13.0						
	Error	+1.9	+1.4						

ENCLOSURE (E), continued

Table IX(E)
CONVERGING ANGLE 10cm GUN

R_1		$a + \sigma$							
		0	10	20	30	40	50	60	70
1	Calculated amt.	137.5	139.6	146.3	158.8	179.5	213.9	275.0	402.1
	Actual amt.	62.2	62.9	65.6	70.9	79.6	93.9	118.7	168.1
	Error	- 75.3	- 76.7	- 80.7	- 87.9	- 99.9	- 120.0	- 156.3	- 234.0
2	Calculated amt.	68.8	69.8	73.2	79.4	89.8	107.0	137.5	201.0
	Actual amt.	54.2	54.9	57.3	61.9	69.5	82.0	103.8	147.0
	Error	- 14.6	- 14.9	- 15.9	- 17.5	- 20.3	- 25.0	- 33.7	-54.0
3	Calculated amt.	45.8	46.5	48.8	52.9	59.8	71.3	91.7	134.0
	Actual amt.	45.1	45.9	48.0	51.9	58.5	69.0	87.1	123.2
	Error	- 0.7	- 0.6	- 0.8	- 1.0	- 1.3	- 2.3	- 4.6	- 10.8
4	Calculated amt.	34.4	34.9	36.6	39.7	44.9	53.5		100.5
	Actual amt.	35.0	35.8	37.7	41.0	46.3	54.7		97.3
	Error	+ 0.6	+ 0.9	+ 1.1	+ 1.3	+ 1.4	+ 1.2		+ 2.8
5	Calculated amt.	27.5	27.9	29.3	31.8	35.9	42.8	55.0	80.4
	Actual amt.	27.5	28.1	29.7	32.3	36.3	42.9	54.2	76.5
	Error	0.0	+ 0.2	- 0.4	+ 0.5	+ 0.4	+ 0.1	- [illegible].8	- 3.9
6	Calculated amt.	22.9	23.3	24.4	26.5	29.9	35.7	45.8	67.0
	Actual amt.	22.3	23.1	24.7	27.1	30.6	36.2	45.6	64.2
	Error	- 0.6	- 0.2	+ 0.3	+ 0.6	+ 0.7	+ 0.5	- 0.[illegible]	- 2.8
7	Calculated amt.	19.6	20.0	20.9	22.7	25.6	30.6	39.3	57.4
	Actual amt.	19.0	19.6	21.0	23.0	26.1	30.9	38.9	54.8
	Error	- 0.6	- 0.4	+ 0.1	+ 0.3	+ 0.5	+ 0.3	- 0.4	- 2.6
8	Calculated amt.	17.2	17.5	18.3	19.9	22.4	26.7	34.4	50.3
	Actual amt.	16.5	17.1	18.3	20.1	22.8	27.0	34.0	48.0
	Error	- 0.7	- 0.4	0.0	+ 0.2	+ 0.4	+ 0.3	- 0.4	- 2.3
9	Calculated amt.	15.3	15.5	16.3		20.0	23.8	30.6	44.7
	Actual amt.	14.6	15.2	16.3		20.3	24.0	30.3	42.6
	Error	0.7	- 0.3	0.0		+ 0.3	+ 0.2	- 0.3	- 2.1
10	Calculated amt.	13.8	14.0	14.6	15.9	18.0	21.4	27.5	40.2
	Actual amt.	13.4	13.8	14.8	16.2	18.3	21.6	27.3	[illegible]
	Error	- 0.4	- 0.2	+ 0.2	+ 0.3	+ 0.3	+ 0.2	- 0.2	- 1.7
11	Calculated amt.	12.5	12.7		14.4	16.3	19.5	25.0	36.6
	Actual amt.	12.4	12.8		14.9	16.8	19.8	25.0	35.1
	Error	- 0.1	+ 0.1		+ 0.5	+ 0.5	+ 0.3	0.0	- 1.5
12	Calculated amt.	11.5	11.6	12.2	13.2	15.0	17.8	22.9	33.5
	Actual amt.	11.6	12.0	12.7	13.8	15.6	18.3	23.0	32.3
	Error	+ 0.1	+ 0.4	+ 0.5	+ 0.6	+ 0.6	+ 0.5	+ 0.1	- 1.2
13	Calculated amt.	10.6	10.7	11.3	12.2	13.8	16.5	21.2	30.9
	Actual amt.	11.0	11.3	11.9	12.9	14.5	17.0	21.2	29.6
	Error	+ 0.4	+ 0.6	+ 0.6	+ 0.7	+ 0.7	+ 0.5	0.0	- 1.3
14	Calculated amt.	9.8	10.0	10.5	11.3	12.8	15.3		
	Actual amt.	10.5	10.7	11.3	12.1	13.5	15.6		
	Error	+ 0.7	+ 0.7	+ 0.8	+ 0.8	+ 0.7	+ 0.3		
15	Calculated amt.	9.2	9.3	9.8					
	Actual amt.	9.9	10.1	10.5					
	Error	+ 0.7	+ 0.8	+ 0.7					

ENCLOSURE (E), continued

Table X(E)
CONVERGING ANGLE

8cm GUN

R_1		$\alpha + \sigma$							
		0	10	20	30	40	50	60	70
1	Calculated amt.	137.5	139.6	146.3	158.8	179.5	213.9	275.0	402.1
	Actual amt.	73.8	74.6	77.9	84.1	94.4	113.4	140.7	199.5
	Error	- 63.7	-65.0	- 68.4	-74.7	- 85.1	- 100.5	- 134.3	-202.6
2	Calculated amt.	68.8	69.8	73.2	79.4	89.8	107.0	137.5	201.0
	Actual amt.	61.8	63.5	65.2	70.4	79.0	93.2	117.8	166.6
	Error	- 7.0	- 6.3	- 8.0	- 9.0	-10.8	-13.8	-19.7	-34.4
3	Calculated amt.	45.8	46.5	48.8	52.9	59.8		91.7	134.0
	Actual amt.	46.6	47.3	49.4	53.4	60.0		89.4	125.6
	Error	+ 0.8	+0.8	+0.6	+0.5	+0.2		- 2.3	- 8.4
4	Calculated amt.	34.4	34.9	36.6	39.7	44.9	53.5	68.8	100.5
	Actual amt.	33.3	33.8	35.4	38.3	43.0	50.9	64.1	90.4
	Error	- 1.1	- 1.1	-1.2	-1.4	-1.9	-2.6	-4.7	-10.1
5	Calculated amt.	27.5	27.9	29.3	31.8	35.9	42.8	55.0	80.4
	Actual amt.	25.8	26.2	27.4	29.7	32.4	39.5	49.7	70.1
	Error	-1.7	-1.7	-1.9	-2.1	-3.5	-3.3	- 5.3	-10.3
6	Calculated amt.	22.9	23.3	24.4	26.5	29.9	35.7	45.8	67.0
	Actual amt.	21.2	21.5	22.5	24.4	27.4	32.3	40.6	56.8
	Error	-1.7	- 1.8	-1.9	-2.1	-2.5	- 3.4	-5.2	-10.2
7	Calculated amt.	19.6	20.0	20.9	22.7	25.6	30.6	39.3	57.4
	Actual amt.	18.4	18.6	19.4	21.0	23.5	27.6	34.6	48.6
	Error	-1.2	-1.4	-1.5	-1.7	-2.1	-3.0	- 4.7	-8.8
8	Calculated amt.	17.2	17.5	18.3	19.9	22.4	26.7	34.4	50.3
	Actual amt.	16.5	16.6	17.3	18.6	20.8	24.3	30.3	42.4
	Error	-0.7	-0.9	-1.0	-1.3	-1.6	-2.4	- 4.1	- 7.9
9	Calculated amt.	15.3	15.5		17.6	20.0	23.8	30.6	
	Actual amt.	15.1	15.2		16.8	18.7	21.6	26.7	
	Error	-0.2	- 0.3		- 0.8	-1.3	- 2.2	-3.9	
10	Calculated amt.	13.8	14.0	14.6	15.9				
	Actual amt.	14.0	14.0	14.5	15.3				
	Error	+0.2	0.0	- 0.1	-0.6				
11	Calculated amt.	12.5	12.7	13.3					
	Actual amt.	13.1	13.1	13.3					
	Error	+0.6	+0.4	0.0					

ENCLOSURE (E), continued

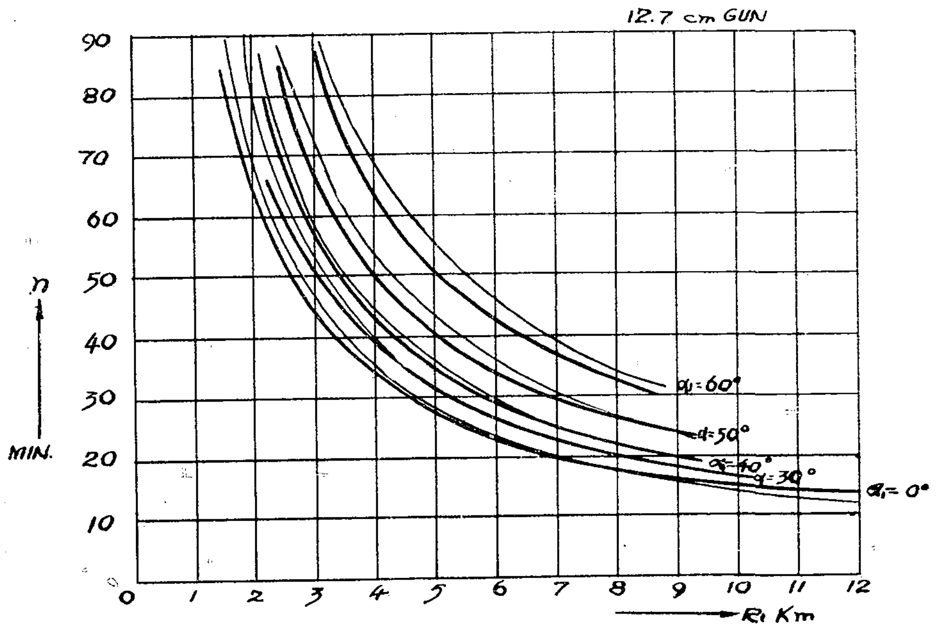


Figure 26(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* n

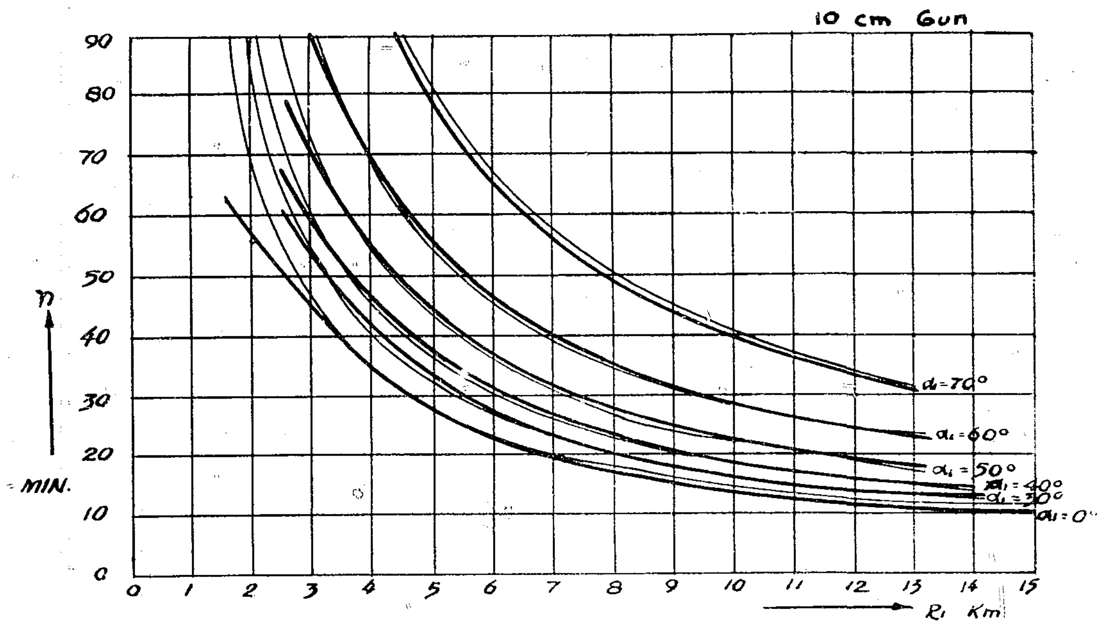


Figure 27(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* n

ENCLOSURE (E), continued

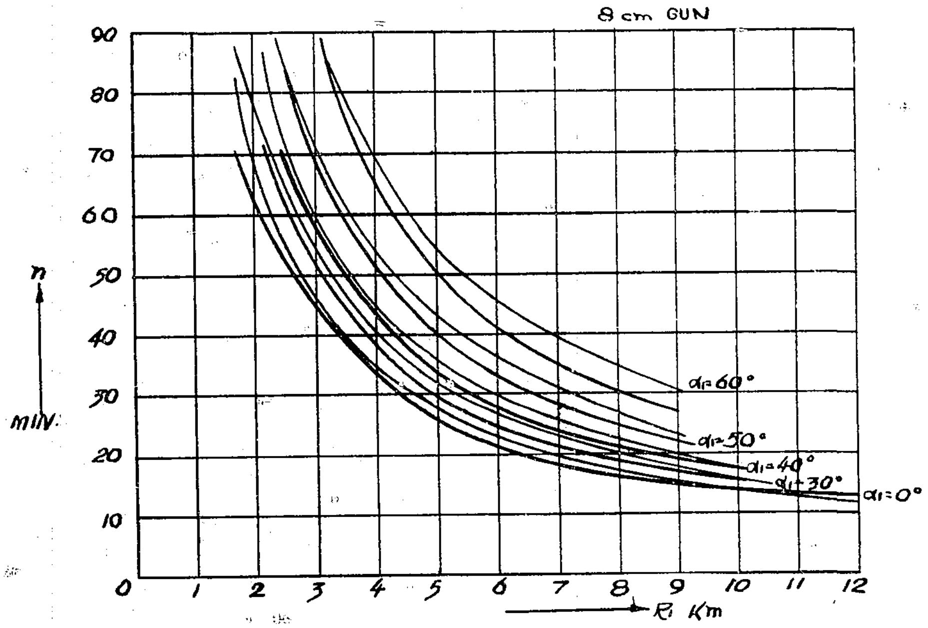


Figure 28(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* n

Hence, graduations are made for $\Delta\zeta$ dependent on T. When we investigate $\Delta\zeta$ to make it correspond to the graduations of T, we find that $\Delta\zeta$ increases. Conversions for gun types are made by changing the graduations.

O. Target Director (AA Director)

The commander is stationed in a projection set-up in the turret of the AA director. When he sees the target in the 8cm AA binoculars (since the pointers and setters are within the turret, field of vision is limited - and since the pointing and setting telescopes are only 4cm, and of inferior telescopic power compared to those of the commander) the commander determines the target. There are many cases of bungling because of the extremely great lapse of time required for the pointers and setters to discover the target. Consequently, it was determined that the commander should define the target; in order to inform the pointers and setters of the director and bearing, the commander communicates the angle of elevation and the angle of turn as shown in his binoculars. This angle is entered on the left lens of the telescopes for pointing and setting. In order to simplify their movements so as to be able to follow the targets closely without moving their eyes from the telescopes, the pointers and setters always announce the guide seen in the left lens over the communicator. When the commander defines the target, he too will flash the pilot light and submit his findings by the communicator, as in Figure 32(E). The pointers too when they pick up the target, will push the foot-operated switch and work the commander's buzzer. Moreover, since previously on the left lens of the pointer's (telescopes) a red light from the panel has meant "Fire", a red light will mean "Fire" and a white light will mean "follow the target".

ENCLOSURE (E), continued

Table XI(E)
HORIZONTAL ERROR WITH A THIRTY KNOT SIDE-WIND 12.7cm GUN

R_1		H_1 0000	1000	2000	3000	4000	5000	6000	7000
1	Calculated amt.	5.3							
	Actual amt.	5.3							
	Error	0.0							
2	Calculated amt.	11.4	13.2						
	Actual amt.	11.2	12.4						
	Error	-0.2	-0.8						
3	Calculated amt.	18.6	19.6	24.5					
	Actual amt.	17.9	19.0	23.9					
	Error	-0.7	-0.6	-0.6					
4	Calculated amt.	26.[illegible]	27.2	30.2	39.2				
	Actual amt.	25.3	26.3	29.4	38.2				
	Error	-1.3	-0.9	-0.8	-1.0				
5	Calculated amt.	35.1	35.7	37.7	42.5	55.8			
	Actual amt.	33.5	34.4	36.8	42.1	55.7			
	Error	-1.6	-1.3	-0.9	-0.4	-0.1			
6	Calculated amt.	43.6	44.1	45.5	48.7	55.5	74.1		
	Actual amt.	42.1	42.9	45.0	49.0	56.8	76.5		
	Error	-1.5	-1.2	-0.5	+0.3	+1.3	+2.4		
7	Calculated amt.	51.7	52.4	51.4	55.8	60.3	70.1	95.0	
	Actual amt.	50.9	51.9	53.6	56.9	63.0	73.6	99.9	
	Error	-0.8	-0.5	+0.2	+1.1	+2.7	+3.5	+4.9	
8	Calculated amt.	59.5	60.2	61.3	63.0	66.5	73.4	86.9	120.3
	Actual amt.	59.6	60.6	62.5	65.2	70.2	78.1	92.8	126.9
	Error	+0.1	+0.4	+1.2	+2.2	+3.7	+4.7	+5.9	+6.6
9	Calculated amt.	66.4	67.5	68.6	70.5	74.1	80.0	90.0	109.2
	Actual amt.	67.9	69.1	70.9	73.9	78.3	84.9	95.9	115.7
	Error	+1.5	+1.6	+2.3	+3.4	+4.2	+4.9	+5.9	- 6.5
10	Calculated amt.	73.7	74.8	76.5	79.3	83.5	90.1	101.8	121.1
	Actual amt.	76.0	77.2	79.4	82.5	86.9	94.5	104.4	119.1
	Error	+2.3	+2.4	+2.9	+3.2	+3.4	+4.4	+2.6	-2.0
11	Calculated amt.	81.4	82.8	85.3	89.3	96.7	110.1		
	Actual amt.	83.6	84.9	87.2	90.9	95.7	103.6		
	Error	+2.2	+2.1	+1.9	+1.6	-1.0	- 6.5		
12	Calculated amt.	89.6	92.2	96.6					
	Actual amt.	90.5	92.0	94.9					
	Error	+0.9	-0.2	-1.7					

ENCLOSURE (E), continued

Table XII(E)
HORIZONTAL ERROR WITH A THIRTY KNOT SIDE-WIND 10cm GUN

R_1		α + σ							
		0	10	20	30	40	50	60	70
1	Calculated amt.	3.2	3.2	3.4	3.4	3.9	4.5	5.7	8.5
	Actual amt.	3.1	3.2	3.3	3.6	4.0	4.7	6.0	8.5
	Error	- 0.1	0.0	-0.1	+ 0.2	+ 0.1	+0.2	+ 0.3	0.0
2	Calculated amt.	7.0	6.6	6.6	7.0	7.7	9.1	11.6	17.2
	Actual amt.	6.6	6.7	7.0	7.5	8.4	9.9	12.5	17.7
	Error	-0.4	+ 0.1	+ 0.4	+0.5	+ 0.7	+0.8	+ 0.9	-0.5
3	Calculated amt.	11.1	10.5	10.5	10.8	11.7	13.8	17.8	26.3
	Actual amt.	10.5	10.5	10.9	11.8	13.1	15.5	19.6	27.9
	Error	-0.6	0.0	+0.4	+1.0	+ 1.4	+1.7	+1.8	+1.6
4	Calculated amt.	16.2	15.0	14.7	15.0	16.4	18.9		
	Actual amt.	14.9	14.8	15.3	16.4	18.3	21.6		
	Error	-1.3	- 0.2	+ 0.6	+ 1.4	+ 1.9	+ 2.7		
5	Calculated amt.	21.9	20.1	19.5	19.6	21.3	24.6	31.8	47.4
	Actual amt.	19.8	19.6	20.1	21.5	24.0	28.3	35.9	51.1
	Error	- 2.1	- 0.5	+ 0.6	+ 1.9	+ 2.7	+ 3.7	+ 4.1	+ 3.7
6	Calculated amt.	28.4	26.0	24.7	24.7	26.7	30.8	39.7	59.3
	Actual amt.	25.3	24.9	25.4	27.0	30.1	35.4	45.0	64.1
	Error	- 3.1	- 1.1	+0.7	+ 2.3	+ 3.4	+ 4.6	+ 5.3	+ 4.8
7	Calculated amt.	36.0	32.6	30.6	30.4	32.6	37.7	48.4	[illegible]
	Actual amt.	31.6	30.8	31.2	33.1	36.7	43.2	54.9	72.2
	Error	- 4.4	- 1.8	+ 0.6	+ 2.7	+ 4.1	+5.5	+ 6.5	+ 3.4
8	Calculated amt.	44.7	39.9	37.1	36.8	39.1	46.0	57.9	85.8
	Actual amt.	38.4	37.3	37.6	39.6	43.9	51.6	65.5	93.4
	Error	- 6.3	- 2.6	+ 0.5	+ 2.8	+ 4.8	+5.6	+ 7.6	+7.6
9	Calculated amt.	53.2	47.6	44.3		46.4	53.8	68.8	101.5
	Actual amt.	45.4	44.0	44.3		51.6	60.7	77.1	110.0
	Error	- 7.8	- 3.6	0.0		+5.2	+ 6.9	+ 8.3	+ 8.5
10	Calculated amt.	60.9	55.0	51.8	51.1	54.4	63.2	80.8	119.4
	Actual amt.	52.2	50.8	51.3	53.9	59.8	70.4	89.5	127.9
	Error	- 8.7	- 4.2	- 0.5	+ 2.8	+5.4	+ 7.2	+ 8.7	+ 8.5
11	Calculated amt.	68.3	62.3		58.9	63.0	73.7	94.3	139.4
	Actual amt.	58.6	57.4		61.5	68.4	80.7	102.7	147.2
	Error	- 9.7	- 4.9		+ 2.6	+ 5.4	+ 7.0	+ 8.4	+ 7.8
12	Calculated amt.	74.9	68.8	66.0	66.9	72.3	85.1	109.9	
	Actual amt.	64.6	63.6	64.9	69.0	77.1	91.4	116.7	
	Error	- 10.3	- 5.2	- 1.1	+ 2.1	+ 4.8	+ 6.3	+ 6.8	
13	Calculated amt.	81.6	75.4	73.2	75.2	82.8	98.9	129.5	
	Actual amt.	70.1	69.4	71.3	76.4	86.0	102.6	131.8	
	Error	- 11.5	-6.0	- 1.9	+ 1.2	+ 3.2	+ 3.7	+ 2.3	
14	Calculated amt.	87.6	82.2	81.0	85.0	96.1	119.3		
	Actual amt.	74.8	74.7	77.4	83.6	95.0	114.8		
	Error	- 12.8	- 7.5	- 2.6	- 1.4	- 1.1	- 4.5		
15	Calculated amt.	93.5	89.3	89.9	98.1				
	Actual amt.	78.7	79.2	82.8	90.5				
	Error	- 14.8	- 10.1	- 7.1	- 7.6				

ENCLOSURE (E), continued

Table XIII(E)
HORIZONTAL ERROR WITH A THIRTY KNOT SIDE-WIND 8cm GUN

R_1		$\alpha + \sigma$							
		0°	10°	20°	30°	40°	50°	60°	70°
1	Calculated amt.	5.7	5.7	6.2	6.5	7.4	8.7	11.6	17.6
	Actual amt.	5.4	5.5	5.7	6.2	6.9	8.2	10.4	14.7
	Error	-0.3	-0.2	-0.5	-0.3	-0.5	-0.5	-1.2	-2.9
2	Calculated amt.	13.4	13.4	13.8	14.7	16.5	19.3	25.3	38.5
	Actual amt.	11.9	12.1	12.6	13.6	15.2	18.0	22.8	32.3
	Error	-1.5	-1.3	-1.2	-1.1	-1.3	-1.3	-2.5	-6.2
3	Calculated amt.	22.7	22.7	23.0	24.6		27.5	41.6	63.0
	Actual amt.	19.9	20.0	20.9	22.5	25.2		37.7	54.0
	Error	-2.8	-2.7	-2.1	-2.1	-2.3		-3.9	-9.0
4	Calculated amt.	33.8	33.5	34.1	36.3	40.0	46.7	60.6	92.1
	Actual amt.	29.5	29.7	30.8	33.2	37.1	43.7	55.5	79.6
	Error	-4.3	-3.8	-3.3	-3.1	-2.9	-3.0	-5.1	-12.5
5	Calculated amt.	46.2	45.6	46.5	49.0	53.9	63.0	82.0	124.5
	Actual amt.	40.6	40.9	42.4	45.5	50.9	59.9	76.3	109.9
	Error	-5.6	-4.7	-4.1	-3.5	-3.0	-3.1	-5.7	-14.6
6	Calculated amt.	57.9	57.2	58.4	62.1	68.1	81.1	104.9	164.9
	Actual amt.	52.5	52.8	55.0	59.1	66.1	78.2	99.7	144.1
	Error	-5.4	-4.4	-3.4	-3.0	-2.0	-2.9	-5.2	-20.8
7	Calculated amt.	68.3	67.7	69.4	73.9	82.0	97.6	127.8	195.0
	Actual amt.	64.2	64.9	67.7	73.1	82.1	97.5	125.1	181.1
	Error	-4.1	-2.8	-1.7	-0.8	+0.1	-0.1	-2.7	-13.9
8	Calculated amt.	77.6	77.1	79.7	85.4	96.3	115.7	153.9	236.7
	Actual amt.	75.7	76.8	80.5	87.4	98.9	118.3	152.9	222.5
	Error	-1.9	-0.3	+0.8	+2.0	+2.6	+2.6	-1.0	-14.2
9	Calculated amt.	85.9	86.5		98.1	112.6	139.4	191.9	307.5
	Actual amt.	86.7	88.4		102.2	116.8	141.5	186.1	275.6
	Error	+0.8	+1.9		+4.1	+4.2	+2.1	-5.8	-31.9
10	Calculated amt.	94.6	96.4	102.4	114.6	138.3			
	Actual amt.	97.2	99.8	106.2	117.8	137.6			
	Error	+2.6	+3.4	+3.8	+3.2	-0.7			
11	Calculated amt.	103.7	107.5	118.5					
	Actual amt.	107.0	110.6	119.3					
	Error	+3.3	+3.1	+0.8					
12	Calculated amt.		123.0						
	Actual amt.		120.7						
	Error		-2.3						

ENCLOSURE (E), continued

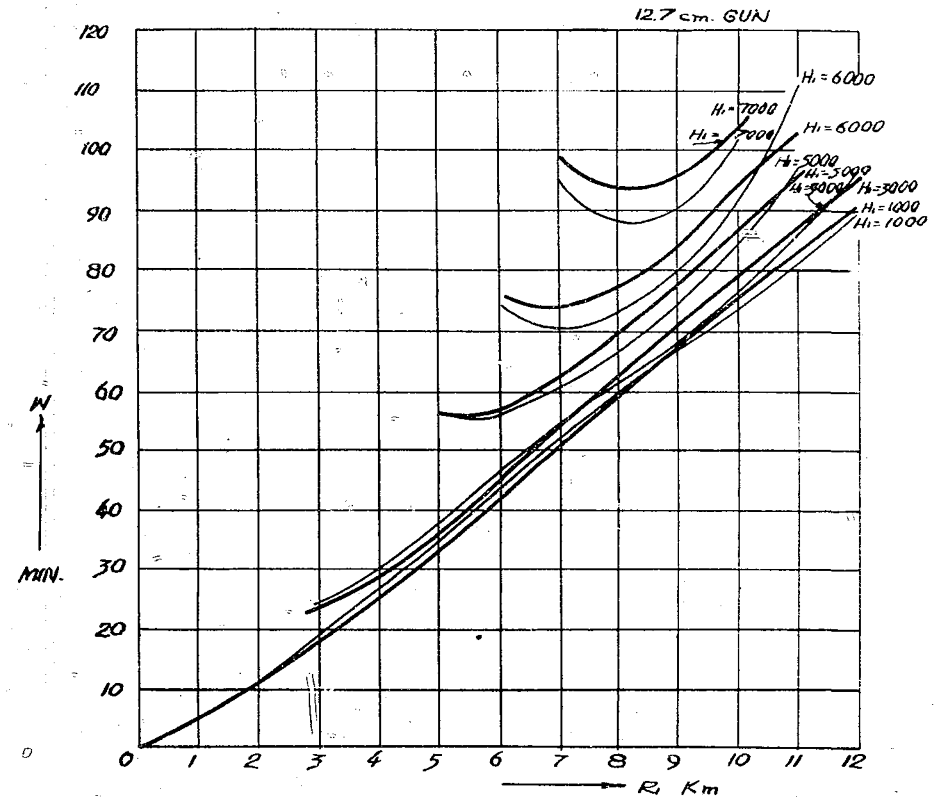


Figure 29(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* w

P. Examples of Computing

As already shown, the calculation of the second form of R in paragraph D the range ratio in paragraphs E and F, and the vertical predictions in paragraph J it is certain that any number of errors may occur with the problem of calculation.

On a course in which the minimum horizontal range is 1000 m, a 12.7cm gun is fired at a flying target with an altitude of 4000 m and a speed of 200 m/sec.

(1) $$R_1 = R + \frac{dR}{dt}T + R_1 \left\{ (1 - \cos\delta) + \cos\alpha\cos(\alpha+\sigma)(1 - \cos\delta) \right\}$$

$$\frac{d\alpha}{dt}\frac{R}{R_1}T = \sin\sigma + \sin\alpha\cos(\alpha+\sigma)(1 - \cos\delta)$$

$$\frac{dB}{dt}\frac{R}{R_1}T = \frac{\cos(\alpha+\sigma)}{\cos\alpha}\sin\delta$$

ENCLOSURE (E), continued

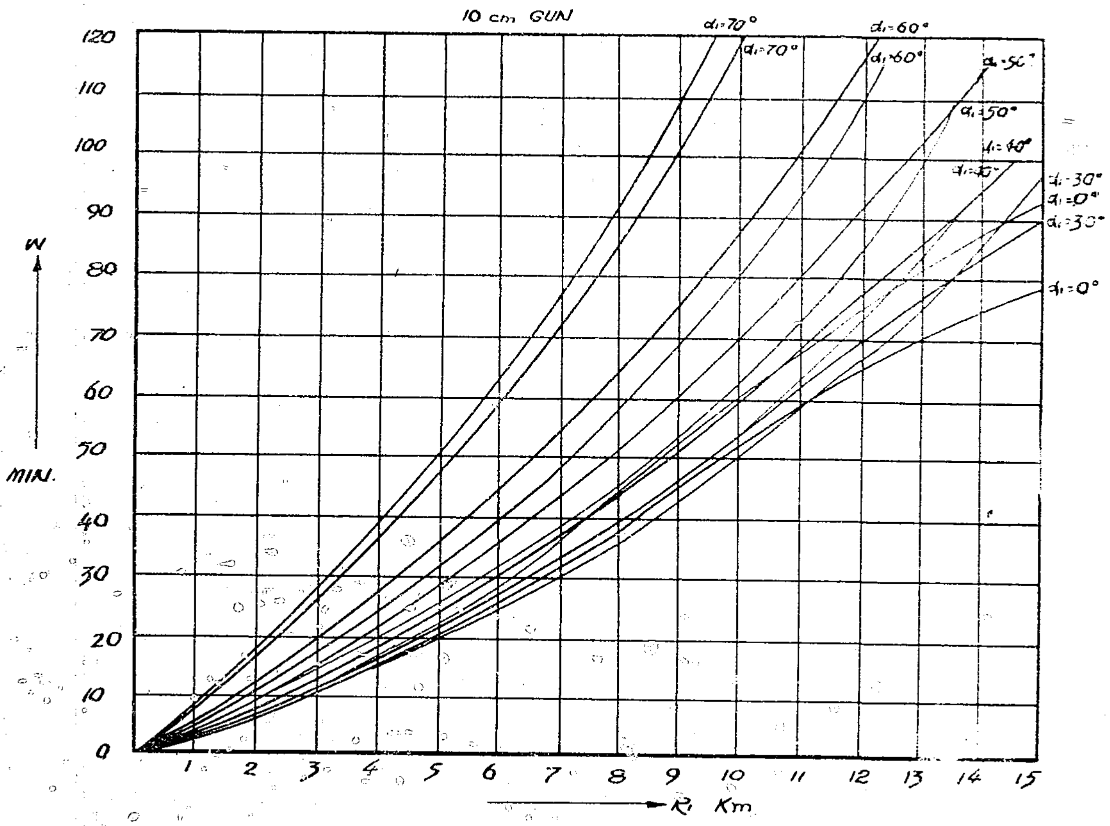


Figure 30(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* w

(2) $$R_1 = R + \frac{dR}{dt} T$$

$$\frac{d\alpha}{dt} \frac{R}{R_1} T = \sigma_{rad} + \sin 2(\alpha + \sigma) \frac{1 - \cos \delta}{2}$$

$$\frac{dB}{dt} \frac{R}{R_1} T = \frac{\cos (\alpha + \sigma)}{\cos \alpha} \sin \delta$$

(3) $$R_1 = R + \frac{dR}{dt} T$$

$$\frac{d\alpha}{dt} [T - \frac{dR}{dt} f(T)] = f(\sigma) + \left\{ \sin (2\alpha + \sigma) - \sigma_{rad} \right\} \frac{1 - \cos \delta}{2}$$

$$\frac{dB}{dt} [T - \frac{dR}{dt} f(T)] = \frac{\cos (\alpha + \sigma) \sin \delta}{\cos \alpha}$$

ENCLOSURE (E), continued

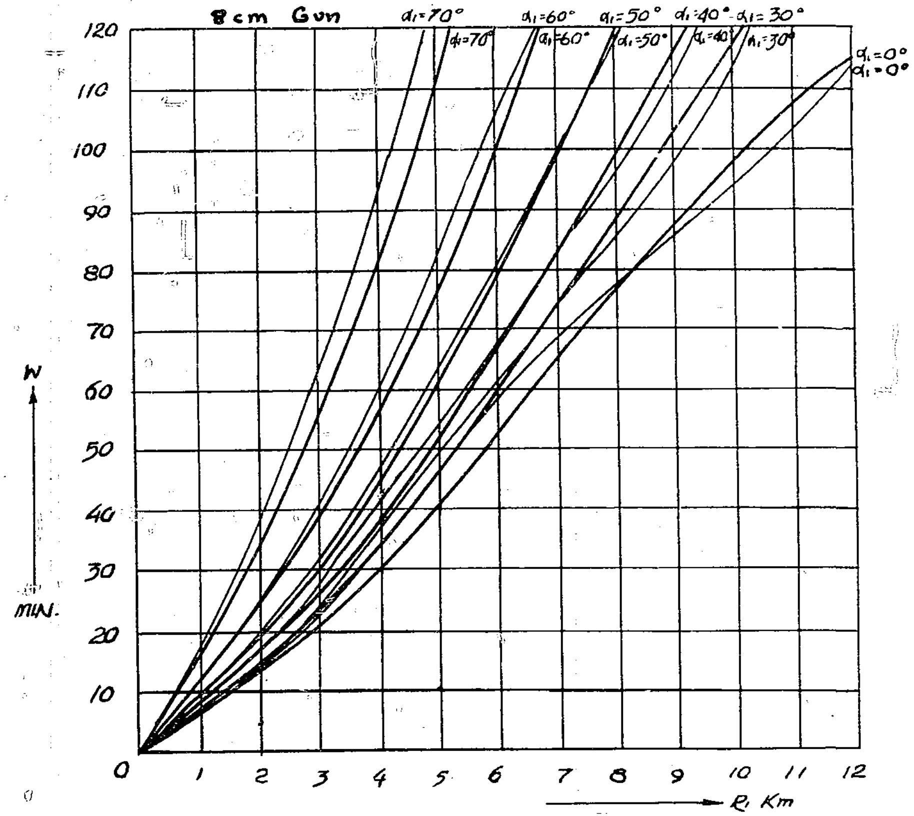


Figure 31(E)
TYPE 94 MOD 1 DIRECTOR
R_1 *vs.* w

In this method of calculation, (1) is correct for all calculations. The basic calculation of (2) is for the old Type 94 and (3) for Type 94, improved. Accordingly the results of the calculations are as in the following table. When R in the upper left hand column is the basis of calculation we calculate the respective α_1, R_1, dR/dt, dα/dt which are in corresponding positions. The R for (2) and (3) which is on the lower half of the table is the R shown since only the values of σ and δ change when calculating (2) and (3), those for (2) are shown as (?) and while those for (3) are shown σ' and δ''.

When we consider these errors, $\Delta\delta'$ and $\Delta\delta''$ are almost identical, and of $\Delta\sigma$ is about the same value as σ. Though the errors have been lessened, we bring the calculation of the upper and lower portions of the table closer to the basic calculations. The influence of the range ratio is hardly shown. But in short it shows that the theory in paragraphs E, F, and G is correct.

That an error occurs in the latter is inevitable when we consider the influence of R. But that will be exact when R is small as shown by Figure 6(E).

ENCLOSURE (E), continued

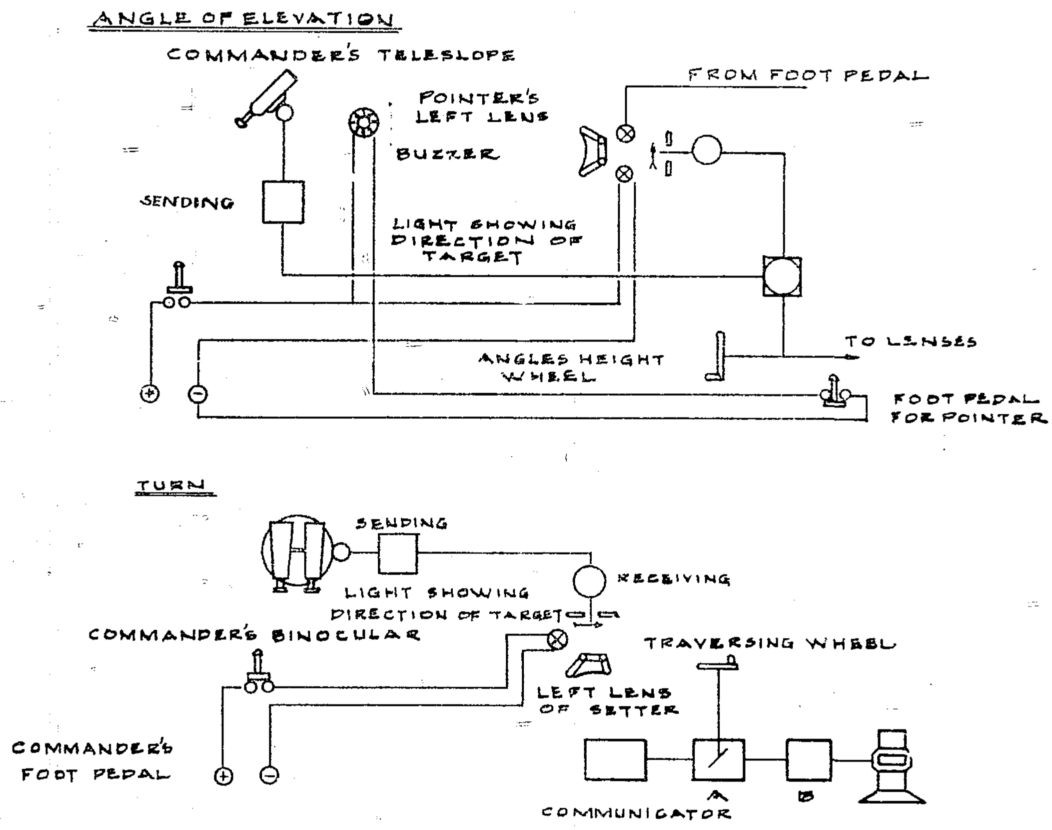


Figure 32(E)
TARGET DIRECTOR LAYOUT

ENCLOSURE (E), continued

12.7cm GUN

Table XIV

P Minutes	T Seconds	α_1 Degrees/ Minutes	α Degrees/ Minutes	R Meters	$d\beta/dt$ Meters/ Seconds	$d\alpha/dt$ Degrees/ Seconds	dR/dt Degrees/ Seconds	σ Degrees/ Seconds	δ Degrees/ Seconds
10000	31.05	23° 35'	14° 36'	15865	-193.1	0.18160	0.04860	8° 59'	2° 32'
9000	25.77	26° 23'	16° 52'	13785	-190.8	0.24048	0.06588	9° 31'	2° 46'
8000	21.17	30° 0'	19° 46'	11830	-187.7	0.32625	0.09239	10° 14'	3° 9'
7000	17.24	34° 51'	23° 35'	9994	-182.8	0.45598	0.13656	11° 16'	3° 45'
6000	13.75	41° 49'	29° 8'	8219	-174.3	0.67212	0.22214	12° 41'	4° 55'
5000	10.57	53° 8'	38° 26'	6437	-156.6	1.08459	0.45052	14° 42'	8° 2'
4500	9.15	62° 44'	46° 42'	5494	-137.8	1.46308	0.80671	16° 2'	13° 38'

R_1 Meters	T Seconds	σ' Degrees/ Minutes	$\Delta\sigma$ Minutes	δ' Degrees/ Minutes	$\Delta\delta'$ Minutes	σ Degrees/ Minutes	$\Delta\sigma$ Minutes	δ'' Degrees/ Minutes	$\Delta\delta''$ Minutes
9937	30.71	8° 53'	- 6'	2° 31'	- 1'	8° 53'	- 6'	2° 30'	- 2'
8932	25.41	9° 25'	- 6'	2° 45'	- 1'	9° 26'	- 5'	2° 45'	- 1'
7920	20.83	10° 7'	- 7'	3° 7'	- 2'	10° 9'	- 5'	3° 7'	- 2'
6906	16.88	11° 5'	-11'	3° 43'	- 2'	11° 7'	- 9'	3° 42'	- 3'
5872	13.47	12° 27'	-14'	4° 51'	- 4'	12° 33'	- 8'	4° 51'	- 4'
4851	10.13	14° 19'	-23'	7° 51'	-11'	14° 24'	-18'	7° 49'	[illegible]
4306	8.62	15° 28'	-34'	13° 8'	-30'	15° 39'	-23'	13° 7'	-31'

ENCLOSURE (F)

TYPE 4 MODIFICATION 3 SIMPLIFIED SHORT RANGE DIRECTOR SYSTEM
(KOSHA SHAGEKI SOCHI)

Legend for Figure 1(F)

(1) 7 Power Monocular
(2) Fuze Time Delay Oscillator
(3) Lateral Correction Handle
(4) Sight Deflection Correction Table
(5) Vertical Correction Table Pointer
(6) Sight Angle Correction Scale
(7) Vertical Correction Handle
(8) Elevating Handwheel
(9) Traversing Oscillator
(10) Traversing Oscillator Scale
(11) Fuze Time Delay Curved Line Cylinder
(12) Fuze Time Delay Pointer
(13) Elevating Scale
(14) Target Process Arrow
(15) Target Speed Scale
(16) Elevating Scale
(17) Azimuth Scale
(18) Super Elevation Scale
(18a) Length of the Base
(18b) For Dual Purpose Gun of 10cm Calibre
20 41147' .... 20 41147'
For Dual Purpose Gun of 12cm Calibre
27 54485' .... 27 54485'
For Dual Purpose Gun of 12.7cm Calibre
31 47047' .... 31 47047'
(19) Fuze Time Delay (curved line) Wheel
(20) Flexible Handle
(21) Elevating Oscillation Scale
(22) Elevating Oscillator
(23) Traversing Pointer
(24) Traversing Scale

ENCLOSURE (F), continued

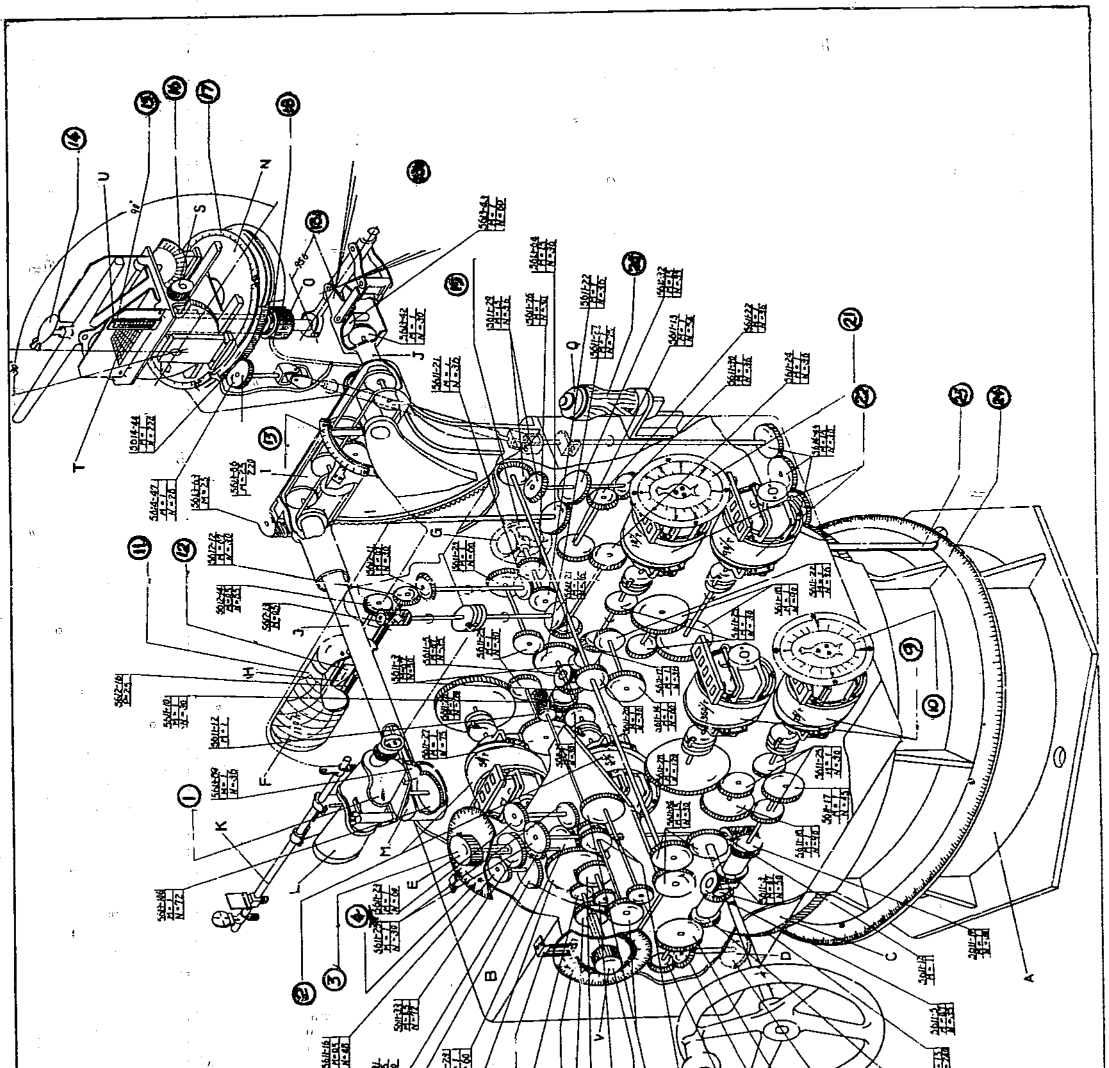


Figure 1(F)
TYPE 4 MOD 3 SIMPLIFIED SHORT RANGE DIRECTOR

ENCLOSURE (F), continued

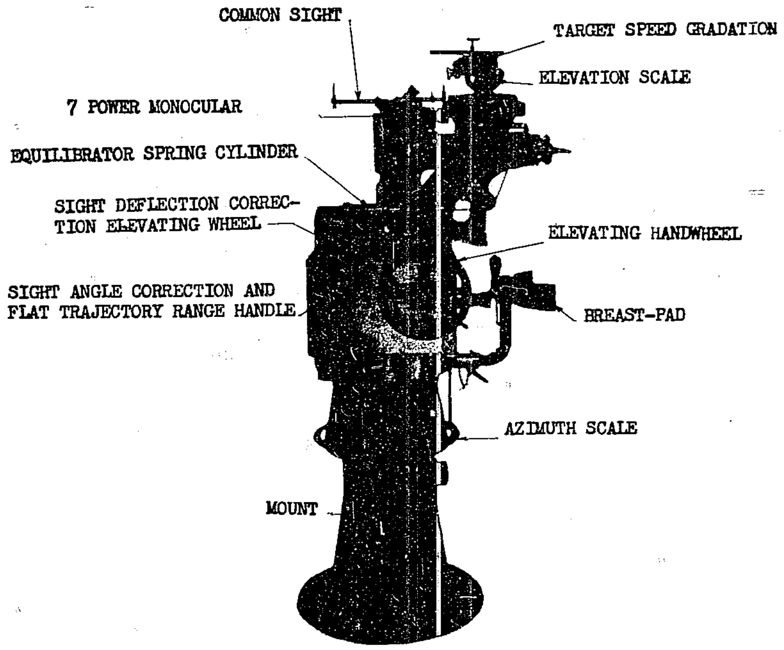


Figure 2(F)
TYPE 4 MOD 3 DIRECTOR, RIGHT VIEW

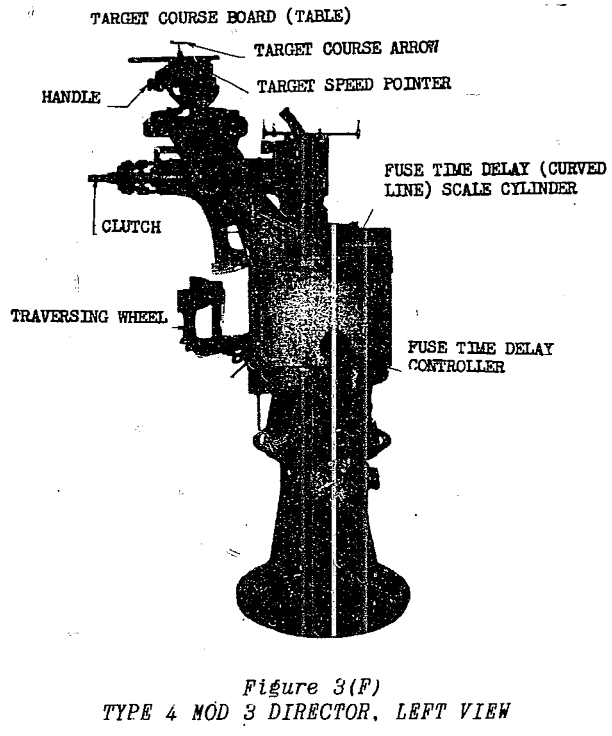


Figure 3(F)
TYPE 4 MOD 3 DIRECTOR, LEFT VIEW

ENCLOSURE (F), continued

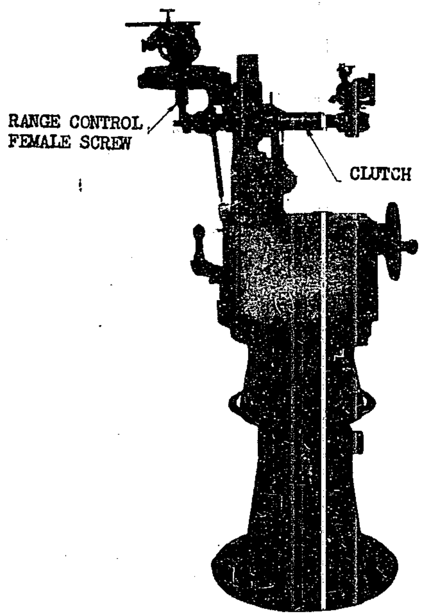


Figure 4(F)
TYPE 4 MOD 3 DIRECTOR, FRONT VIEW

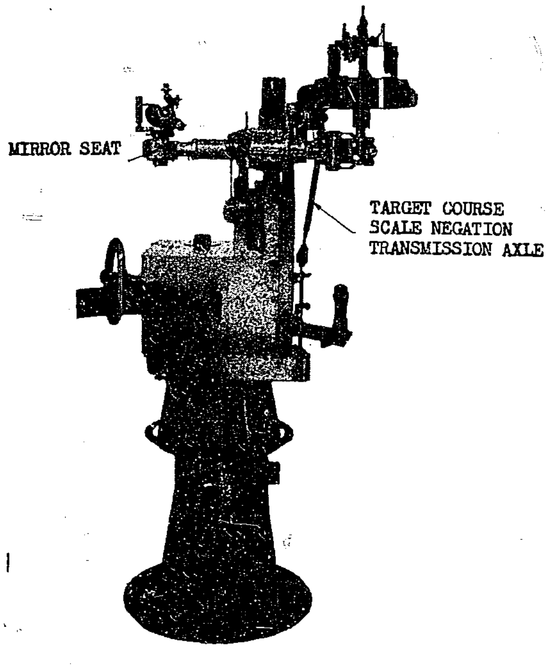


Figure 5(F)
TYPE 4 MOD 3 DIRECTOR, REAR VIEW

ENCLOSURE (F), continued

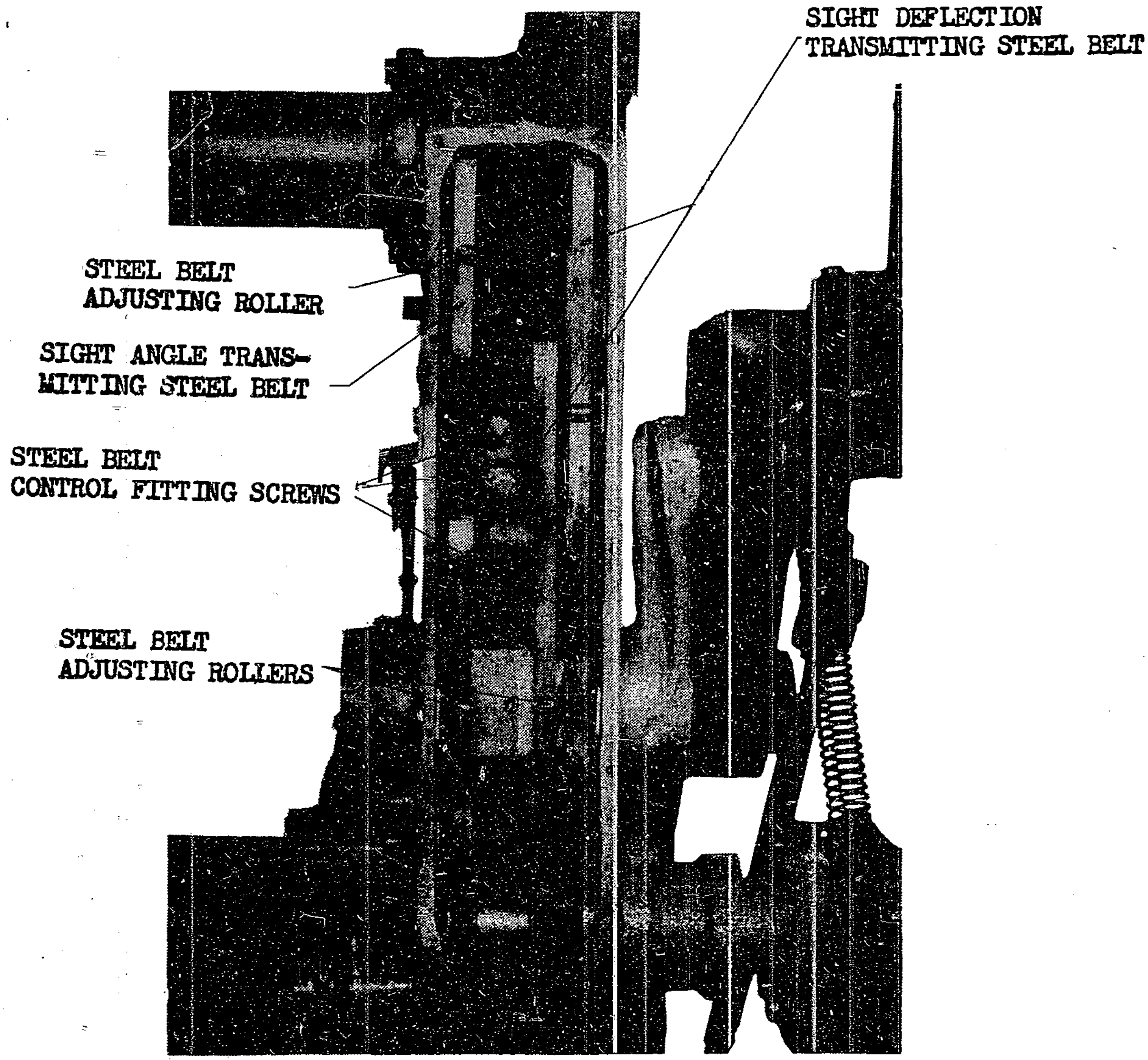


Figure 6(F)
TYPE 4 MOD 3 DIRECTOR. INNER VIEW OF ELEVATING ARC

ENCLOSURE (F), continued

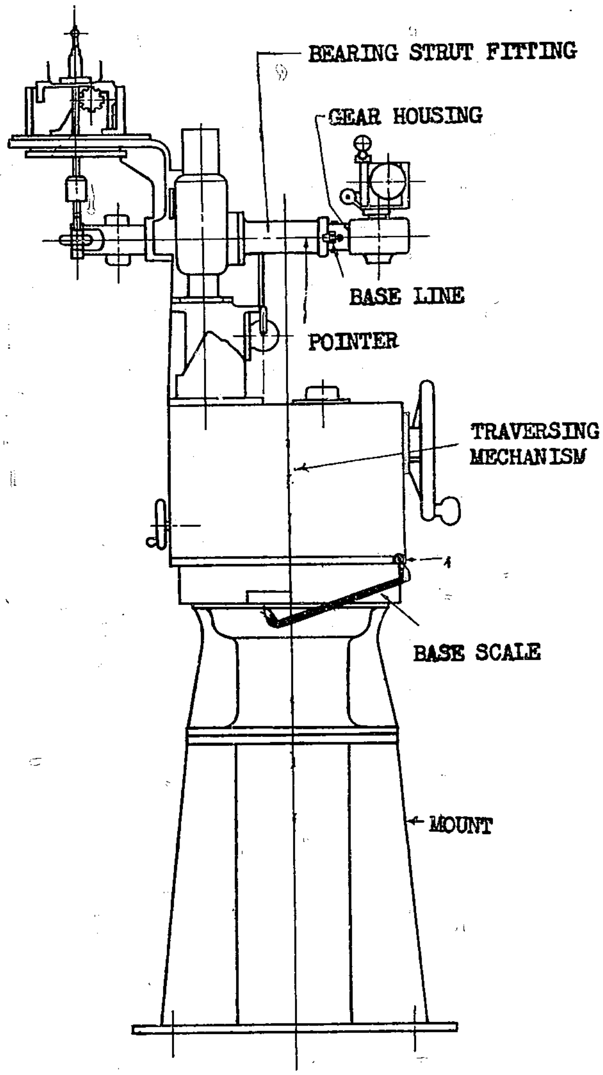


Figure 7(F)
TYPE 4 MOD 3 DIRECTOR. DRAWING, FRONT VIEW

ENCLOSURE (F), continued

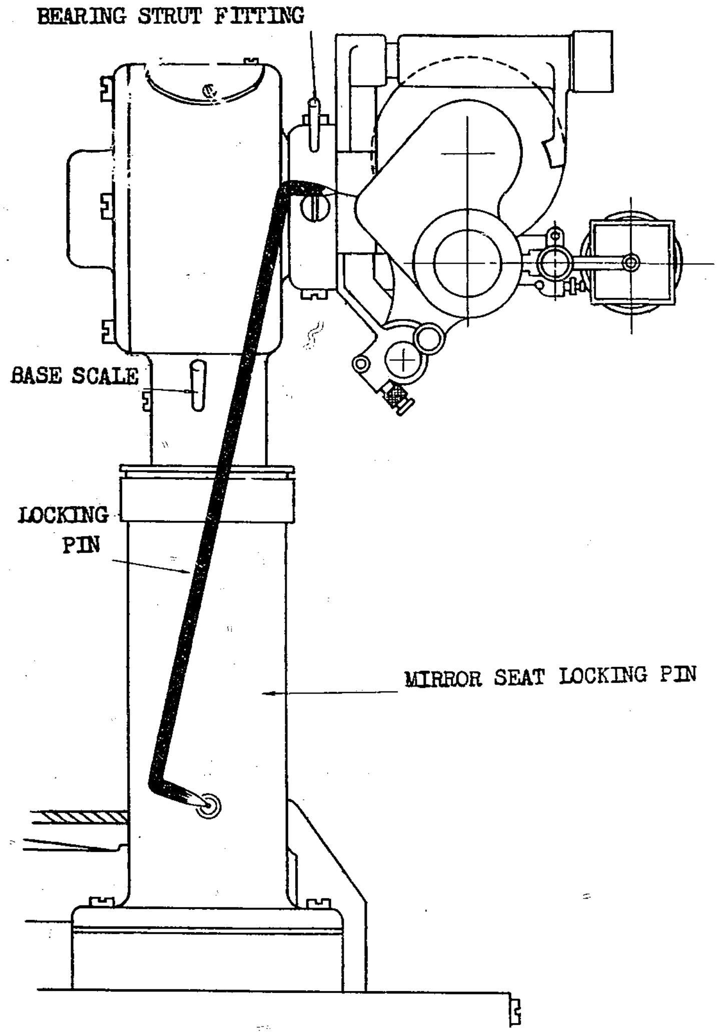


Figure 8(F)
TYPE 4 MOD 1 DIRECTOR, DETAIL, FRONT VIEW

ENCLOSURE (F), continued

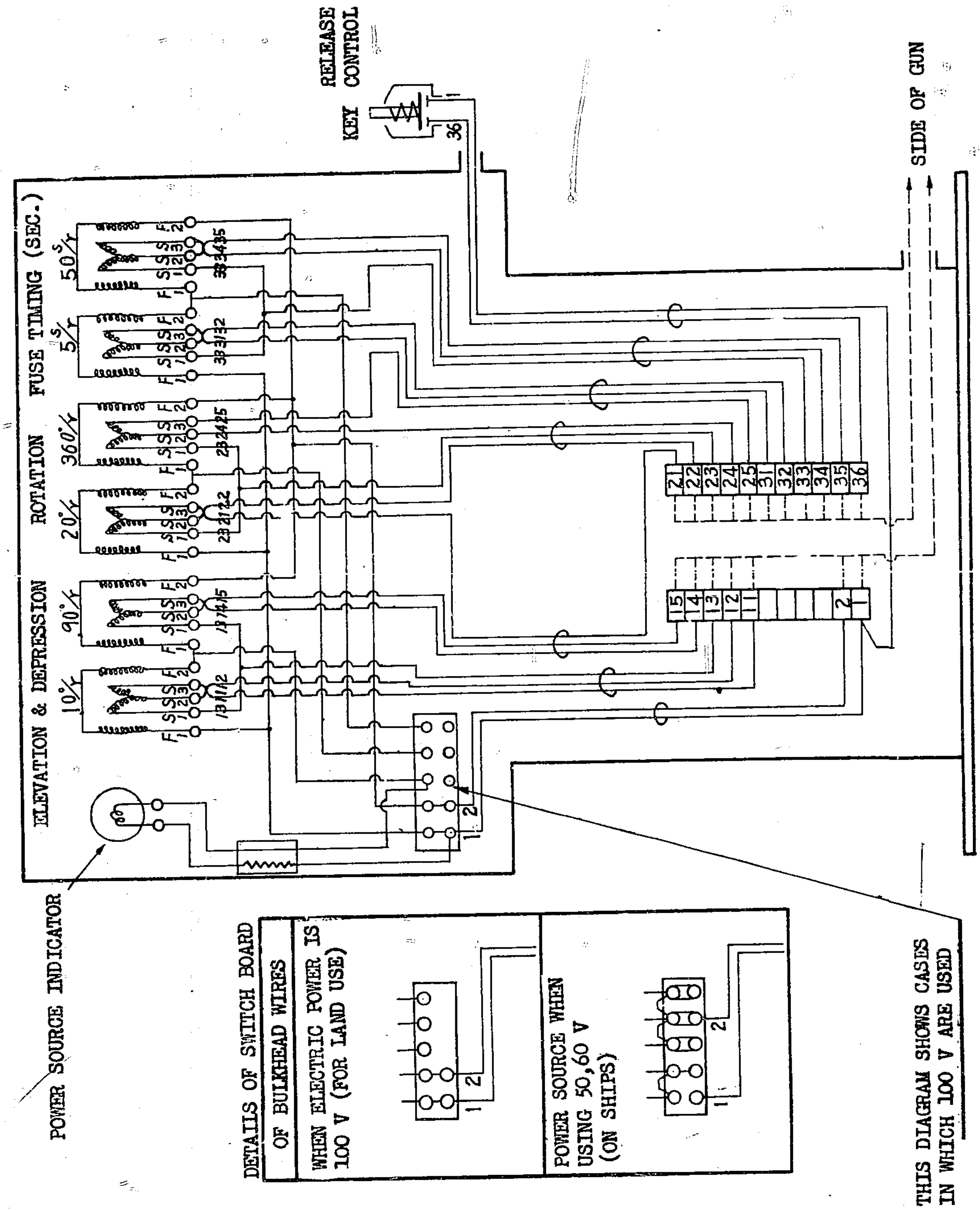


Figure 9(F)
TYPE 4 MOD 1 DIRECTOR, FIRING EQUIPMENT