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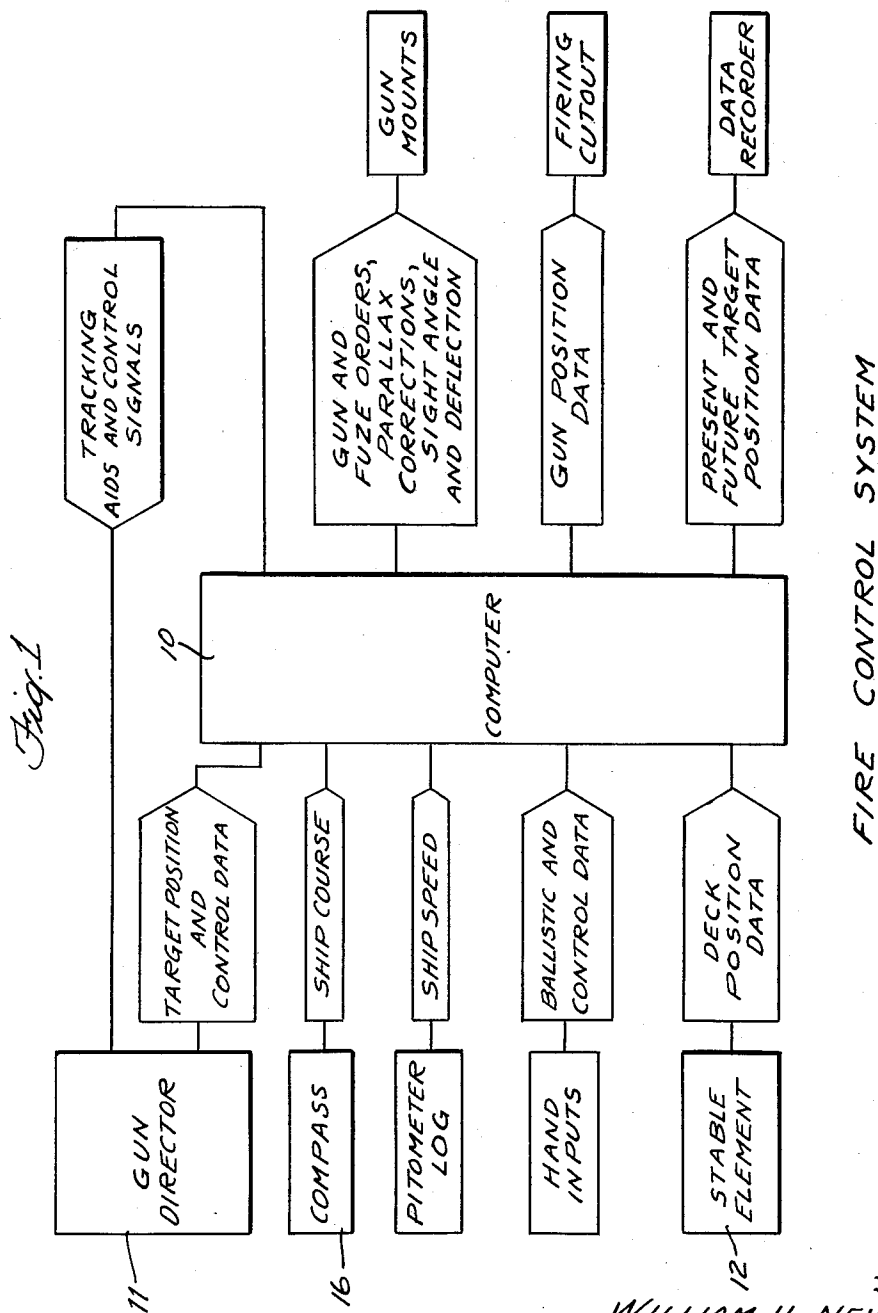
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2,967,663

DECK TILT CORRECTOR

Filed Feb. 18, 1953

4 Sheets-Sheet 1



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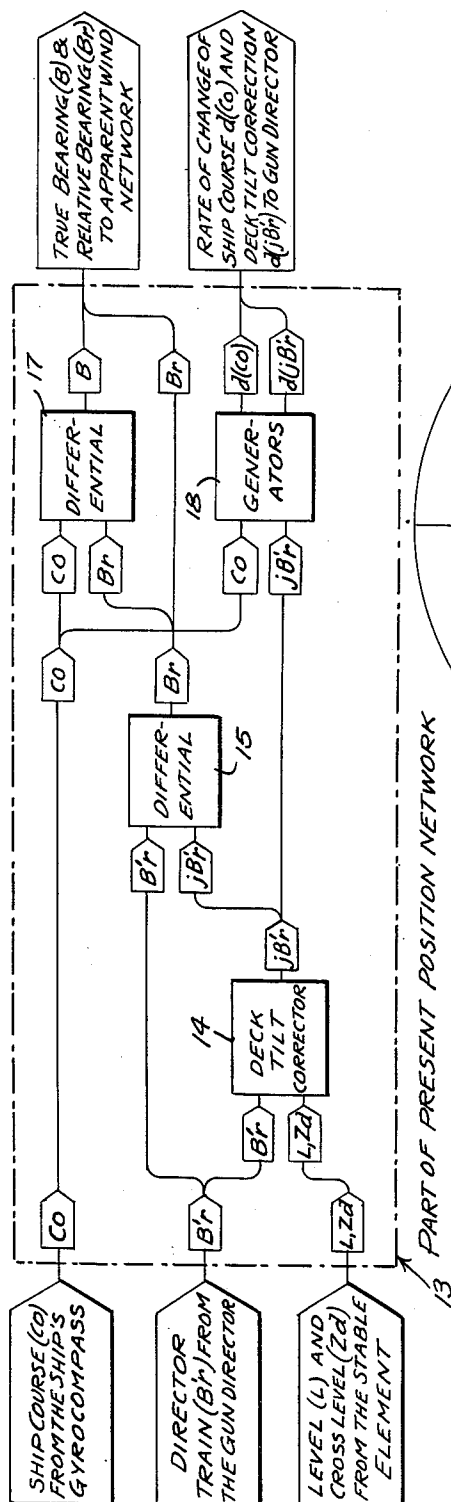


Fig. 2.

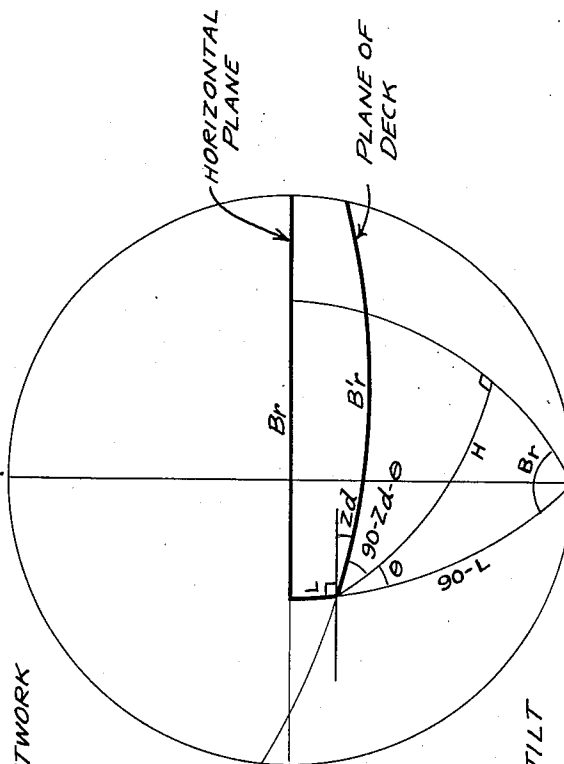


Fig. 3.

SPHERICAL DIAGRAM OF THE DECK TILT PROBLEM

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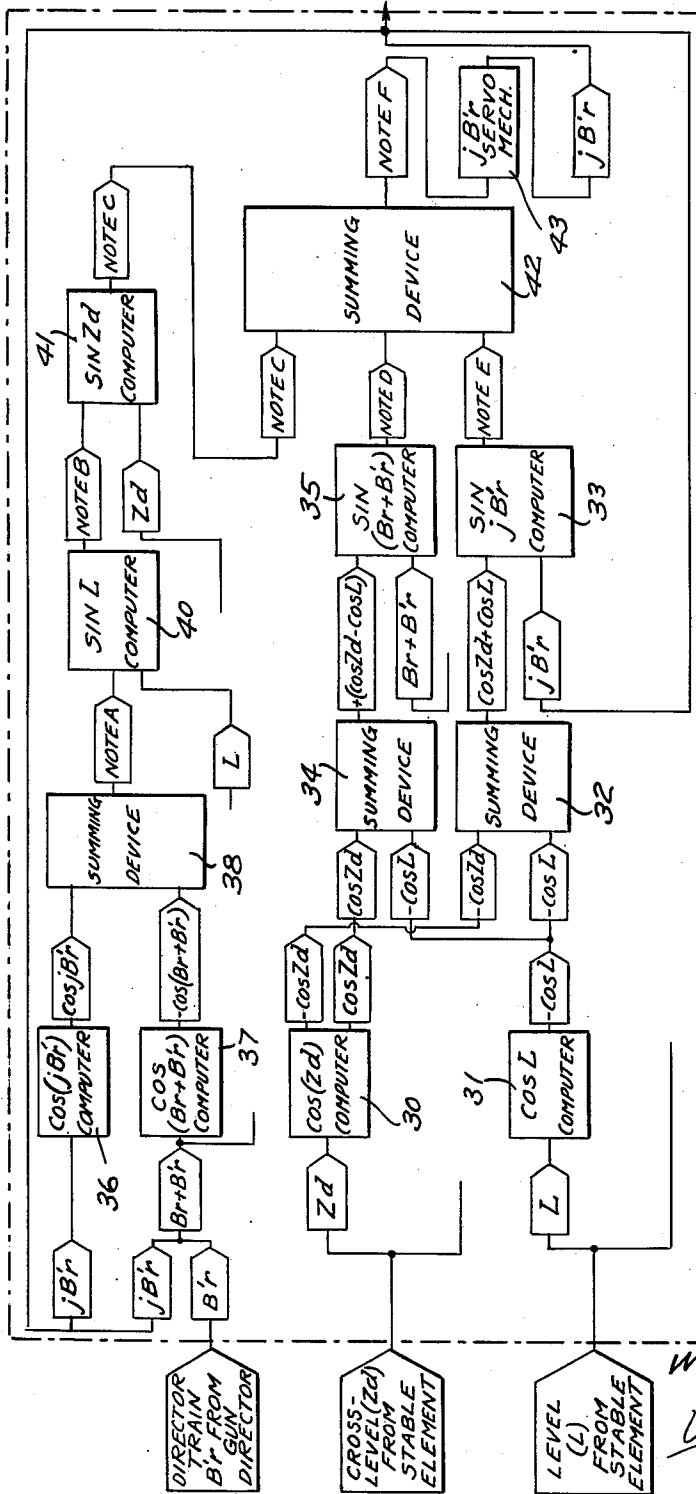
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NOTE A. $\cos jB'r - \cos (B'r + B'r)$ NOTE D. $(\cos Z'd - \cos L) \sin (B'r + B'r)$

NOTE B. $[\cos jB'r - \cos (B'r + B'r)] \sin L$ NOTE E. $-(\cos Z'd + \cos L) \sin jB'r$

NOTE C. $[\cos jB'r - \cos (B'r + B'r)] \sin L \sin Z'd$ NOTE F. $0 = [\cos Z'd - \cos L] \sin (B'r + B'r) +$

$[\cos jB'r - \cos (B'r + B'r)] \sin L \sin Z'd -$

$[\cos Z'd + \cos L] \sin jB'r$

DECK TILT CORRECTOR
BLOCK DIAGRAM.

Fig. 4.

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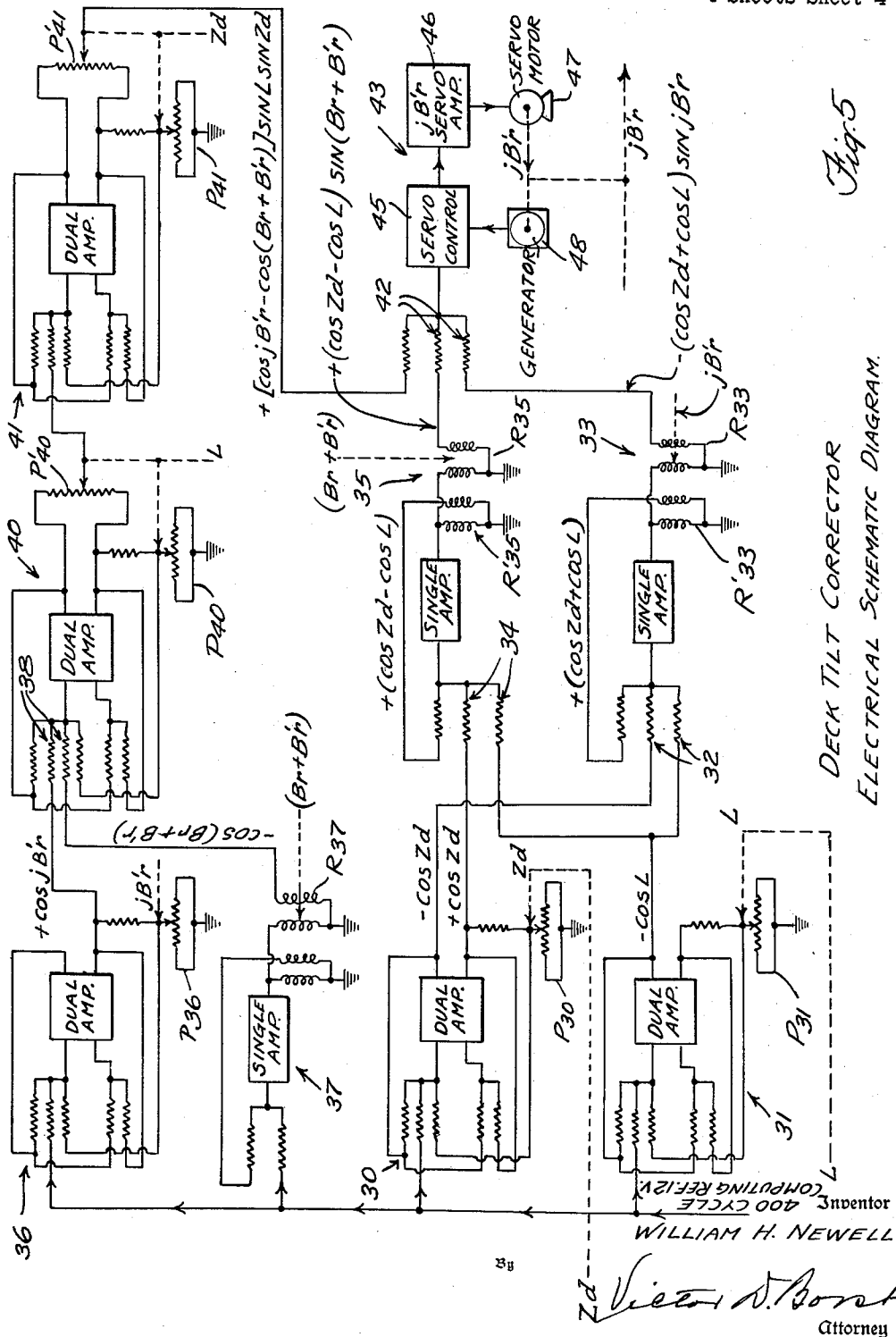
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DECK TILT CORRECTOR

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2,967,663

DECK TILT CORRECTOR

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1 Claim. (Cl. 235—61.5)

The invention relates to a method and apparatus for determining the tilt correction of an angularly movable control supporting platform or deck such as that of a ship, and although the invention has a wide range of utility, it is particularly useful in connection with the control of ordnance for anti-aircraft and surface firing.

The invention has utility, for example, in connection with a fire control system, by which guns or like ordnance are controlled from a director which measures the present position of the target in train and elevation, and by which from this data and other data, the predicted position of the target in train and elevation at the end of the time of flight of the projectiles is computed. On a ship, director train (i.e. the angle between the vertical plane through the ship's centerline and the vertical plane through the line of observation or sight) is measured clockwise from the bow in the deck plane. Since the ship will roll and pitch, angles measured in the deck plane usually vary in phase with the ship's movement and hence must be corrected to determine deflection rates or other necessary fire control quantities.

The mechanization of deck tilt correctional equations derived by empirical means introduces errors affecting the accuracy of determination of deck tilt correction.

One object of the present invention is to provide a new and improved method and instrument by which the values of deck tilt correction (i.e. correction due to inclination from horizontal of a movable deck or platform supporting at least part of a control, computing or predicting system, such as the director of a fire control system) are accurately, quickly and continuously computed, thus eliminating the effect of angular movement of the deck and causing thereby the system to operate as if said part were mounted upon a stable platform.

From the director, there is obtained the director train (described above) and from a stable element, there is obtained the level angle and the cross-level angle. The level angle is the angle between the deck plane and the horizontal plane, measured in the vertical plane through the line of sight, this angle being considered positive when the portion of the deck towards the target is down, and cross-level angle is the angle between the vertical plane through the line of sight and the plane perpendicular to the deck plane through the intersection of the deck plane and the vertical plane through the line of sight.

As a feature of the present invention, from the level angle, cross-level angle and director train, a true solution formula is derived for the deck tilt correction, which is solved continuously for the value of deck tilt correction by a servo or null seeking system, which so drives the deck tilt correction line that a balance is obtained between the quantities on opposite sides of the equality sign of the formula.

Various other objects, features and advantages of the invention are apparent from the following particular description and from inspection of the accompanying drawings, in which:

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Fig. 1 is a simplified block diagram showing the functional connections between the general computer assembly, of which the deck tilt corrector embodying the present invention may be made a part, and the other components of a gun fire control system;

Fig. 2 is a simplified block diagram showing the parts of a present position network directly related to the deck tilt corrector where said corrector is employed as part of a gun fire control system;

Fig. 3 is a spherical diagram of the deck tilt problem solved by the present invention;

Fig. 4 is a simplified block diagram of the deck tilt corrector embodying the present invention; and

Fig. 5 is a simplified basic circuit diagram of a specific example of a deck tilt corrector embodying the present invention.

GLOSSARY

A tabulation of symbols and terms used in the drawings and in the description in connection with a ship and a gun fire control system thereon is submitted herein.

(B) true target bearing. The angle between true north and the vertical plane through the line of sight, measured in a horizontal plane clockwise from true north

$$B = Co + Br$$

(Br) relative target bearing. The angle between the vertical plane through the ship's centerline and the vertical plane through the line of sight, measured in the horizontal plane clockwise from the bow.

(B'r) director train. The angle between the vertical plane through the ship's centerline and the vertical plane through the line of sight, measured in the deck plane clockwise from the bow.

(jB'r) deck tilt correction. Inclination of director roller path from horizontal. This correction added to director train (B'r) results in relative target bearing (Br) as follows

$$jB'r + B'r = Br$$

(Co) ship course. The compass heading of the ship.

(E) position angle. The angle between the line of sight and the horizontal plane, measured in a vertical plane

$$E = Eb - L$$

(Eb) director elevation. The angle between the line of sight and the deck plane, measured in the vertical plane through the line of sight, this angle being considered positive when the line of sight is elevated.

(L) level angle. The angle between the deck plane and the horizontal plane, measured in the vertical plane through the line of sight, this angle being considered positive when the portion of the deck toward the target is down.

(R) present range. The distance in yards from the gun director to the target.

(Zd) Cross-level angle. The angle between the vertical plane through the line of sight and the plane perpendicular to the deck plane through the intersection of the deck plane and the vertical plane through the line of sight.

FIRE CONTROL SYSTEM

A suitable fire control system in which the deck tilt corrector of the present invention may be employed includes a computer assembly capable of solving gun fire control problems both anti-aircraft and surface. Fig. 1 illustrates in a simplified manner, the connections between such a computer assembly designated by numeral 10 and the other components of the system including a gun director 11 and a stable element 12. The computer assembly 10 is of so-called linear rates type and includes

a present position, rates and acceleration portion for converting target data to a stable reference frame and for computing the rates of ship, wind, and target motion and target acceleration. This portion of the computer assembly is employed during the acquisition, tracking and firing phases of each engagement.

The present position network converts the polar coordinates ($B'r$, Eb and R) of relative target position as supplied by the gun director 11 into a stable system of polar coordinates (B , E and R) whose values do not change with the rolling, pitching and changes in course of own ship. The level angle (L) and cross-level angle (Zd) supplied by the stable element 12 are used to refer the director outputs to a horizontal plane, while own ship course from the fire control gyro compass 16, is used to establish a north-south reference.

Fig. 2 shows a diagram of part of the present position network 13 and especially that part around the deck tilt corrector 14, which will be described hereinafter. In this present position network, the director train ($B'r$) measured in the tiltable deck plane and derived from the gun director 11 (Fig. 1) and the level angle (L) and the cross-level angle (Zd) derived from the stable element 12 (Fig. 1), are put into the deck tilt corrector (Fig. 2) to obtain the deck tilt correction ($jB'r$). This deck tilt correction ($jB'r$) and the director train ($B'r$) are added in a component such as a differential 15 to obtain the relative target bearing (Br) according to the equation

$$Br = B'r + jB'r$$

Ship course (Co) from the fire control gyro compass 16 (Fig. 1), is combined with relative target bearing (Br) in an adding component such as the differential 17 to form the true target bearing (B) as follows:

$$B = Co + Br$$

This true target bearing (B) is sent to the linear rates network (not shown) and especially to the apparent wind network, which forms part of the computer assembly 10 (Fig. 1) and which performs two functions; it supplies the range and deflection components of apparent wind to the ballistic network (not shown) and it supplies the components of own ship velocity to the linear rates network (not shown). The ballistic network computes all the corrections that the curved nature of the trajectory of the projectile requires, and the linear rates network takes inputs from the present position, apparent wind and ballistic networks, and from these inputs computes the deflection, horizontal range and height rates and accelerations.

The ship course (Co) also drives one of the generators 18 (Fig. 2) whose output $d(Co)$ is used at the gun director 11 (Fig. 1) as an aid in tracking.

Aside from the present position problem, the correction ($jB'r$) from the deck tilt corrector 14 (Fig. 2) also drives another generator 18, whose output is the rate of change of ($jB'r$) or $d(jB'r)$. This quantity is sent to the gun director 11 (Fig. 1) to aid in the tracking problem.

Derivation of true solution formula for deck tilt correction $jB'r$

In accordance with the present invention, a true solution for the deck tilt problem is employed, thereby eliminating errors, such as those that would be inherent if empirical solution were employed. As a result of the procedure of the present invention, a true solution formula is obtained containing as terms the deck tilt correction ($jB'r$), the level angle (L), the cross-level angle (Zd), the relative target bearing (Br) and the director train ($B'r$). This formula is solved for the deck tilt correction ($jB'r$) by a servo or null seeking system, which so drives the ($jB'r$) line that a balance is obtained between the quantities on opposite sides of the equation.

The deck tilt problem is indicated in the spherical diagram shown in Fig. 3. This problem is solved in accord-

ance with a true solution, using as inputs the level angle (L) and the cross-level angle (Zd) obtained from the stable element 12 (Fig. 1) on the ship or craft carrying the fire control system, and the director train ($B'r$) in deck plane obtained from the gun director 11, to derive the relative target bearing or director train (Br) in horizontal plane.

Applying the rules of spherical trigonometry to the triangle formed by (H), (θ) and ($90-L$) (Fig. 3), the following expressions may be written

$$\begin{aligned} (1) \quad & \sin(H) = \sin(Br) \sin(90-L) \\ & \sin(H) = \sin(Br) \cos(L) \\ (2) \quad & \cos(Br) = \sin(\theta) \cos(H) \\ (3) \quad & \cot(Br) \cot(\theta) = \cos(90-L) \\ & \cot(\theta) = \sin(L) \tan(Br) \end{aligned}$$

Similarly the following expression may be written concerning the triangle formed by ($B'r$), ($90-Zd-\theta$) and (H)

$$\begin{aligned} \tan(B'r) \cos(90-Zd-\theta) &= \tan(H) \\ \sin(Zd+\theta) &= \tan(H) \cot(B'r) \end{aligned}$$

$$\sin(Zd) \cos(\theta) + \cos(Zd) \sin(\theta) = \cot(B'r) \frac{\sin(H)}{\cos(H)}$$

Dividing both sides by $\sin(\theta)$

$$(4) \quad \sin(Zd) \cot(\theta) + \cos(Zd) = \frac{\cot(B'r) \sin(H)}{\sin(\theta) \cos(H)}$$

substituting the following in Expression 4

$$\begin{aligned} (a) \quad & \sin(Br) \cos(L) \text{ for } \sin(H) \text{ from (1)} \\ (b) \quad & \cos(Br) \text{ for } \sin(\theta) \cos(H) \text{ from (2)} \\ (c) \quad & \sin(L) \tan(Br) \text{ for } \cot(\theta) \text{ from (3)} \end{aligned}$$

there is obtained

$$\sin(Zd) \sin(L) \tan(Br) + \cos(Zd) = \frac{\cot(B'r) \sin(Br) \cos(L)}{\cos(Br)}$$

$$\sin(Zd) \sin(L) \tan(Br) + \cos(Zd) = \frac{\cot(B'r) \cos(L)}{\cot(Br)}$$

Multiplying by $\cot(Br)$, there is obtained

$$\sin(Zd) \sin(L) + \cos(Zd) \cot(Br) = \cot(B'r) \cos(L)$$

solving for (Br), results in

$$(5) \quad \cos(Zd) \cot(Br) = \cot(B'r) \cos(L) - \sin(Zd) \sin(L)$$

$$\cot(Br) = \frac{\cot(B'r) \cos(L) - \sin(Zd) \sin(L)}{\cos(Zd)}$$

$$(6) \quad Br = \cot^{-1} \left[\frac{\cot(B'r) \cos(L) - \sin(Zd) \sin(L)}{\cos(Zd)} \right]$$

Expression 6, the explicit solution for (Br) includes a cotangent function of quantity ($B'r$). Since the cotangent function varies through infinity for unlimited angle motion, Expression 6 is not satisfactory for mechanization in a computer. By manipulating Expression 5 to contain only sine or cosine functions, a mathematical solution for this problem will result which will be possible of mechanization. For that purpose, there is substituted into

Expression 5

$$(a_1) \quad \frac{\cos(Br)}{\sin(Br)} \text{ for } \cot(Br)$$

$$(b_1) \quad \frac{\cos(B'r)}{\sin(B'r)} \text{ for } \cot(B'r)$$

resulting in

$$\frac{\cos(Zd) \cos(Br)}{\sin(Br)} = \frac{\cos(B'r) \cos(L)}{\sin(B'r)} - \sin(Zd) \sin(L)$$

5

Clearing of fractions results in

$$(7) \quad \cos(Zd) \cos(Br) \sin(B'r) = \cos(L) \cos(B'r) \sin(Br) - \sin(L) \sin(Zd) \sin(Br) \sin(B'r)$$

But:

$$(a_2) \quad \cos(Br) \sin(B'r) = \frac{\sin(B'r - Br) + \sin(Br + B'r)}{2}$$

$$(b_2) \quad \sin(Br) \cos(B'r) = \frac{\sin(Br - B'r) + \sin(Br + B'r)}{2}$$

$$(c_2) \quad \sin(Br) \sin(B'r) = \frac{\cos(Br - B'r) - \cos(Br + B'r)}{2}$$

Substituting a_2 , b_2 and c_2 in Expression 7

$$(8) \quad \frac{\cos(Zd)}{2} [\sin(B'r - Br) + \sin(B'r + Br)] \\ = \frac{\cos(L)}{2} [\sin(Br - B'r) + \sin(Br + B'r)] \\ - \frac{\sin(L) \sin(Zd)}{2} [\cos(Br - B'r) - \cos(Br + B'r)]$$

But

$$\sin(B'r - Br) = -\sin(Br - B'r) \\ \cos(Zd) [-\sin(Br - B'r) + \sin(Br - B'r)] \\ = \cos(L) [\sin(Br - B'r) + \sin(Br + B'r)] \\ - \sin(L) \sin(Zd) [\cos(Br - B'r) - \cos(Br + B'r)]$$

Multiplying out by coefficients

$$-\cos(Zd) \sin(Br - B'r) + \cos(Zd) \sin(Br + B'r) \\ = \cos(L) \sin(Br - B'r) \\ + \cos(L) \sin(Br + B'r) - \sin(L) \sin(Zd) [\cos(Br - B'r) - \cos(Br + B'r)]$$

Transposing like terms and multiplying by minus one

$$\cos(Zd) \sin(Br - B'r) + \cos(L) \sin(Br - B'r) \\ = \cos(Zd) \sin(Br + B'r) \\ - \cos(L) \sin(Br + B'r) + \sin(L) \sin(Zd) [\cos(Br - B'r) - \cos(Br + B'r)]$$

Combining coefficients of common terms

$$[\cos(Zd) + \cos(L)] \sin(Br - B'r) \\ = [\cos(Zd) - \cos(L)] \sin(Br + B'r) \\ + \sin(L) \sin(Zd) [\cos(Br - B'r) - \cos(Br + B'r)]$$

$$(9) \quad \text{Let } (jB'r) = (Br) - (B'r)$$

or

$$(Br) = (B'r) + (jB'r)$$

$$(10) \quad [\cos(Zd) + \cos(L)] \sin(jB'r) \\ = [\cos(Zd) - \cos(L)] \sin(Br + B'r) \\ + \sin(L) \sin(Zd) [\cos(jB'r) - \cos(Br + B'r)]$$

Expression 10 indicates the solution that is mechanized in this computer. Note that the solution contains quantity $(jB'r)$ (deck tilt correction) which when added to $(B'r)$ produces (Br) director train in the horizontal plane. Inspection of Expression 10 containing functions of $(jB'r)$ indicates that the solution mechanized utilizes a regenerative network.

The solution equation for the deck tilt problem as shown in Equation 10 must be rearranged and equated to zero, such that the polarity of each of the three computation channels may be determined

$$0 = [\cos(Zd) - \cos(L)] \sin(Br + B'r) \\ + \sin(L) \sin(Zd) [\cos(jB'r) - \cos(Br + B'r)] \\ - [\cos(Zd) + \cos(L)] \sin(jB'r)$$

Therefore, the computation to be mechanized involves the following three channels

- (1) $-[\cos(Zd) + \cos(L)] \sin(jB'r)$
- (2) $+[\cos(Zd) - \cos(L)] \sin(Br + B'r)$
- (3) $+\sin(L) \sin(Zd) [\cos(jB'r) - \cos(Br + B'r)]$

6

The computer for solving the Equation 10 is essentially one in which quantities in the form of the proper functions of input and output quantities are added, subtracted and multiplied in each of three channels of computation. From Expression 10, the summation of these three channels should be zero. Consequently, the output of a three input electrical differential or adding network is used as a servo input to drive in accordance with the deck tilt correction quantity. When the servo nulls the output of this network, the equation of this solution has been satisfied.

The specific deck tilt corrector 14 employed for the mechanization of the Equation 10 is made up of a series of components, which may be of any suitable design, and which per se, form no part of the present invention. Fig. 4 shows this deck tilt corrector 14 diagrammatically in block form, and Fig. 5 shows as a specific example, an electrical schematic circuit diagram of the deck tilt corrector, the different component networks being shown schematically in their basic forms, the solid lines in this latter diagram indicating electrical connections, and the dotted lines indicating mechanical lines or movements arising, for example, from shafts and rotations thereof.

The specific example of a deck tilt corrector shown in Fig. 5, utilizes 400 cycle A.C. as a computing reference, with an input level of 12 volts, the representation of data by the 400-cycle voltage being such, that the root mean square value of each voltage is proportional to the quantity represented. For the purpose of discussion, this reference voltage is regarded as (+1). The different computed quantities are indicated in Figs. 4 and 5, without parametric coefficients. These coefficients are a function of the reference voltage (12 volts) and the characteristics of the constituent elements of the networks or loops involved and are constant for any one mechanism. For example, in a resolver network of the potentiometer type having dual channel amplifier, such as that disclosed in copending application Serial No. 33,186, filed June 15, 1948, and operating with an input reference voltage of 12 volts and with the mechanical input cross-level angle (Zd) , the outputs will be $-8 \cos Zd$ and $+8 \cos Zd$. The parametric coefficients -8 and $+8$ will however not be shown in Fig. 5 nor otherwise indicated.

CHANNEL 1

$$-[\cos(Zd) + \cos(L)] \sin(jB'r)$$

Referring to Figs. 4 and 5, the mechanical cross-level quantity (Zd) from the stable element of the ship, is brought as an input into a cosine computer 30, which may be of any well-known suitable type, but which is shown in Fig. 5 as an angle function computer or resolver of the limited angle potentiometer type disclosed in copending application Serial No. 33,186, filed June 15, 1948. The input voltage reference (+1) and the mechanical quantity (Zd) are brought into the potentiometer P30 of the computer 30 to obtain the outputs $+\cos(Zd)$ and $-\cos(Zd)$.

The mechanical level quantity (L) from the stable element of the ship is brought as an input into a suitable cosine computer 31, which may be of any suitable type, but which is shown in Fig. 5 of the limited angle potentiometer type disclosed in the aforesaid copending application.

The input voltage reference (+1) and the mechanical quantity (L) are brought into the potentiometer P31 of the computer 31 to obtain the output $-\cos(L)$.

The quantities $-\cos(Zd)$ and $-\cos(L)$ obtained from the resolvers 30 and 31 respectively as described, are added in a suitable summing device 32, indicated in Fig. 5 as an adding network, comprising two input resistances in parallel, a computing amplifier (not shown) at the common connection of these resistors, having a very large gain, so as to draw no significant current from this point and maintain this connection at a zero potential; a feedback resistor (not shown) and a load resistor (not

shown). The different resistance ratios are selected to convert the two input voltages to a common scale, i.e. to the same value per volt.

The output of the summing device 32, namely $\cos(Zd) + \cos(L)$ is brought as an input to a sine computer 33, which may be of any suitable type, but which is shown in Fig. 5 of the magnetic type disclosed in copending application Serial No. 157,892, filed April 25, 1950, now Patent No. 2,646,218. This electrical computer 33 comprises a computing resolver R33 and an error compensating resolver R'33, as described in the latter application. The quantity $(jB'r)$ is introduced into the computing resolver R33 through its rotor as previously described, and the angle function computer 33 is so connected, that its operator is $+\sin(jB'r)$. The output of the angle function computer 33 is

$$-[\cos(Zd) + \cos(L)] \sin(jB'r)$$

which was previously specified as channel 1.

CHANNEL 2

$$+[\cos(Zd) - \cos(L)] \sin(Br + B'r)$$

The quantities $+\cos(Zd)$ and $-\cos(L)$ obtained from the computers 30 and 31 respectively as described in connection with channel 1, are added in a suitable summing device 34, indicated in Fig. 5 as an adding network of the parallel resistance type similar to the adding network 32. The resulting output quantity

$$+[\cos(Zd) - \cos(L)]$$

is brought as an input to a suitable sine computer 35 having as mechanical inputs the quantities $(2B'r)$ and $(jB'r)$. This angle function computer 35 is indicated in Fig. 5 as being of the magnetic type, similar to the computer 33 and similarly comprises a computing resolver R35 and an error compensating resolver R'35.

The quantity $(2B'r)$ is the relative target bearing obtained from the gun director or other source, multiplied by two through suitable gearing. This quantity $(2B'r)$ drives the rotor of the computing resolver R35. The deck tilt correction $(jB'r)$ obtained from the output of the corrector 14 drives the stator of the computing resolver R35 in a direction, so that the angle being operated upon is $2B'r + jB'r$ which by the Expression 9 becomes $(Br + B'r)$. The computing resolver R35 provides a $(+\sin)$ operator, so that its output becomes

$$+[\cos(Zd) - \cos(L)] \sin(Br + B'r)$$

This expression conforms with channel 2.

CHANNEL 3

$$+\sin(L) \sin(Zd) [\cos(jB'r) - \cos(Br + B'r)]$$

The mechanical tilt correction $(jB'r)$ derived from the output of the deck tilt corrector is brought in as an input into a suitable cosine computer 36, indicated in Fig. 5 as a limited angle function computer of the potentiometer type, similar to the computer 30. The voltage reference $(+1)$ and the mechanical quantity $(jB'r)$ are brought into the potentiometer P36 of the computer 36 to obtain the output $+\cos(jB'r)$.

The mechanical quantity $(Br + B'r)$ obtained from the quantities $(2B'r)$ and $(jB'r)$ in the manner described in connection with the computer 35 is applied as an input to a suitable cosine computer 37, indicated in Fig. 5 as an angle function computer of the magnetic type, similar to the computer 33. The electrical reference $(+1)$ and the mechanical quantity $(Br + B'r)$ obtained as described are applied to the electrical computer 37 of Fig. 5, the components of this mechanical quantity being fed to the rotor and stator of the computing resolver part R37 of said computer. The computer 37 provides a $(-\cos)$ operator, so that its output becomes $-\cos(Br + B'r)$.

The quantities $+\cos(jB'r)$ and $-\cos(Br + B'r)$ derived from the computers 36 and 37 respectively as explained, are added in a suitable summing device 38, indicated in Fig. 5 of the parallel resistance network type,

similar to the adding network 32. The output of this summing device 38

$$\cos(jB'r) - \cos(Br + B'r)$$

5 becomes the electrical input of a suitable sine computer 40, shown specifically in Fig. 5 of the limited angle potentiometer type, disclosed in the aforesaid copending application Serial No. 33,186. This computer 40 has two potentiometers P40 and P'40 to serve as sine resolver. Into these potentiometers P40 and P'40 are fed the mechanical quantity (L) constituting the level angle obtained from the stable element of the ship, to produce the output

$$[\cos(jB'r) - \cos(Br + B'r)] \sin(L)$$

15 The latter product of the sine computer 40 becomes an input of another sine computer 41, which may, for example, be a limited angle resolver of the potentiometer type, similar to the resolver 40, as shown in Fig. 5, having potentiometers P41 and P'41 with mechanical inputs (Zd) obtained from the stable element of the ship. The output of this sine computer 41 will be

$$+[\cos(jB'r) - \cos(Br + B'r)] \sin(L) \sin(Zd)$$

constituting the channel 3 referred to.

Production of $(jB'r)$ from channels

The three computation channel outputs

$$\begin{aligned} & -[\cos(Zd) + \cos(L)] \sin(jB'r) && \text{(channel 1)} \\ & +[\cos(Zd) - \cos(L)] \sin(Br + B'r) && \text{(channel 2)} \\ & +\sin(L) \sin(Zd) [\cos(jB'r) - \cos(Br + B'r)] && \text{(channel 3)} \end{aligned}$$

are conducted to a suitable summing device 42, shown specifically in Fig. 5 of the parallel resistance type, similar to the summing device 32, except that three input resistances are provided instead of two. Theoretically, according to Equation 10, the summation of these computation channels should be zero. If the conditions of the Equation 10 are not satisfied, an error is produced at the output of the summing device 42, which in the case of an electrical system such as that of Fig. 5 is a voltage having the proper polarity to drive the servo motor of a servomechanism 43 of the well-known type, to produce a null in the error voltage. When this null is achieved, the value of $(jB'r)$ converted into a mechanical quantity (shaft rotation) becomes the deck tilt correction desired. This quantity $(jB'r)$ when added to the director train $(B'r)$ becomes the relative target bearing (Br) .

A servomechanism, such as the servomechanism 43 is an automatic drive which positions a mechanical load in accurate correspondence with an input, without placing an appreciable load upon this input. The input can be either mechanical or electrical (in Fig. 5, the input is electrical) but the output is always mechanical.

55 The basic components of the specific servomechanism shown in Fig. 5 comprises a servo control 45, a servo amplifier 46, a servo motor 47 and an induction generator 48 connected in a double loop circuit with a control network which in the present case is the summing loop 42. Essentially, the control network 42 computes a voltage proportional to the error between a function of the input and a function of the output. This error voltage is converted to a frequency of 60 cycles by the servo control 45, amplified by the servo amplifier 46 and finally supplied to the servo motor 47 for its control. The servo motor furnishes the mechanical output and drives the induction generator 48. From this generator 48, a voltage proportional to the output velocity is supplied to the servo control 42. After being modified by computing elements in the servo control 42, the modified voltage is combined with the error voltage to improve the operation of the servomechanism.

Equation 10 mechanized by the deck tilt correction 14 of the present invention can be expressed in different form, as for example, by the substitution of trigonometric

equivalents, without altering the basic substance of the equation. It should be understood therefore, that the reference to the specific equation in the following claim covers such equivalent substitutions.

While the invention has been described with particular reference to a specific embodiment, it is to be understood that it is not to be limited thereto, but is to be construed broadly and restricted solely by the scope of the appended claim as interpreted in accordance with the above explanation.

What is claimed is:

A deck tilt corrector adaptable for a gun fire control system for obtaining the quantity $(jB'r)$ representing deck tilt correction, comprising means responsive to the quantity $(jB'r)$ as input obtained from the output of the corrector for obtaining $\cos(jB'r)$, means responsive to the input (Zd) representing cross-level angle for obtaining $-\cos(Zd)$ and $+\cos(Zd)$, means responsive to the input (L) representing level angle for obtaining $-\cos(L)$, means responsive to $(jB'r)$ and $(B'r)$ representing director train as inputs for obtaining $(Br+B'r)$, in which (Br) represents relative target bearing, means responsive to $(Br+B'r)$ as input for obtaining $-\cos(Br+B'r)$, means responsive to $+\cos(Zd)$ and $-\cos(L)$ as inputs for adding $+\cos(Zd)$ and $-\cos(L)$ to obtain $\cos(Zd)-\cos(L)$, means responsive to $\cos(Zd)-\cos(L)$

and $(Br+B'r)$ as inputs for obtaining the first computation quantity

$$[\cos(Zd)-\cos(L)] \sin(Br+B'r)$$

- 5 means responsive to $\cos(jB'r)$ and $-\cos(Br+B'r)$ as inputs for adding $\cos(jB'r)$ and $-\cos(Br+B'r)$ to obtain $\cos(jB'r)-\cos(Br+B'r)$, means responsive to $\cos(jB'r)-\cos(Br+B'r)$, and (L) and (Zd) as inputs for obtaining the second computation quantity

$$10 \quad \sin(L) \sin(Zd) [\cos(jB'r)-\cos(Br+B'r)]$$

- means responsive to $-\cos(Zd)$ and $-\cos(L)$ as inputs for adding $-\cos(Zd)$ and $-\cos(L)$ for obtaining 15 $-\cos(Zd)+\cos(L)$, means responsive to $-\cos(Zd)+\cos(L)$ and $(jB'r)$ as inputs, for obtaining the third computation quantity

$$-\cos(Zd)+\cos(L) \sin(jB'r)$$

- 20 and a null seeking device for equating the sum of said three computation quantities to zero and for obtaining thereby the quantity $(jB'r)$.

References Cited in the file of this patent

- 25 UNITED STATES PATENTS
2,658,675 Darlington Nov. 10, 1953