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Dec. 2, 1947. K. CLARK 2,431,919

COMPUTER FOR AERONAUTICAL BOMB SIGHTS

Filed Jan. 21, 1944 9 Sheets-Sheet 1

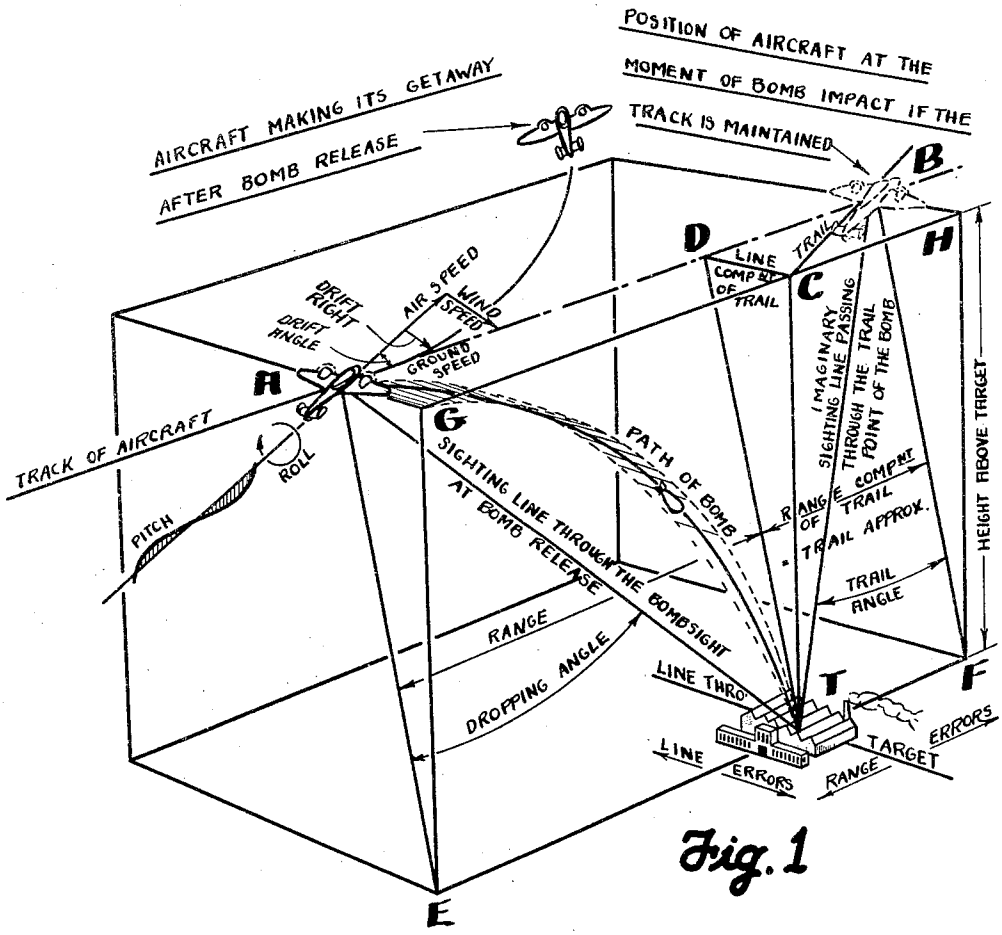


Fig. 1

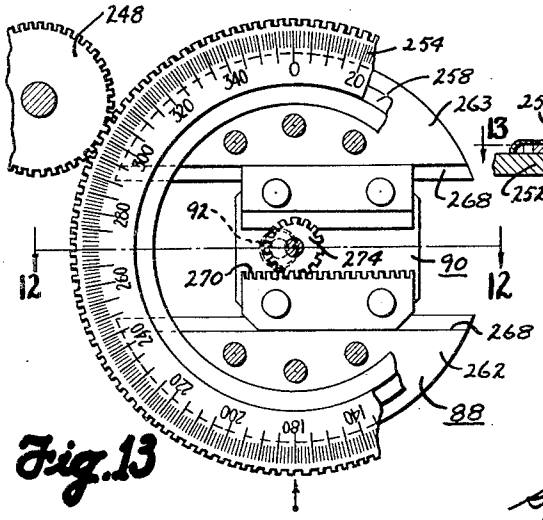


Fig. 13

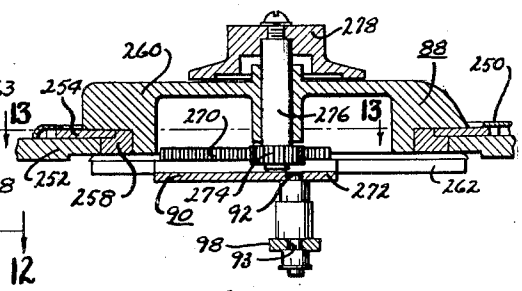


Fig. 12

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

Filed Jan. 21, 1944 9 Sheets-Sheet 2

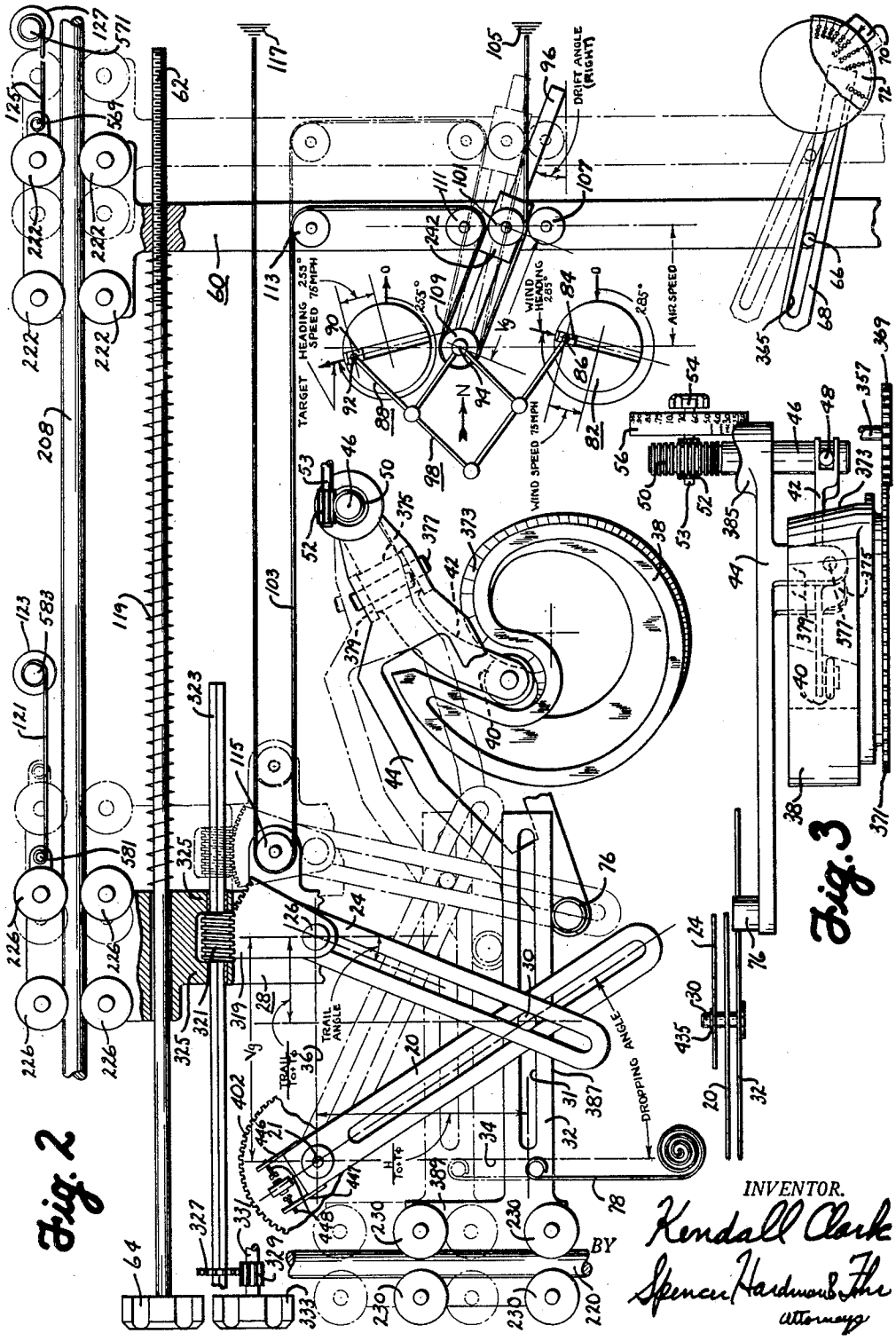


Fig. 2

Fig. 3

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

Filed Jan. 21, 1944 9 Sheets-Sheet 3

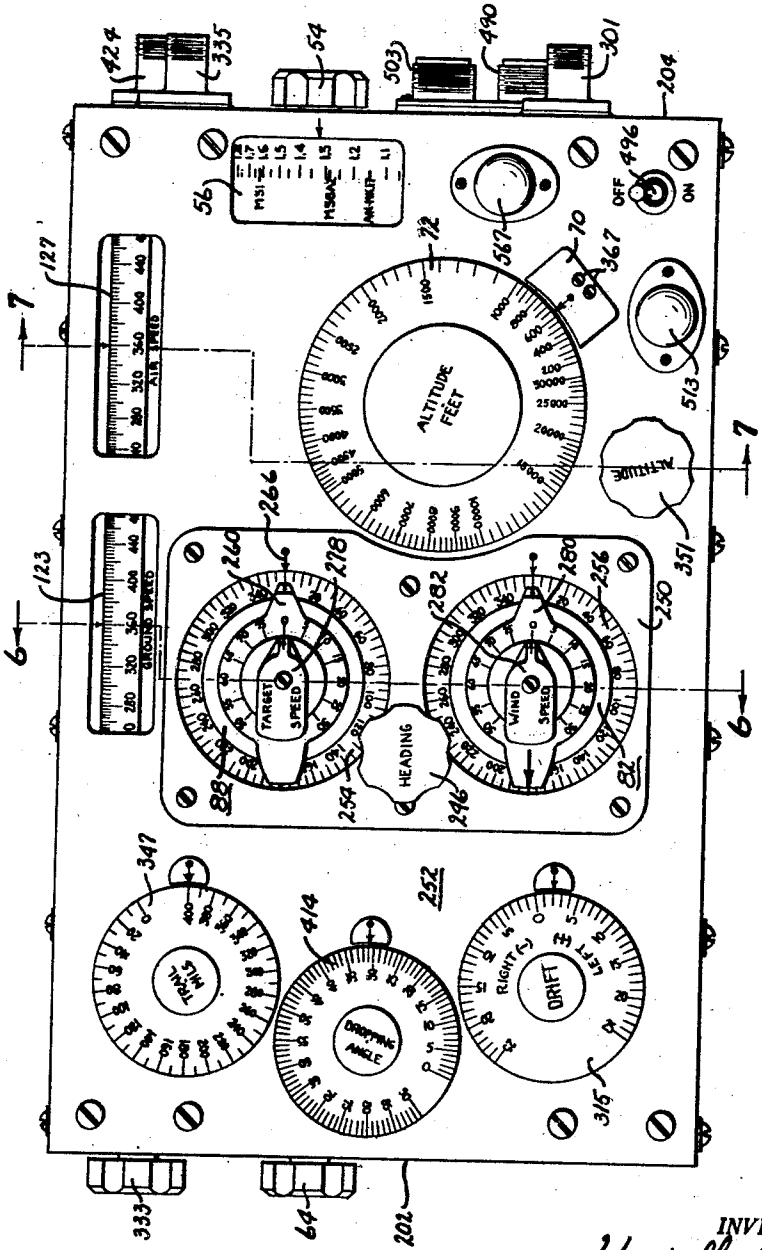


Fig. 4

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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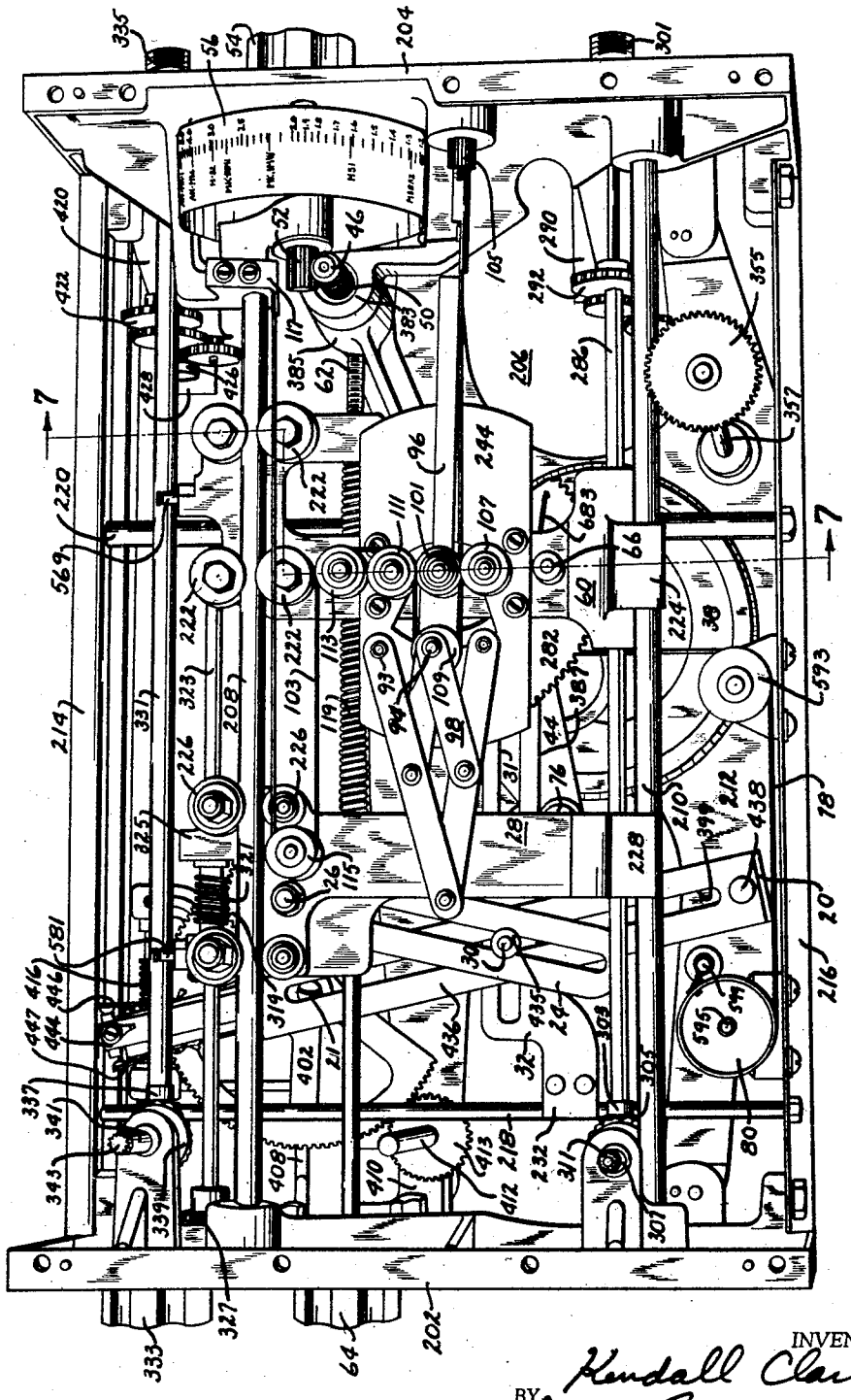


Fig. 5

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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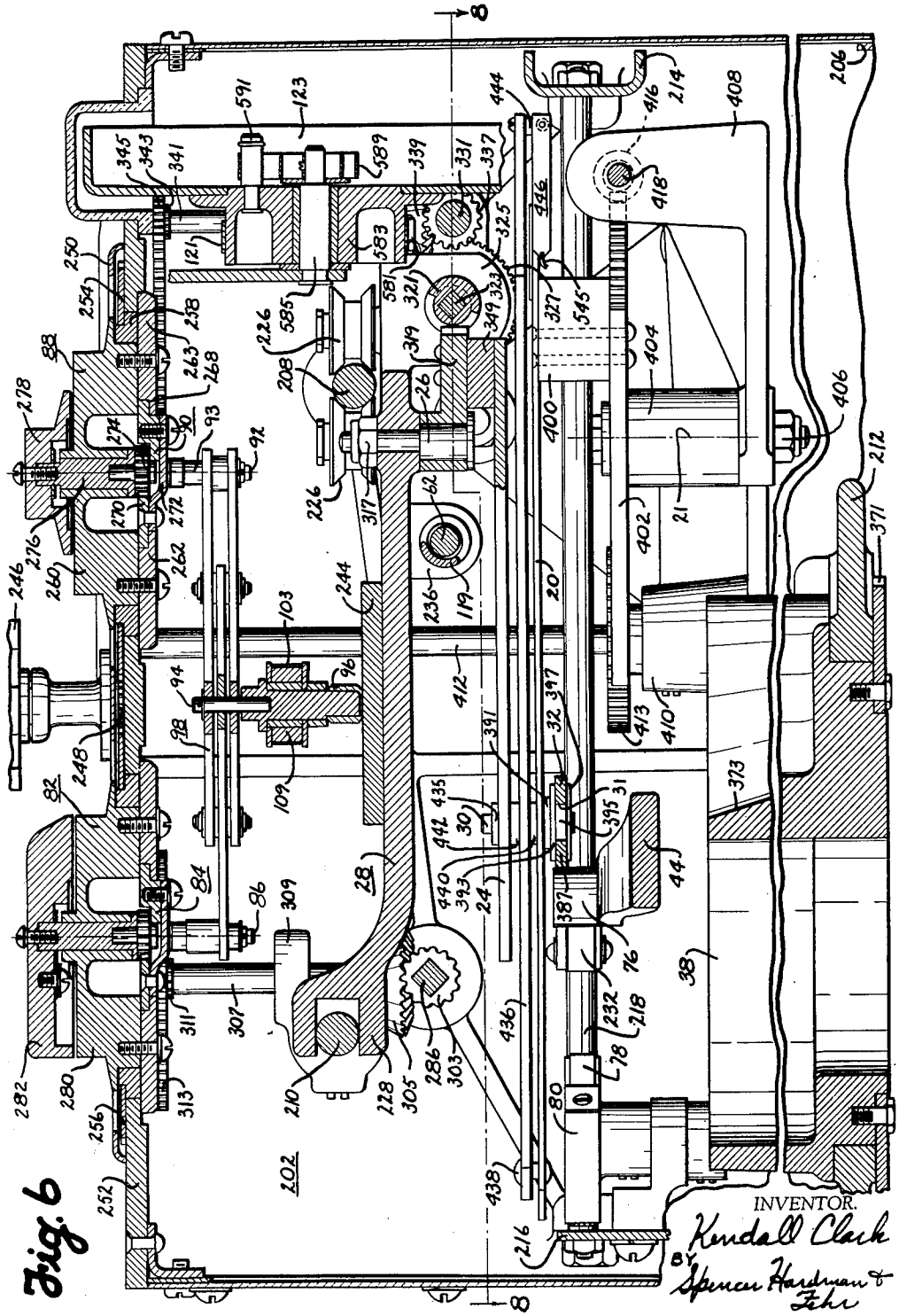


Fig. 6

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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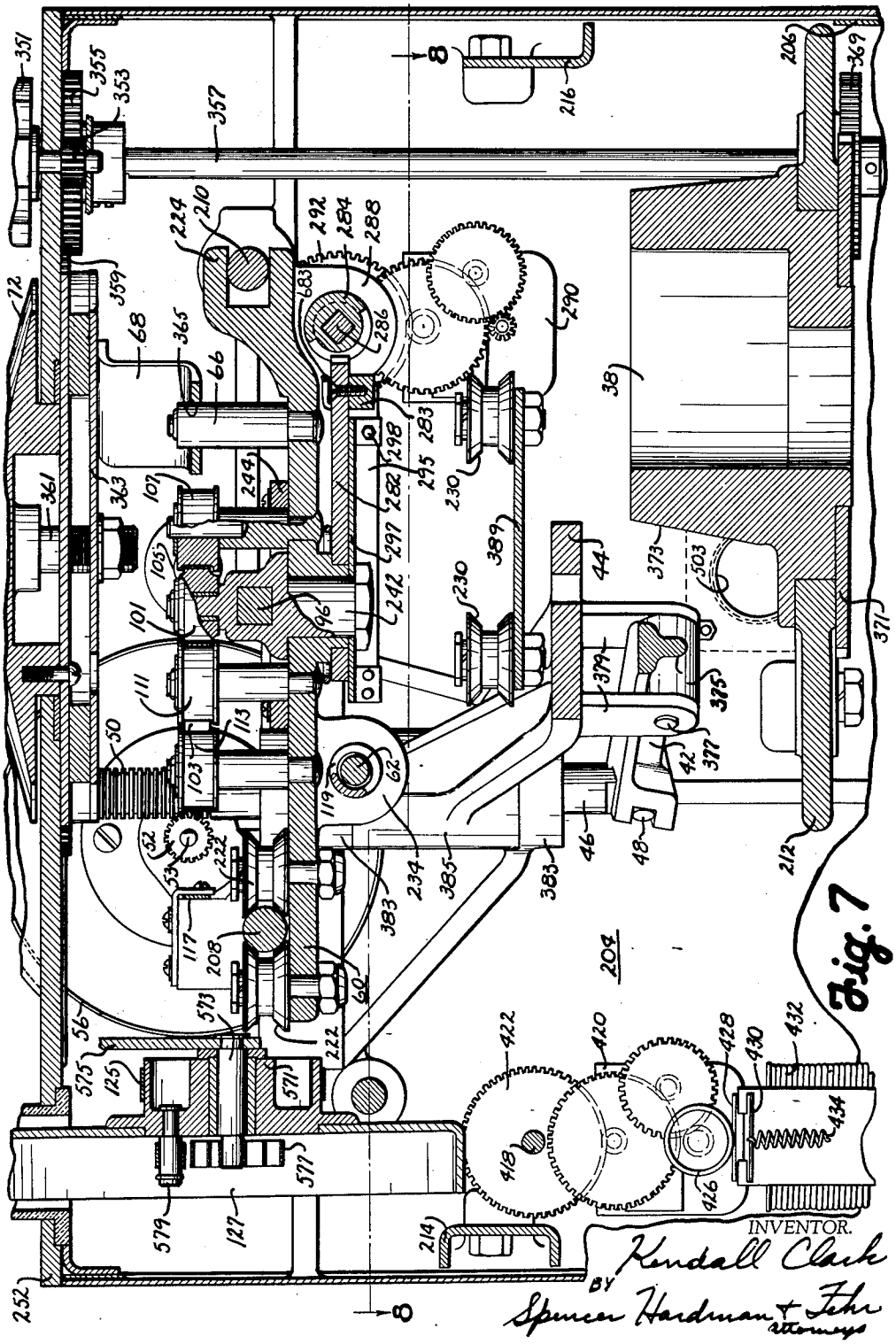


Fig. 7

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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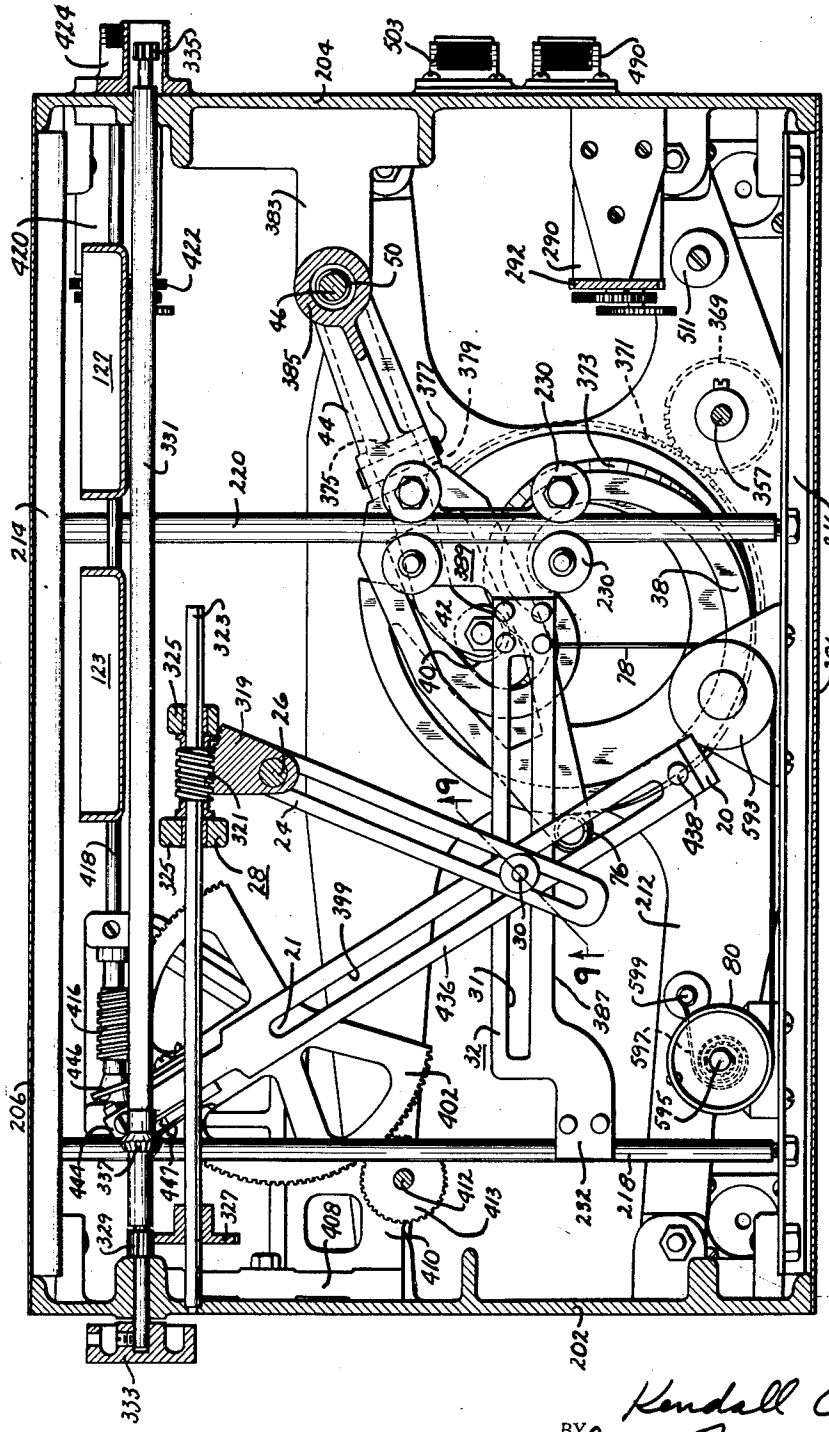


Fig. 8

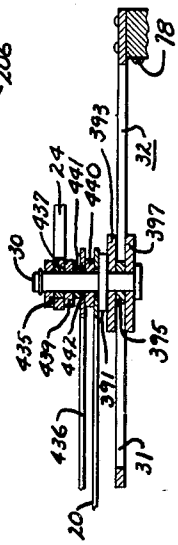


Fig. 9

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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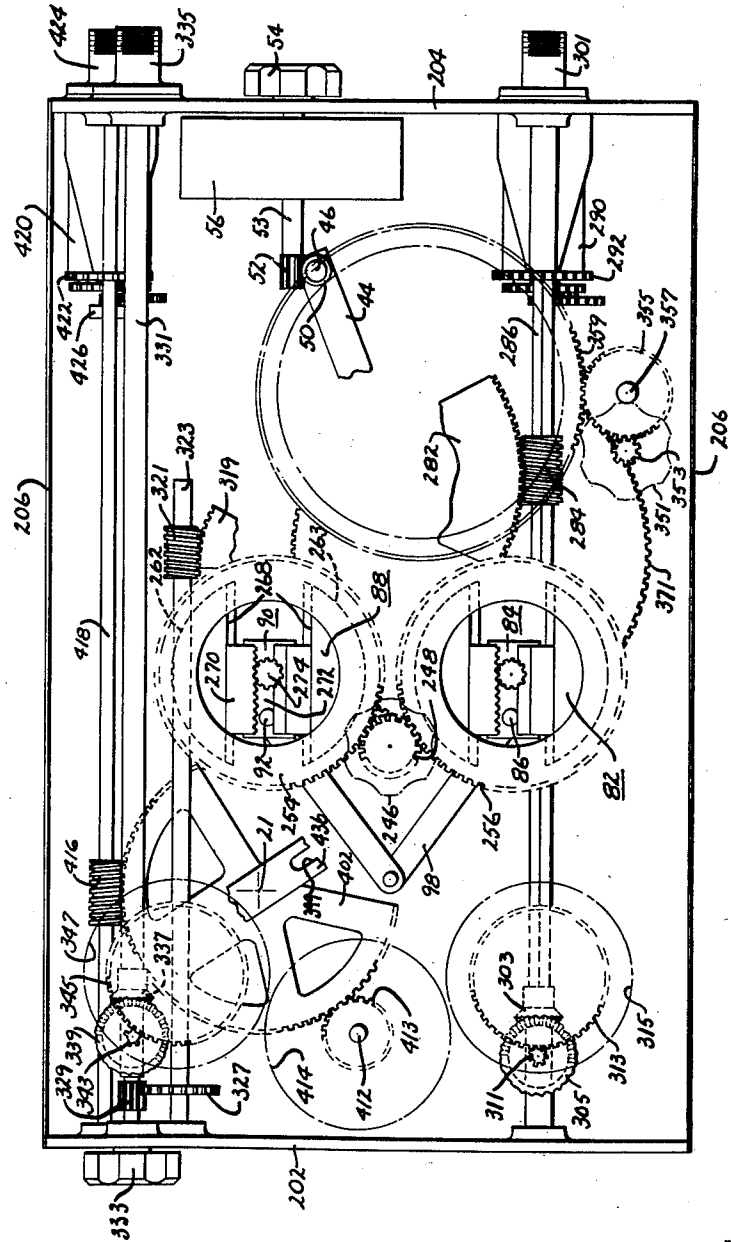


Fig. 10

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COMPUTER FOR AERONAUTICAL BOMB SIGHTS

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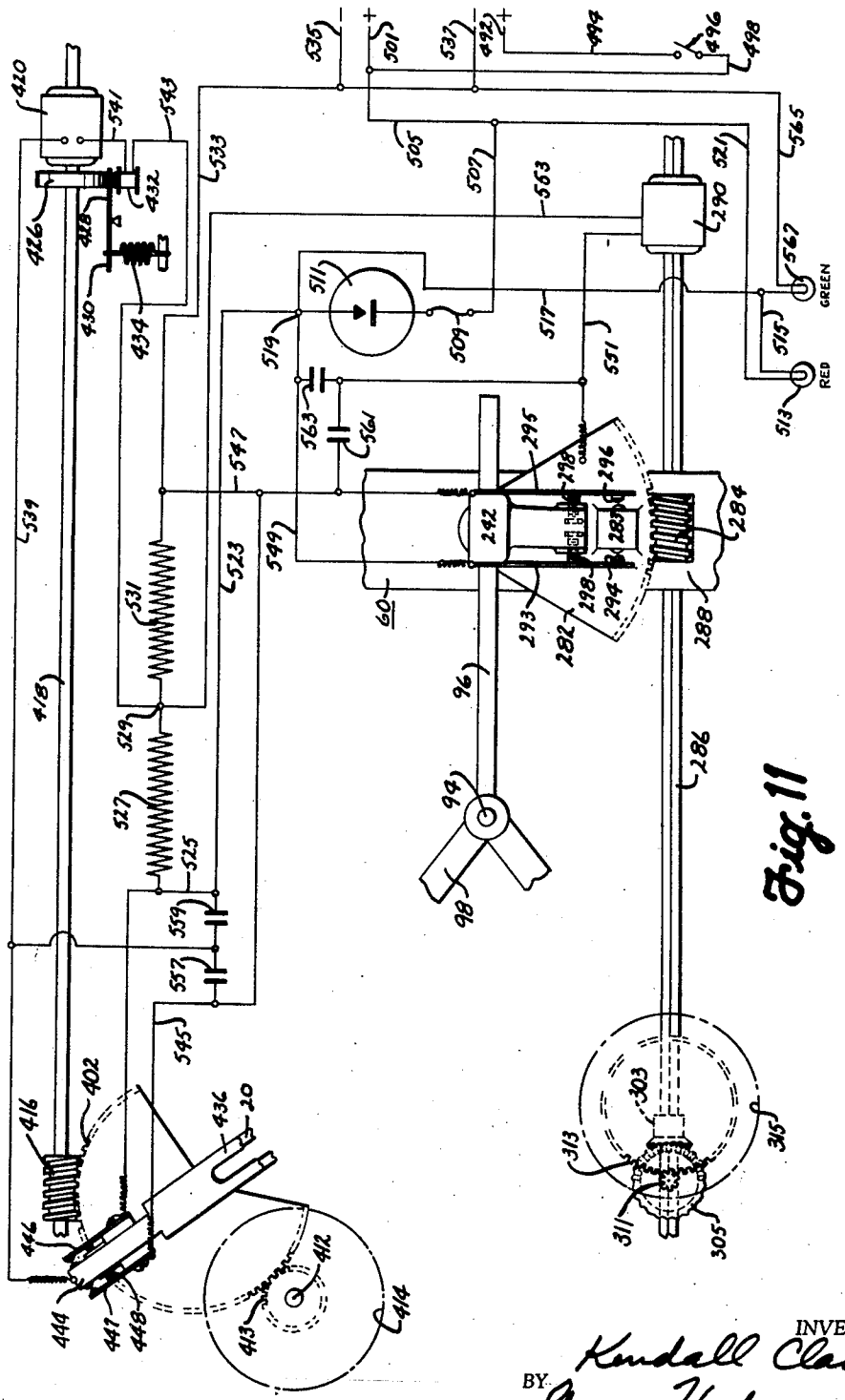


Fig. 11

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Patented Dec. 2, 1947 2,431,919

UNITED STATES PATENT OFFICE

2,431,919

COMPUTER FOR AERONAUTICAL BOMB SIGHTS

Kendall Clark, Oakwood, Ohio, assignor to General Motors Corporation, Dayton, Ohio, a corporation of Delaware

Application January 21, 1944, Serial No. 519,224

7 Claims. (Cl. 235—61.5)

1

This invention relates to aeronautical apparatus and more particularly to computers for aerial navigation and bombing.

In the past bombsights have been either very simple and without computers for low altitude bombing or very complex with built-in computers for high altitude bombing. The computers for low altitude bombing were not satisfactory for medium or high level bombing while the bombsights for high altitude bombing were not satisfactory for low altitude bombing.

It is an object of my invention to provide a computer for level bombing which can be used for either low, medium or high altitude bombing.

It is another object of my invention to provide a computer for level bombing which will be separate from the bombsight but which will accurately transmit its solutions to the bombsight.

It is another object of my invention to provide a simple computer for level bombing which will be accurate, inexpensive to build and which will take into account the effect of air speed and altitude on the time of fall, the drift, the target speed and direction and the effect of the air resistance of the bomb.

It is another object of my invention to provide a computer for bombing which can also be used as a navigation instrument.

It is still another object of my invention to provide an improved navigation computer which will determine the drift angle and the true ground speed.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein a preferred form of the present invention is clearly shown.

In the drawings:

Fig. 1 is a diagrammatic illustration of a level bombing attack on a stationary target;

Fig. 2 is a diagrammatic view of the computer;

Fig. 3 is a schematic view of the altitude and bomb coefficient correction mechanism;

Fig. 4 is a top view of the exterior of the computer;

Fig. 5 is a top perspective view of the interior of the computer;

Fig. 6 is a vertical sectional view taken along the line 6—6 of Fig. 4 with the wind and target dials set at headings of 180 degrees;

Fig. 7 is a vertical sectional view taken along the lines 7—7 of Figs. 4 and 5;

Fig. 8 is a horizontal sectional view taken along the lines 8—8 of Figs. 6 and 7;

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Fig. 9 is a fragmentary vertical sectional view taken along the lines 9—9 of Fig. 8;

Fig. 10 is a plan schematic view of the gearing and shafting connections with the target and wind mechanisms both at zero positions;

Fig. 11 is a schematic view of the follow-up motors, controls and electrical circuits;

Fig. 12 is a vertical sectional view of the target control positioned for a plane heading south (180°) and a target heading west (270°) at 20 M. P. H. taken along the lines 12—12 of Fig. 13; and

Fig. 13 is a fragmentary sectional view taken substantially along the lines 13—13 of Fig. 12 with the knobs and cover plate removed.

Fig. 1—Bombing factors

A typical bombing problem is illustrated in Fig. 1 where the effect of the wind has been grossly exaggerated so that the various features can be seen clearly. The bombing plane is shown making a level bombing attack upon a stationary target. The principal problem for the computer to determine is the dropping angle, that is, the angle EAT on Fig. 1 which is the angle of the sighting line represented by the line AT of the bombsight at the time of the release of the bomb.

The instruments carried by the airplane determine the air speed, and information from meteorology stations or from other instruments, supplies the wind speed and the direction of the wind. An aerial navigation compass supplies the direction of the plane. The elevation of the target above sea level must be known in advance while the height of the airplane is determined by the altimeter from which the height AE of the plane above the target may be determined.

The line AB represents what would be the movement of the plane if it kept on in the same path as taken at the time of release of the bomb. The distance AB is computed by finding the true ground speed and multiplying it by the time it takes the bomb to fall to the earth. If the bomb would travel through a vacuum it would fall directly under the bombing plane at the point B. In air, the bomb will be deflected by the wind and it will be slowed up by the air resistance, so that it will fall short of the point B by an angle BTF which is called the trail angle. This trail angle is found in bombing tables which are the result of experiments on actual bombs dropped on targets from planes. From the trail angle and the height above the target the distance TF, called the range component of trail, can be determined and by subtracting the distance TF from

the distance AB or its equal EF, the distance ET may be determined. The dropping angle is then the angle whose tangent is TE/AE.

In my computer I employ velocity vectors. In so doing each of the values of Fig. 1 is divided by the total time of fall of the bomb expressed mathematically by $To+T\phi$ representing the time of fall in a vacuum plus the additional time due to the air resistance. For example, the distance AB, which in Fig. 1 is represented by the true ground speed times the time of fall $Vg(To+T\phi)$, when divided by the time of fall becomes the true ground speed Vg. The height above the target H is also divided by the total time of fall of the bomb $To+T\phi$. Thus all the values are in proportion and the triangles formed are similar. The advantage of using the velocity vectors is that the ratio of the size of the various factors changes less from one extreme condition to the other than when the space vectors are used, as in Fig. 1. Since the actual wind speed is small compared to the other factors, the distances AE and GE, BC and BD may be considered as being substantially equal.

Figs. 2 and 3—Diagram

In Fig. 2 there is shown diagrammatically the computer with the principal moving parts shown as for a high altitude low speed bombing in full lines and for a low altitude high speed bombing in dot and dash lines. A slotted dropping angle slotted arm **20** is pivoted at the point **21** upon a fixed pivot pin and can swing through a wide arc as illustrated by the two positions. The pivot point **21** corresponds to the point A in Fig. 1, while the slotted arm **20** corresponds to the sighting line AT of Fig. 1. The slotted trail arm **24** is bodily movable laterally and can also swing because it is pivoted upon a movable pivot pin **26** provided upon the laterally movable ground speed carriage **28**. This pivot pin **26** is movable toward and away from the pivot point **21** along the line **36** a distance proportional to the line AB. The pivot pin **26** corresponds to the point B and the slotted trail arm **24** corresponds to the imaginary sighting line BT and its angular position (which is set by the knob **333** through the worm **321** and sector gear **319**) corresponds to the trail angle formed by the angle TBF. The connection (corresponding to the point T in Fig. 1) between the slotted dropping angle arm **20** and the slotted trail arm **24** is made by a movable pin **30** which slides within a slot **31** in the slotted falling velocity carriage **32** movable parallel to the rod **220**.

The intersection between the dropping angle arm **20** and the trail arm **24** provided by the movable pin **30** must be moved by the falling velocity carriage **32** away from the line **36** connecting the pivot pins **21** and **26** a perpendicular distance proportional to the height above the target represented by the line AE in Fig. 1 and in the velocity vector solution by the component

$$\frac{H}{To+T\phi}$$

This makes the angle between the dropping angle arm **20** and the vertical axis **34** correspond to the dropping angle EAT of Fig. 1. This also makes the distance corresponding to the trail distance CB, BD or TF in Fig. 1 proportional to the trail divided by the falling time

$$\left(\frac{\text{Trail}}{To+T\phi}\right)$$

in Fig. 2. Thus the triangular solution provided by Fig. 2 is similar to the triangular solution in

Fig. 1, the distances are proportional and the dropping angles and the trail angles will be identical.

The falling velocity computation

To properly locate the falling velocity carriage **32** in accordance with the factor

$$\frac{H}{To+T\phi}$$

its position must be varied according to the height of the plane above the target and the specific air resistance of the particular bomb used which must be further corrected according to the air speed of the plane. Therefore, I have provided a three dimensional cam **38** which is better shown in Fig. 3. This cam is provided with such a surface that the cam roller follower **40** may be moved to the bottom of the cam for low bomb coefficients, such as 0.75 and to the top of the cam for high bomb coefficients, such as 10, with the intermediate values corresponding. The cam is rotated about its axis to move the cam roller outwardly from the center of the cam, a value which corresponds to the factor

$$\frac{H}{To+T\phi}$$

for any bomb coefficient between the range of 0.75 to 10 according to the vertical position of the cam roller **40**.

In principle, this three dimensional cam **38** is derived from the falling velocity in a vacuum

$$\left(\frac{H}{To}\right)$$

which would supply the values for a cam surface without the sloping sides for a bomb coefficient of 0.00 representing a bomb having no air friction. The sloping sides modify the cam to supply falling velocity values

$$\frac{H}{To.+T\phi}$$

which include corrections for the effect of air friction on the bomb in the factor $T\phi$ and these values naturally vary according to the frictional resistance of the individual bombs as represented by their bomb coefficients C_t. The portion of the cam for values of C_t+0 has of course been omitted and the cam has been limited to the coefficient of the bombs expected to be used, $C_t=0.75$ to 10.

The cam roller **40** is supported upon the end of a lever **42** pivoted on a horizontal pivot pin **377** between ears **379** extending downwardly from a cam arm **44** which is pivoted upon a vertical bomb coefficient rack member **46**. This vertical member **46** in addition to serving as the pivot for the cam arm **44** is connected by a pin **48** at its lower end to the forked end of the cam roller lever **42**. The upper end of the member **46** is provided with circular teeth to form a circular rack **50** which meshes with a pinion **52** upon the end of the bomb coefficient knob shaft **53** provided with a bomb coefficient knob **54** and a bomb coefficient dial **56**. The bomb coefficient knob **54** may be turned so that the dial **56** indicates the bomb coefficient of the particular bomb to be used which rotates the pinion **52** to raise or lower the bomb coefficient circular rack member **46** to lower or raise the cam roller **40** accordingly so that it will ride upon the part of the cam corresponding to the bomb coefficient and giving the proper values of

$$\frac{H}{To+T\phi}$$

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for that particular bomb when the cam **38** is turned to the correct altitude.

The additional correction made for the effect of air speed upon the factor

$$\frac{H}{To+T\phi}$$

is accomplished by the following arrangement. There is provided an air speed carriage **60** which is moved to the left or right as illustrated by the full line and dot and dash line positions in Fig. 2 in accordance with a decrease or increase in air speed by an air speed screw **62** provided with an adjusting knob **64** at its opposite end. This air speed carriage **60** carries a pin or roller **66** which rides in a slotted arm **68** extending from the altitude dial index member **70** which carries the index for the altitude dial. By this arrangement the altitude dial index member **70** is rotated as illustrated by the full line and dot and dash line positions by changes in position of the air speed carriage **60**. The rotations of the index member **70** necessitates a resetting and corresponding rotation of the position of the altitude dial **72** and the altitude cam **38** for the same altitude to correct the value

$$\frac{H}{To+T\phi}$$

for different air speeds.

The altitude dial **72** and cam **38** are so designed that the cam roller **40** is in contact with the part of the cam furtherest from its axis of rotation for low altitudes and the part of the cam closest to its axis for high altitudes, and intermediate parts of the cam for intermediate altitudes. This causes the cam roller lever arm **42** through its connection with the cam arm **44** to move the cam arm **44** about its vertical pivot provided by the member **46** to move the falling velocity carriage **32** as illustrated by the full and dot and dash line positions to make the distance between the center line **36** and the pin **30** proportional to the correct falling velocity, that is, the

$$\frac{H}{To+T\phi}$$

factor. This is done by providing a roller **76** at the end of the arm **44** which bears against the one edge of the falling velocity carriage **32**. This falling velocity carriage **32** is provided with parallel guides and is yieldingly held against the roller **76** by being connected to a steel tape **78** which is maintained under tension at all times.

The true relative speed computation

The distance between the pivot points **21** and **26** of the dropping angle and trail arm **20** and **24** is determined by the position of the ground speed carriage **28** and this must be proportional to the relative velocity Vg between the plane and the target. If the target is stationary this is the true ground speed. In order to properly set the ground speed carriage **28** there is provided a wind dial assembly **82** in which the direction of the wind is taken care of by the rotation of the dial in accordance with the wind direction, and the wind velocity is taken care of by varying the eccentricity of a slide member **84** bodily rotatable with the dial **82** and carrying a pin **86**. The movement of the target is taken care of by the target dial assembly **88** which is turned to the direction of movement of the target and the target speed is taken care of by varying the eccentricity of a slide block member **90** carrying

a pin **92**, both of which are rotatable with the target dial **88**.

The pins **86** and **92** of the wind speed and target speed control are connected together and to the pin **94** at the end of the drift slide bar **96** by a pantograph **98**. The drift slide bar **96** is slidably mounted in a member pivoted to the air speed carriage **60** directly beneath the pulley **101** carried directly by the air speed carriage **60**. The angle of the drift slide bar **96** relative to the air speed carriage **60** determines the drift angle relative to the ground when the target is stationary and when the target is moving it determines the drift angle relative to the targe.

In order to translate the wind speed and direction, the target speed and direction, and the air speed and direction into the relative velocity between the bombing plane and the target I provide a thin flexible steel tape **103**. This steel tape **103** extends from a stationary anchorage **105** between the pulleys **101** and **107** around a pulley **109** upon the axis of the pantograph pin **94** at the end of the drift slide bar **96** and thence between the pulleys **101** and **111**, thence around the pulley **113** on the air speed carriage **60** from which point it extends around the pulley **115** upon the ground speed carriage **28** and thence back to a second stationary anchorage **117**. A compression type coil spring **119** threaded upon the air speed screw **62** extends between the air speed carriage **60** and the ground speed carriage **28** to keep the steel tape **103** under sufficient tension at all times to keep it straight so that the ground speed carriage **28** will exactly reflect the movements of the pantograph **98** and the air speed carriage **60**. The ground speed carriage **28** is moved to the right for an increase in relative ground speed as shown in the dot and dash lines and to the left as shown in full lines for a decrease in relative speed.

Connected to the ground speed carriage **28** by a flexible steel tape **121** is the ground speed dial **123** having a drum **583** upon which the end of the tape **121** is wrapped. The ground speed dial **123** is provided with a clock spring to keep the tape **121** under tension. The ground speed dial **123** indicates the relative speed between the bombing plane and its target and if the target is stationary it will indicate the true ground speed. A flexible steel tape **125** also connects air speed carriage **60** with a drum **571** upon the air speed dial **127** by which the air speed carriage **60** may be set by the use of the knob **64**. The air speed dial **127** is provided with a clock spring to maintain tension upon the steel tape **125**.

In aerial navigation the points of the compass are indicated as angles from zero degrees to 360 degrees with true North being the 0–360-degree position, with east 90 degrees, south 180 degrees and west 270 degrees. A wind coming from the east is called a 90 degree wind. In Fig. 2 the wind direction is 285 degrees which is a west wind. The slide block **84** is shown at its maximum eccentricity indicating a wind velocity of about 75 M. P. H. When properly set, the wind speed dial **82** mechanism moves the slide block **84** and the pin **86** toward the direction from which the wind is coming.

The target dial **88** is positioned in Fig. 2 for a a target direction of 255 degrees at substantially a maximum target velocity of 75 M. P. H. The target mechanism moves the slide block **90** and the pin **92** in the direction towards that which the moving target is heading. The pantograph

98 performs a vector addition of the wind speed and direction, and the target speed and direction at the pin 94. The relationship of the wind speed and target speed mechanism 82 and 88 to the air speed carriage 60 and the air speed dial 127 is such that the distance between the center of the pin 94 and the center of the pulley 101 represents the true relative speed between the bombing plane and its target. If the target is stationary this distance represents the true ground speed.

For example, if the plane is headed into the wind the wind dial 82 is turned to bring the slide block 84 and the pin 86 closer to the air speed carriage 60 which will reduce the distance between the pin 94 and the pulley 101. Likewise if the target is moving in the safe direction as the plane the target dial mechanism and the slide block 90 and the pin 92 are turned to bring them closer to the air speed carriage 60. This will move the pin 94 closer to the air speed carriage 60, thereby reducing the distance between the pin 94 and the pulley 101. This will reduce the amount of the steel tape 103 extending between the air speed carriage 60 and the pulley 109 corresponding to the reduction in speed due to the relative motion. The spring 119 will then move the ground speed carriage 28 an equal distance which will keep the steel tape 103 tight and make the distance between the pivot points 21 and 26 equal to the distance between the centers of the pulleys 101 and 109. If the target velocity is zero, the angle between the drift bar 96 and a line perpendicular to the air speed carriage 60 indicates the true drift angle. In Fig. 2 the slide bar 96 indicates drift relative to the target. The true angle of drift relative to the ground, however, could only be determined if the target mechanism were turned to zero target speed bringing the pin 92 to the center point of the target mechanism. As illustrated by the dot and dash lines, a change in air speed changes the drift angle.

The structure

Considering now the actual structural embodiment disclosed in the remaining figures, there is shown the housing (Figs. 4 and 5) for the computer formed by two cast end plates 202 and 204. These end plates are joined by a sheet metal bottom plate with upturned edges 206 (Figs. 6 to 8) at the side as well as by the guide rods 208 and 210, by a H-shaped cam supporting casting 212 (Figs. 5 to 8) at the bottom and by a channel-shaped side member 214 and an angle side member 216. These side members 214 and 216 are joined by the cross guide rods 218 and 220.

The longitudinal guide rods 208 and 210 (Figs. 5 to 7) support the air speed carriage 60 which is provided with a set of four guide rollers 222 at one end providing a substantially frictionless rolling connection with the guide rod 208 and a forked end 224 which receives the guide rod 210 forming a second support for the air speed carriage 60. The air speed carriage 60 is provided with a pin 569 (see Fig. 5) to which is attached the steel tape 125 (see Fig. 7) which extends to and is wrapped around the drum 571 which carries the air speed dial 127. The drum 571 is rotatably mounted upon the bearing pin 573 which is riveted to a bracket 575 extending downwardly from the cover 252. A spiral clock spring 577 has its inner end fastened to the bearing pin 573 and its outer end provided with a loop which is mounted upon a pin 579 extending from the drum 571. This spiral clock spring tends to wind the steel tape 125 upon the drum 571 and thereby keeps the tape 125 taut and the dial 127 in a position corresponding to the position of the air speed carriage 60.

Likewise the ground speed carriage 28 (Figs. 5 and 6) is provided with four flanged rollers 226 engaging the guide rod 208 and a forked end 228 for receiving the guide rod 210. The ground speed carriage 28 is also provided with a pin 581 to which is attached the steel tape 121 (see Fig. 6) the other end of which extends to and is wrapped around a drum 583 to which is attached the ground speed dial 123. The drum 583 is rotatably mounted upon the pin 585 riveted to a bracket 587 extending downwardly from the cover 252. In order to keep the steel tape 121 wound tightly upon the drum 583, I fasten the inner end of a spiral clock spring 589 to the reduced outer end of the bearing pin 585 while the outer end of the spring 589 is provided with a loop surrounding the pin 591 extending from the drum 583. The dial 123 is thereby rotated to its proper position corresponding to the distance of the point 26 ground speed carriage 28 from the stationary pivot point 21 in Fig. 2.

The cross guide rods 218 and 220 (Fig. 8) support the falling velocity slotted carriage 32 which at one end is provided with a plate 389 carrying four flanged rollers 230 providing a rolling support upon the cross guide rod 220. The opposite end 232 is forked to provide a bearing upon the cross guide rod 218. In the structural embodiment, the steel tape 78 and the drum 80 are connected somewhat differently than in Fig. 2. As shown in Fig. 8, the tape 78 is fastened to the end of the falling velocity carriage 32 provided with the four rollers 230 and extends around an idler pulley 593 on its way to the drum 80. The drum 80 has the end of the steel tape 78 fastened to its rim and in turn is fixed to a rotatable shaft 595 to which is fastened the inner end of a spiral clock spring 597 having its outer end looped over the pin 599 projecting upwardly from the H-shaped cam supporting casting 212. The spiral clock spring 597 tends to turn the drum 80 in a clockwise direction to keep the steel tape 78 under tension for keeping the edge 387 of the falling velocity carriage 32 against the roller 76 on the cam arm 44 and the cam roller 40 on the cam roller arm 42 against the surface of the altitude cam 38. The use of four double flanged rollers on the one end of each of the carriages 60, 28 and 32, insures that these carriages will move parallel to either the longitudinal guide rod 208 or the cross guide rod 220.

The air speed carriage

The air speed carriage knob 64 (Fig. 4) is on the left end of the computer and the air speed screw 62 has a bearing in the left end casting. Its opposite end is threaded through a boss 234 (see Fig. 7) depending from the air speed carriage 60. This screw also passes through a boss 236 depending from the ground speed carriage 28 (see Fig. 6). The tape 103 (Fig. 5) is connected to a fixed anchorage 117 at one end and extends above and alongside the longitudinal guide 208 to the pulley 115 on the ground speed carriage 28, thence back to the air speed carriage 60 and around the pulleys 113 and 111 to the pulley 109 on the pantograph and back between the pulleys 101 and 107 on the air speed carriage to an adjustable anchorage 105 comprising a nut rotatably mounted in the end frame 204

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and threaded onto a pin which is riveted to the end of the steel tape. By this adjustment on the end of the steel tape, the ground speed carriage **28** can be brought into proper adjustment with the air speed carriage **60**, so that it will indicate the true ground speed when the target speed is zero. This is possible by reason of the resilient connection between the air speed carriage **60** and the ground speed carriage **28** through the compression spring **119**, which keeps the steel tape **103** taut and yet allows the distance between the carriage to be adjusted by moving the anchorage **105** of the steel tape **103** in or out. The pulleys **107**, **109**, **111**, **113** and **115** are rotatably mounted on posts high enough to keep the steel tape **103** above the path of the carriages **28** and **60**.

The wind and target mechanisms

The top cover **252** (see Figs. 6 and 4) is removable and carries all of the dials as well as altitude, heading, wind and target knobs. The wind and target dial mechanism are identical in mechanical construction. The heading knob **246** connects to a thin gear **248** mounted directly under the cover plate **250** on top of the cover **252**. This gear, as shown in Fig. 10, meshes with two large flat heading gears **254** and **256** constituting a part of the target and wind compensation mechanisms respectively. These heading gears, which are also mounted directly between the cover plate **250** and the top of the cover **252**, are each provided with legends from zero degrees to 360 degrees as shown in Figs. 4 and 13. These indicate the heading of the bombing plane and they are turned simultaneously by the heading knob **246** and gear **248** carrying bodily both the target and the wind mechanisms so that they may be simultaneously moved to correspond with the heading of the bombing plane. Since the target and wind mechanisms are mechanically identical, the construction will be explained in connection with the target dial mechanism shown particularly in Figs. 12 and 13, set for a 180 degree plane heading (S), a 270 degree target heading (W) at 20 M. P. H.

Fastened to the gear **254** is a ring **258** which is held in a groove formed between the target directional knob **260** and the twin segment target bottom plates **262** and **263** which are fastened to the knob **260** by screws to form the target assembly **88**. The friction between the ring **258** and its groove formed between the target knob and the bottom plates **262** and **263** is sufficient to cause the target assembly **88** to be rotated normally with the gear **254**, but if the heading knob **246** is held or locked, the entire target assembly **88** may be rotated independently of the gear **254** to set the direction of the target relatively to the gear **254**. By this arrangement, the wind assembly **82** as well as the target assembly **88** may be set, and assuming the target maintains its same direction and the bombing plane turns, the heading knob **246** and the gears **254** and **256** may be turned to take into account the change of direction of the plane thereby turning around the target and the wind assemblies **88** and **82** maintaining the proper directional indication between the target and wind direction knobs and the points of the compass and also indicating the difference in direction between the heading of the plane, the wind and the heading of the target by the difference in direction between the wind and target knobs **280** and **260** and the index **266** provided on the cover plate **250** for the target dial assembly.

The bottom plates **262** and **263** are in the form of two circular segments, the straight edges of which provide the guide-ways **268** for supporting the slide block assembly **90**. The slide block assembly **90** includes a rack **270** and a bottom member **272** which carries the pin **92** extending into an eyelet **93** provided in the adjacent arm of the pantograph **98**. The rack **270** is always in mesh with a pinion **274** fastened to the lower end of the target speed shaft **276** provided with the target speed knob **278** at its upper end. This target speed knob **278** cooperates with legends 0 to 75 (M. P. H.) provided on the upper face of the target directional knob **260**. Sufficient friction is provided between the target directional knob **260** and the target speed knob **278** and the mechanism controlled thereby, that the target speed knob will remain in its set position when the target directional knob or the gear **254** is rotated. The rotation of either the gear **254** or the target directional knob will change the angularity of the guide-ways **268** and thereby change the direction of movement of the slide block assembly **90**. The slide block assembly **90** is so arranged that when the target speed is zero the pin **92** will be directly on the axis of the target dial assembly which is concentric, and this will place the pin **92** directly beneath the shaft **276**. In Figs. 12 and 13 the target speed knob is turned to show a target speed of about 20 M. P. H., so that the pin **92** is eccentrically located a corresponding distance. The slide block assembly **90** with the pin **92** moves to one side of the target assembly **88** to indicate by its eccentricity the amount of target speed in whatever direction the target directional knob **260** is turned.

The wind assembly is identical in mechanical construction but differs in that the wind directional knob **280** has an index which points in the direction from which the wind is coming and therefore the direction in which the wind is travelling is 180 degrees from this index. Since the wind direction and the target direction have the opposite effect upon the relative velocity between the bombing plane and the target their assemblies will be placed in the same position when the target direction is the same as the wind heading. Fig. 6 is drawn to show a plane heading of zero, a target heading or direction of 180 degrees and a target speed of zero, and a wind heading of south, or 180 degrees and a wind speed of 20 M. P. H.

The drift bar **96** is slidably held in a rotatable member **242** (see Fig. 7) which is pivotally mounted in a bearing provided in the central portion of the air speed carriage **60**. The top of this rotatable member carries the pulley **101**. The plate **244** is provided with an aperture for receiving the portion of the member **242** on top of the air speed carriage **60** for providing a more firm support for the drift bar **96** regardless of the extent of its overhang in either direction.

The drift indicating mechanism

The target and wind mechanisms **88** and **82** and the pantograph serve to properly locate the pulley **109** (Figs. 5 and 6) and the adjacent end of the drift bar **96** and thereby control the angular position of the drift bar in conjunction with the member **242** (Fig. 7) rotatably mounted on the air speed carriage **60**. The rotatable member **242** extends beneath the air speed carriage **60** and has a sector gear **282** rotatably mounted on its lower end which is always in engagement with a worm **284** slidably mounted upon the square

shaft 286. To prevent any lost motion or backlash between the worm 284 and the sector gear 282, there is provided between the air speed carriage 60 and the sector gear 282 a wire spring 683 which keeps the sector gear teeth in constant engagement with one side of the worm teeth. This worm 284 is rotatably mounted between a pair of bosses 288 depending from the air speed carriage 60. It is practically impossible to cause the sector gear 282 to drive the worm 284 to rotate the shaft 286.

Therefore to drive the worm 284, I have provided a follow-up control mechanism which includes an electric motor 290 connected through gearing to a gear 292 provided upon the square shaft 286. As is better shown in Figs. 7 and 11, to control this electric motor, I provide beneath the sector gear 282 a pair of oppositely disposed leaf springs 293 and 295 connected to the member 242 through a plate 297. These leaf springs carry the contacts 294 and 296. The normal position of the leaf springs is made adjustable by means of the screws 298 which are threaded through ears projecting from the plate 297 into contact with the leaf springs 293 and 295. These leaf springs rotate with the plate 297, the member 242 and the drift bar 96. In this rotation, either of the contacts 294 or 296 will engage one of the contacts provided upon the boss or member 283. This will close the proper electrical circuit to the reversible direct current motor 290 to operate the motor 290 in such a direction as to move the sector gear 282 to a position in which the contacts 294 and 296 are again separated from the contacts of the boss 283. In this way, the rotation of the shaft 286 will correspond to the rotation of the drift bar 296 and the member 242.

The shaft 286 (Figs. 5 and 10) extends through the end member 204 which is provided with a drift output connection 301 for imparting the drift connection to the bombsight. At the opposite end, the shaft 286 is provided with a bevel pinion 303 in engagement with a bevel gear 305 provided at the bottom of a vertical shaft 307 (Fig. 6) supported in a pair of spaced bearings 309 upon the end member 202. At the upper end of the shaft 307 is a pinion 311 in engagement with a large spur gear 313 which carries the drift dial 315 on top of the top plate 252. By this arrangement, the drift dial 315 will indicate the angularity of the drift bar 96, the member 242 and the sector gear 282.

As has been previously mentioned, in order to impart the value V_g (Fig. 2), the ground speed carriage 28 which rides upon the rods 208 and 210 (Fig. 5) is located by the steel tape 103. Fastened by a nut 317 to the ground speed carriage 28 is the trail arm pivot pin 26 carrying a sector gear 319 in engagement with a worm 321 slidably mounted upon the square shaft 323 and rotatably mounted between a set of bosses 325 provided on the adjacent end of the ground speed carriage 28. The square shaft 323 is connected by a gear 327 to a pinion (Figs. 8 and 10) upon the trail shaft 331 provided with a knob 333 upon the outside of the end plate 202. This trail shaft 331 extends to the opposite end plate 204 where a trail output connection 335 is provided for connecting to a bombsight. Adjacent the pinion 329, the trail shaft 331 is provided with a bevel pinion 337 meshing with a bevel gear 339 (Figs. 5, 6 and 10) upon the lower end of a vertical shaft 341 carrying a pinion 343 in engagement with a large spur gear 345 provided beneath the trail dial 347 on top of the top plate 252.

The sector gear 319 is rigidly connected through a block 349 with one end of the trail arm 24. The trail knob 333 is turned until the dial 347 is set to the proper trail values given in the ballistic tables for bombs. This, through the worm 321 and the sector gear 319, will turn the trail arm 24 to the proper trail angle regardless of the position of the air speed carriage 28.

The altitude control

Upon the top of the cover 252 there is provided an altitude knob 351 (Fig. 4) provided with a pinion 353 (Fig. 7) meshing with a spur gear 355 on a vertical shaft 357. The spur gear 355 engages a large thin gear 359 fastened to a portion of the altitude dial 72 which extends beneath the cover 252. The altitude dial 72 is rotatably mounted on the cover 252 and has a downwardly extending pin 361 upon which is rotatably mounted an altitude dial index plate 363 provided with the altitude index slotted arm 68 described briefly in connection with Fig. 2. This altitude index slotted arm 68 is provided with a slot 365 which receives the roller 66 extending upwardly from the air speed carriage 60. The angular position of the roller 66 relative to the slot 365 and the index plate 363 is such that the movement of the air speed carriage will move the index plate 363 an amount equal to the variation in the falling time of the bomb caused by the change in air speed. This amount is very small and could be neglected if extreme accuracy was not desired.

The index plate 363 is provided with a pair of pins 367 (Fig. 4) extending through a slot in the cover 252 for carrying the index member 70, which cooperates with the altitude dial 72 to indicate the altitude for which the computer is set. In setting the computer, the air speed carriage should be first set to indicate the proper air speed, after which the altitude dial should be set to indicate the proper altitude. If desired, following such a setting a removable wedge of rubber may be placed between the altitude dial index member 70 and the altitude dial 72 in order to cause the dial 72 to keep its same position relative to the index member 70 for varying air speeds. When the altitude changes, the wedge must be removed to set the dial to a different altitude, after which it may be replaced. A manually deflectable leaf spring fastened to the index plate may be provided with a friction surface engaging the bottom face of the altitude dial as a substitute for such a wedge.

The altitude cam

The lower end of the vertical shaft 357 (Fig. 7) is provided with a spur gear 369 beneath the casting 212. This gear meshes with a large spur gear 371 which is fastened by screws, as shown in Fig. 6, to the bottom of the altitude cam 38 which is rotatably mounted in a large aperture in the casting 212. As will be most clearly seen in Fig. 7, the altitude cam 38 has sloping cam surfaces 373 so that it forms a three-dimensional cam. The outer surface in each horizontal plane of this cam provides a value of

$$\frac{H}{T_D + T_\phi}$$

(the falling velocity factor) for bombs of one particular bomb coefficient for altitudes or heights above the target of 200 to 30,000 ft. for

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which the dial 72 may be set. For example, the outer surface 373 of the altitude cam 38 in the horizontal plane nearest the bottom of the cam, provides the proper falling velocity factor for bombs of a low bomb coefficient (C_t—0.75) for all heights while the upper horizontal plane of the outer surface 373 provides the proper factor for high bomb coefficients (C_t—10) for all heights.

The cam roller 40 (Figs. 2, 3 and 8) is rotatably mounted upon the end of the cam roller arm 42 which is provided with a transverse bearing 375 so that it may pivot on a pin 377 held in a pair of ears 379 depending from the cam arm 44. The bearing 375 fits comparatively tightly between the ears 379 so that there is little or no side play and the movements of the cam roller 40 are accurately transmitted through the bearing boss 375 to the cam arm 44. The forked end of the cam roller arm 42 receives a transverse pin 48 at the lower end of the vertical pin 46 which is rotatably mounted in a pair of bosses 383 extending from the inner face of the end plate 204. The upper end of the pin 46, as mentioned before, is provided with a circular rack 50 (Figs. 5 and 7) in engagement with a spur gear 52 upon the bomb coefficient dial shaft 53 provided with the bomb coefficient dial 56 and the bomb coefficient knob 54. As the bomb coefficient knob 54 and the dial 56 are turned to the proper bomb coefficient the spur gear 52 will turn to raise or lower the circular rack 50 and the pin 46 to raise or lower the forked end of the cam roller arm 42 to cause it to pivot about the pin 377 to lower or raise the cam roller 40 so as to contact the outer surface of the cam 38 in the horizontal plane corresponding to the bomb coefficient setting of the dial 56.

The cam arm 44 is provided with a boss 385 at one end which is pivotally mounted upon the pin 46 between the bosses 383. At the opposite end of the cam arm 44 there is provided the roller 76 (Figs. 6 and 8) which is in engagement with the edge 387 on the adjacent edge of the falling velocity slotted carriage 32. At one end of the falling velocity slotted carriage 32 is a plate 389 carrying the four rollers 230 which ride upon the transverse rod 220. As mentioned before the steel tape 78 moves the slotted carriage 32 to keep it in contact with the roller 76 and through the roller 76 moves the cam and cam roller arms 42 and 44 about their pivot pin 46 to keep the cam roller 40 in engagement with the cam 38.

Slidably mounted upon the falling velocity carriage 32 is a pin 30 having a collar 391 fixed thereto beneath which there is a slide block flange 393, and beneath the flange 393 is a roller 395 upon the pin 30 which rides in the slot 31 of the falling velocity carriage 32. Beneath the roller 395 is a second slide block flange 397 which aids in firmly supporting the pin 30 in sliding engagement with the falling velocity carriage 32. Above the fixed collar 391, the pin 30 extends through the slot 399 in the dropping angle arm 20. Above the dropping angle arm 20 the pin 30 is provided with a spacing collar 440 above which is a roller 442 in the dropping angle slotted member 436. Above the roller 442 are a small spacing collar 441 and a large spacing collar 439. Above the large spacing collar 439 is a roller 437 which rolls within the slot of the trail arm 24. Above the roller 437 is another spacing collar 435 above which is a removable snap ring holding the assembly together. The rollers 395 and 437 cause the pin 30 to be moved readily in accordance with the

movement of the trail arm 24 and the falling velocity slotted carriage 32.

The other end of the dropping angle arm 20 is fastened to a block 400 on top of the dropping angle sector gear 402. The dropping angle sector gear 402 is provided with a hub 404 rotatably mounted upon a bolt 406 fastened to a casting 408 which, in turn, is fastened to the end member 202. This casting 408 is also provided with a bearing boss 410 supporting the lower end of a vertical dropping angle dial shaft 412 provided with a spur gear 413 meshing with the dropping angle sector gear 402. The upper end of the dropping angle dial shaft 412 is provided with the dropping angle dial 414 on top of the top plate 252.

The sector gear 402 is constantly in mesh with a worm 416 upon a longitudinal shaft 418 mounted in bearings provided in the end members 202 and 204. At the opposite end of this shaft 418 is provided the spur gear 422 which is connected through gearing with a dropping angle follow-up motor 420. This end of the shaft 418 is provided with an output connector 424 which may connect by flexible shaft means or other form of connection with the bombsight. In order to prevent any overrunning from destroying the accuracy of the dropping angle output, the armature shaft of the dropping angle motor 420 is provided with a brake drum 426 normally engaged by a brake member 428 which forms a part of the pivoted armature 430 of an electromagnet 432. This pivoted armature 430 is provided with a tension spring 434 which normally maintains the brake 428 in engagement with the brake drum 426. However, the electromagnet 432 is energized concurrently with the dropping angle motor 420 so as to remove the brake member 428 from contact with the brake drum 426 during the operation of the dropping angle motor 420. When the motor 420 is deenergized, the brake member 428 is immediately applied to the drum 426 by the spring 434 to prevent any overrunning.

The dropping angle motor 420 is controlled by a follow-up mechanism which is somewhat similar to that described for the drift motor 290. This follow-up mechanism includes a slotted member 436 pivotally connected through the pivot pin 438 with the end of the dropping angle arm 20 which is remote from the sector gear 402. This dropping angle slotted member 436 is substantially directly above the dropping angle arm 20, but on the pin 30 there is a spacing collar 440 which spaces the arm 20 from the member 436. The pin 30, however, is provided with a collar 442 above the collar 440 which rides in the slot in the member 436, as is best shown in Fig. 9. The pin 30, however, is not provided with any collar in the slot 399 in the dropping angle arm 20. This slot in the arm 20 is sufficiently wide to allow the pin 30 to have considerable lateral movement with respect to the arm 20. The dropping angle slotted member 436, by reason of the roller 442, must move with the pin 30 which causes a movement of the member 436 with respect to the dropping angle arm 20 about the pivot 438. At the opposite narrowed end of the member 436 there is provided a contact block 444 provided with a pair of contacts located on opposite sides thereof. The adjacent end of the dropping angle arm 20 is provided with a pair of cantilever mounted leaf springs 446 and 447 carrying a set of contacts at their ends for making engagement with the contacts upon the block 444. The positions of these leaf springs 446 are made adjust-

able by the adjusting screws 448 (Fig. 11) which are supported by the adjacent end of the dropping angle arm 20.

The relative movement of the member 436 relative to the dropping angle arm 20 will cause the engagement of one or the other of the set of contacts to energize the dropping angle motor 420 in either the forward or reverse direction, as required, in order to cause the motor 420 to turn the shaft 418 and the worm 416 as well as the sector gear 402 and the dropping angle arm 20 to cause it to follow the movement of the member 436 and the pin 30. In this way, the correct dropping angle is set up by the computer as indicated upon the dial, and this computation is transmitted through the dropping angle output 424 to the bombsight.

The electrical system

The electrical system is provided with a standard 24-volt direct-current aircraft power inlet connection 490 provided with a positive terminal 492 connected by the conductor 494 to the on-off switch 496 which, in turn, is connected by the conductor 498 to the positive terminal 501 of a power output connector 503 (Fig. 4). This terminal 501 is connected (Fig. 11) by the conductors 505 and 507 to a fuse 509 which, in turn, is connected to the copper oxide rectifier 511 provided to insure that direct current of the proper polarity is always supplied to the motors of the computer. If the computer were improperly connected to the power source and current of incorrect polarity were allowed to operate the follow-up motors, instead of the contact mechanism controlling the motors to follow up the drift and dropping angle mechanisms they would control these motors to cause the motors to attempt to operate in opposite direction until jambing and breakage or bending of the parts would occur thereby seriously damaging the computer and seriously destroying its accuracy perhaps beyond repair from a practical standpoint.

The fuse 509 and the rectifier 511 are shunted by a red light 513 which will light upon the blowing of either the fuse 509 or the rectifier 511 or the application of direct current of the incorrect polarity. This red light 513 is connected by the conductors 515 and 517 to the junction 519 and by the conductor 521 to the junction with the conductors 505 and 507. The junction 519 is connected by the conductors 523 and 525 to the 500 ohm resistance 527 which, in turn, is connected to the junction 529. The junction 529 is connected to the 500 ohm resistance 531 which, in turn, is connected by the conductor 533 to the negative terminals 535 and 537 of the output connector 503 and the input connector 490. By this arrangement, there is provided twelve volts across each of the resistances 527 and 531.

The conductor 525 connects to the dropping angle spring contact strip 446 which, in turn, makes contact with the dropping angle double contact member 444 which, in turn, is connected by the conductor 539 to the dropping angle motor 420 which, in turn, is connected by the conductor 541 to the dropping angle braking relay 432 which, in turn, is connected by the conductor 543 to the junction 529. By this arrangement, the dropping angle motor 420 is connected across the resistance 527 and supplied with twelve-volt current passing from the conductor 539 through the motor to the conductor 541. The contacts 444 may also make contact with the other spring contact member 447 which is connected by the conductor 545 which connects to the conductor 547 which, in turn, connects to the conductor 533 on the opposite end of the resistance 531 from the junction 529. When this circuit is closed, the current will flow from the conductor 541 through the motor 420 in the opposite direction to the conductor 539, connecting the motor 420 across the resistance 531 and causing it to reverse its direction of operation.

In a similar manner, the conductor 549 connects to the drift spring contact member 293 of the drift follow-up mechanism which is adapted to make contact through the contact 294 with the contacts on the drift contact block 283 which is connected electrically to the conductor 551 connecting to the drift motor 290 which, in turn, is connected by the conductor 553 to the junction 529 in order to cause the drift motor 290 to operate in one direction. To cause the drift motor to operate in the opposite direction, the drift spring contact member 295 is connected to the conductor 547. When the contact strip 295 and its contact 296 makes engagement with the contact on the member 283, the current will flow from the conductor 553 through the motor 290 in the opposite direction to the conductor 551 to cause it to rotate in the opposite direction. The capacitors 557 and 559 are connected across the contacts of the dropping angle control to reduce arcing while the capacitors 561 and 563 are connected across the contacts of the drift angle control to prevent arcing. A green light 567 is connected in parallel circuit relationship with both of the resistances 527 and 531 as well as the two motors by its connection with the conductor 517 and by the conductor 565 to show that the current is "on" and is of the proper polarity.

The use of the follow-up motor system makes it possible to arrange the gearing so that there will be considerable rotation of the trail shaft 331, the dropping angle shaft 418, and the drift shaft 286 for a small amount of movement of the trail arm 24, the dropping angle arm 20 and the drift bar 96. By this arrangement comparatively small flexible shafts may connect the trail, dropping angle and drift output connections to a bombsight a considerable distance away with a negligible loss in accuracy in the transmission thereof.

Operation

In operation, the computer is placed in the bombing plane and the connector 490 (Fig. 4) is connected to a 24 volt D. C. source of power. The switch 496 (Fig. 11) is turned from the off to the on position and if the power supply is correct the green light 567 will be lighted while the red light 513 will remain dark. If the power source is incorrect the red light 513 will be lighted while the green light 567 will remain dark. Normally, the bombardier will know in advance what bombs are to be used and the bomb coefficient knob 54 (Fig. 4) may be set, so that the dial 56 indicates the proper bomb coefficient of the bombs to be used.

When the plane is in the vicinity of the target the pilot must obtain information from other sources as to the wind direction and the wind speed. The knob 280 is then set to the proper wind direction and the wind speed knob 282 is set to the proper wind speed. If the target is stationary the target dial 260 and the target speed knob 278 remain at their zero positions. If a moving target is sighted the target dial 260 and the target speed knob 278 may be set. The heading knob 246 may be turned from time to time

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to keep the wind and target dial mechanisms 82 and 88 set to conform with the changing direction of the plane. This sets and keeps properly set the pantograph system 98 (Fig. 5) which properly sets the position of the pulley 109 and the end of the drift bar 96. The knob 64 (Fig. 4) may then be turned to move the air speed dial 127 to designate the proper air speed. This, through the screw 62 (Fig. 5), will move the air speed carriage 60 to the proper position and in so doing will move the pulley 101 the proper distance away from the pulley 109 on the pantograph system so that the distance between their centers will equal the ground speed or the relative speed between the plane and its target Vg (Fig. 2). At the same time, this will cause a movement of the middle portion of the steel tape 103 which in conjunction with the spring 119 will move the ground speed carriage 28 to the proper position so that the pivot 26 of the trail arm 24 will be positioned a distance from the pivot pin 21 of the dropping angle arm 20 which is proportional to the relative speed between the plane and the target Vg. This distance is equal to the distance between the centers of the pulleys 101 and 109.

The position of the air speed carriage 60 through the pin 66 in the slotted arm sets the position of the altitude dial index member 70. The altitude knob 351 may then be turned so that the altitude dial 72 indicates the correct altitude or height above the target. The turning of the altitude knob 351 sets the altitude cam 38 corresponding to the position of the altitude dial 72 to move the cam roller 40, the roller arm 42, the cam arm 46, the projection 76 and finally the falling velocity carriage 32 which thereby is moved so that its perpendicular distance from the center line 36 connecting the pivot points 21 and 26 will be proportional to the falling velocity factor

$$\frac{H}{To+T\phi}$$

The position of the cam roller 40 and the angularity of the cam roller arm 42 was previously set by setting the bomb coefficient knob 54 through the pinion 52 and the rack member 46.

The bombardier, from the bombing tables, will determine the trail and this is set into the computer by turning the trail knob 333 until the trail dial 347 indicates the correct trail angle. The knob 333 will turn the square shaft 323 and the worm 321 which will turn the sector gear 319 to swing the trail arm 24 to the correct trail angle. This will move the movable pin 30 in the slot 31 of the falling velocity carriage 32 to its proper position and in so doing will carry the dropping angle member 20 to its proper position with the aid of the follow-up motor system. The follow-up motor system will cause the dropping angle shaft 418 (Fig. 11) and the dropping angle dial 414 (Fig. 4) to be turned to the proper position to give the correct dropping angle.

The drift follow-up motor system through the rotation of the sector gear 282 (Fig. 11) by the drift bar 96 will cause the drift worm 284, the drift shaft 286 and the drift dial 315 to be turned to give the proper drift angle. These factors may be set manually in the bombsight by the bombardier or they are set automatically in the bombsight through flexible shaft connections connecting the connectors 391, 335 and 424 with similar connectors on the bombsight. Thus, through this computer the drift angle and the dropping angle are automatically computed for the bombardier. The drift angle computed by the computer may also be used by the navigator as a check upon his navigation instruments.

While the form of embodiment of the invention as herein disclosed, constitutes a preferred form, it is to be understood that other forms might be adopted, as may come within the scope of the claims which follow.

What is claimed is as follows:

1. A navigating instrument for a movable body capable of moving relative to a fluid medium comprising a pantograph, a first movable member, a second movable member, means for moving one portion of the pantograph in accordance with the relative result of the movement of the body and the movement of the medium through which the body moves, means for moving said first member in accordance with the rate of movement of the body with respect to the medium, a rotatable means mounted upon said first member, an arm provided with a slidable connection connecting said pantograph and said rotatable means for rotating said rotatable means, the angular position of said rotatable means being in proportion to the angle of drift of the body, means connecting the pantograph and said first and second members for moving the second member in accordance with the vector sum of movements of the pantograph and the first member to position the second member in mathematical proportion to the rate of movement of the body relative to the earth.

2. A navigating instrument for a movable body capable of moving relative to a fluid medium comprising a pantograph, a first movable member, a second movable member, means for moving one portion of the pantograph in accordance with the movement relative to the earth of the medium through which the body moves, means for moving another portion of the pantograph in accordance with the movements of another body, means for moving said first member in accordance with the rate of movement of the first body with respect to the medium, a rotatable means mounted upon said first member, an arm provided with a slidable connection connecting said pantograph and said rotatable means for rotating said rotatable means, the angular position of said rotatable means being in proportion to the angle of drift of the first body, means connecting the pantograph and said first and second members for moving the second member in accordance with the vector sum of the movements of the pantograph and the first member.

3. A navigating instrument for a body moving in a fluid medium comprising a first movable member, a first indicating means cooperating with the first movable member for indicating the rate of movement of the body relative to the medium, a rotatable means rotatably mounted upon said first member, a second indicating means indicating the direction of movement of the body, a third indicating means indicating the direction of movement of the medium, a fourth indicating means indicating the rate of movement of the medium, movable means responsive to the vector sum of the movements of the second, third and fourth indicating means, an arm provided with a slidable connection connecting said movable and rotatable means for causing rotation of the rotatable means in accordance with the movements of the movable means and the first member, and indicating means for indicating the rotation of the rotatable means.

4. A navigating instrument for a body moving in a fluid medium comprising a first movable member, a first indicating means cooperating with

the first movable member for indicating the rate of movement of the body relative to the medium, a rotatable means rotatably mounted upon said first member, a second indicating means indicating the direction of movement of the body, a third indicating means indicating the direction of movement of the medium, a fourth indicating means indicating the rate of movement of the medium, movable means responsive to the vector sum of the movements of the second, third and fourth indicating means, an arm provided with a slidable connection connecting said movable and rotatable means for causing rotation of the rotatable means in accordance with the movements of the movable means and the first member, and indicating means for indicating the rotation of the rotatable means, a second movable member, means for moving said second member in accordance with the vector sum of the movements of the first member and said movable means, and indicating means responsive to the position of said second member.

5. A sight computing mechanism for movable ordnance to be used against a moving target comprising a pantograph, means for moving one portion of the pantograph in accordance with the relative result of the movement of the ordnance and the movement of the medium through which the ordnance moves, means for moving another portion of the pantograph in accordance with the movement of the target, a first movable member, means for moving the first movable member in accordance with the rate of movement of the ordnance with respect to the medium, a second movable member, a means for determining an angle of sight operably connected to said second movable member, and means connecting the pantograph and said first and second members for moving the second member in accordance with the vector sum of the movements of the pantograph and the first member.

6. A navigating instrument for a body moving in a fluid medium comprising a first movable member, means for moving the first movable member in proportion to the rate of movement of the body relative to the medium, a rotatable means rotatably mounted on the first member, a settable means and means for moving the settable means in accordance with the rate and direction of movement of the fluid medium, an arm provided with a slidable connection connecting said settable means and said rotatable means for rotating the

rotatable means in accordance with the position of the settable means, a second movable member movable along the same line of movement as the first member, said first member being provided with pulley means, means providing a yielding force tending to separate the first and second members, and a continuous filament extending from said settable means around said pulley means to said second member for moving said second member in proportion to the rate of movement of the body relative to the earth.

7. A navigating instrument for a body moving in a fluid medium comprising a rotatable member carrying a transverse slideway, a slide member, means for moving said slide member in said slideway in proportion to the rate of movement of the medium, said rotatable member being rotatable in accordance with the direction of movement of the medium, a first movable member movable toward and away from said rotatable member in proportion to the rate of movement of said body relative to the medium, a second rotatable member rotatably mounted upon said first movable member, and means including an arm provided with a slidable connection connecting said slide member and said second rotatable member for rotating said second rotatable member in proportion to the angle of drift.

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