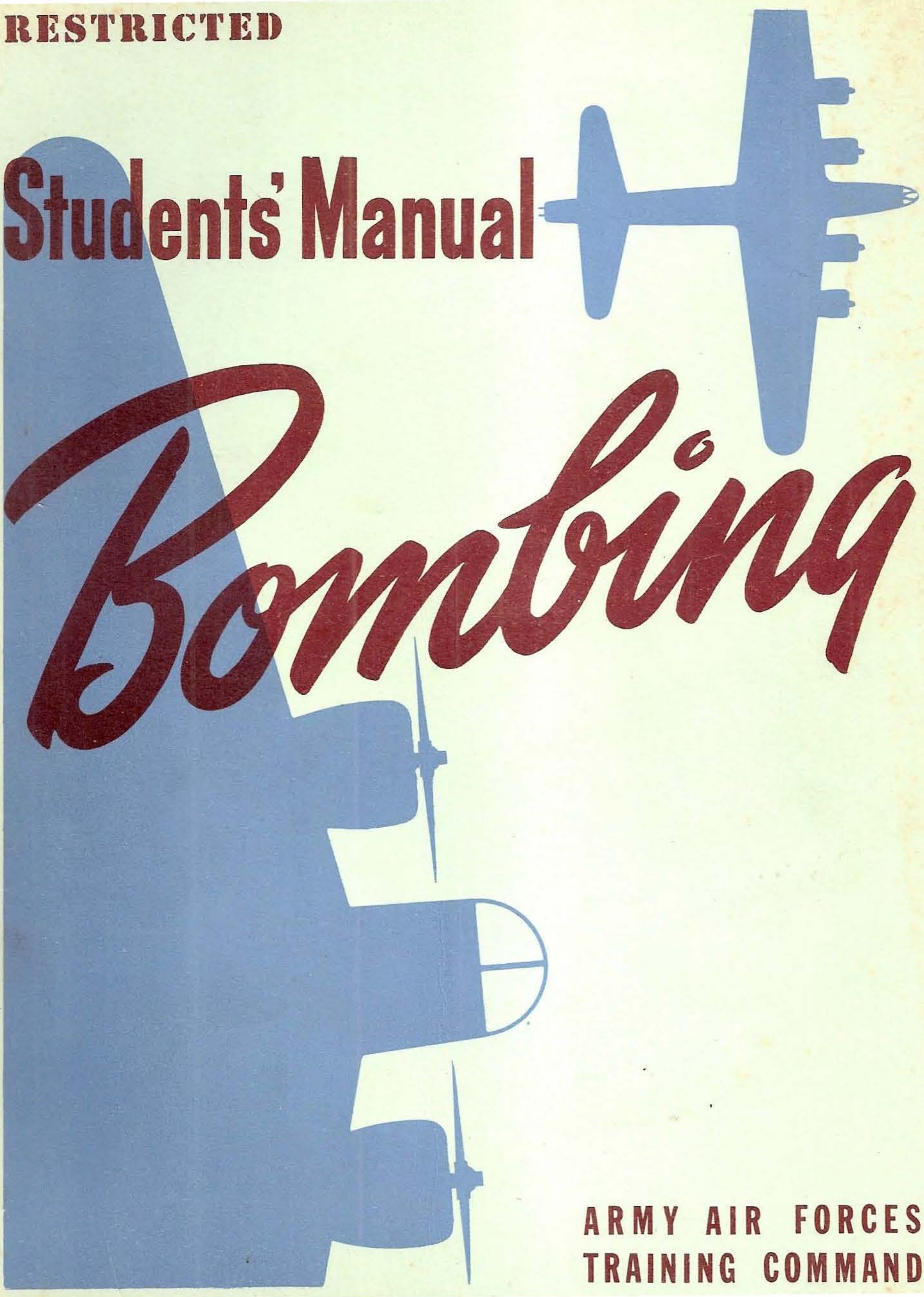
RESTRICTED

Students' Manual

Bombing



ARMY AIR FORCES
TRAINING COMMAND

STUDENTS' MANUAL

Bombing

Prepared by the

ARMY AIR FORCES TRAINING COMMAND

Visual Training Department, in Collaboration with the

ARMY AIR FORCES INSTRUCTORS' SCHOOL (BOMBARDIER)

M.A.A.F., Midland, Texas, and

ARMY AIR FORCES BOMBARDIER SCHOOLS

TO BE USED AS A SUPPLEMENT TO CURRENT AAF TRAINING COMMAND MEMORANDUM COVERING BOMBARDIER TRAINING

ARMY AIR FORCES TRAINING COMMAND

Foreword

The Air Force demands precision and absolute accuracy from the Bombardier. There is no middle ground. You are either an expert or you are not a bombardier. The importance of your responsibility is obvious. You, and your pilot, have equipment and training that will destroy the enemy.

This is your manual. It contains the combined combat experience plus the teaching experience of thousands of instructors. *Study It. Learn It.* Then, when you enter combat there will be no doubt of the results.

H. H. Arnold

Lieutenant General, U.S.A.,
Commanding

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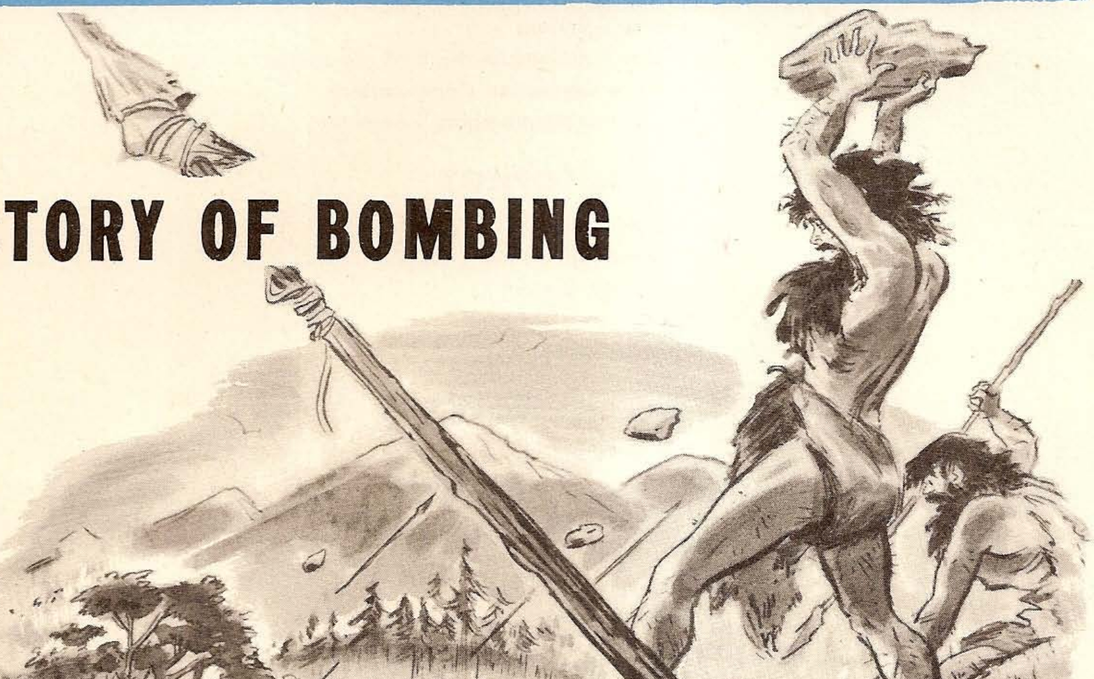
HISTORY OF BOMBING



Fleets of bombers, operating thousands of miles from their home bases, daily give new effectiveness to strategy.

This objective is to get above the enemy and drop destructive missles on him.

To get this "upper hold," warfare began with prehistoric man dropping rocks and spears from cliffs and trees. As the years went by and armies developed complexity in make-up and methods, it was still found advantageous to fight from heights. When free-floating balloons appeared, it took no imagination to foresee the possibilities of shooting down at the enemy and of dropping missles on him.

With the development of the airplane, men realized that here, for the first time in history, was a weapon with which to get above the enemy at any place and at any time. It was apparent that the airplane's range would far exceed that of the finest artillery, or of any known ground equipment.

Air Attack in World War I

At the start of World War I, the airplane was a frail craft with engines that needed most of their power to get the airplane off the ground and hold it aloft. For this reason, the early airplanes could carry only a small load of missiles. These were feather-weight, compared to the present-day block-busters.

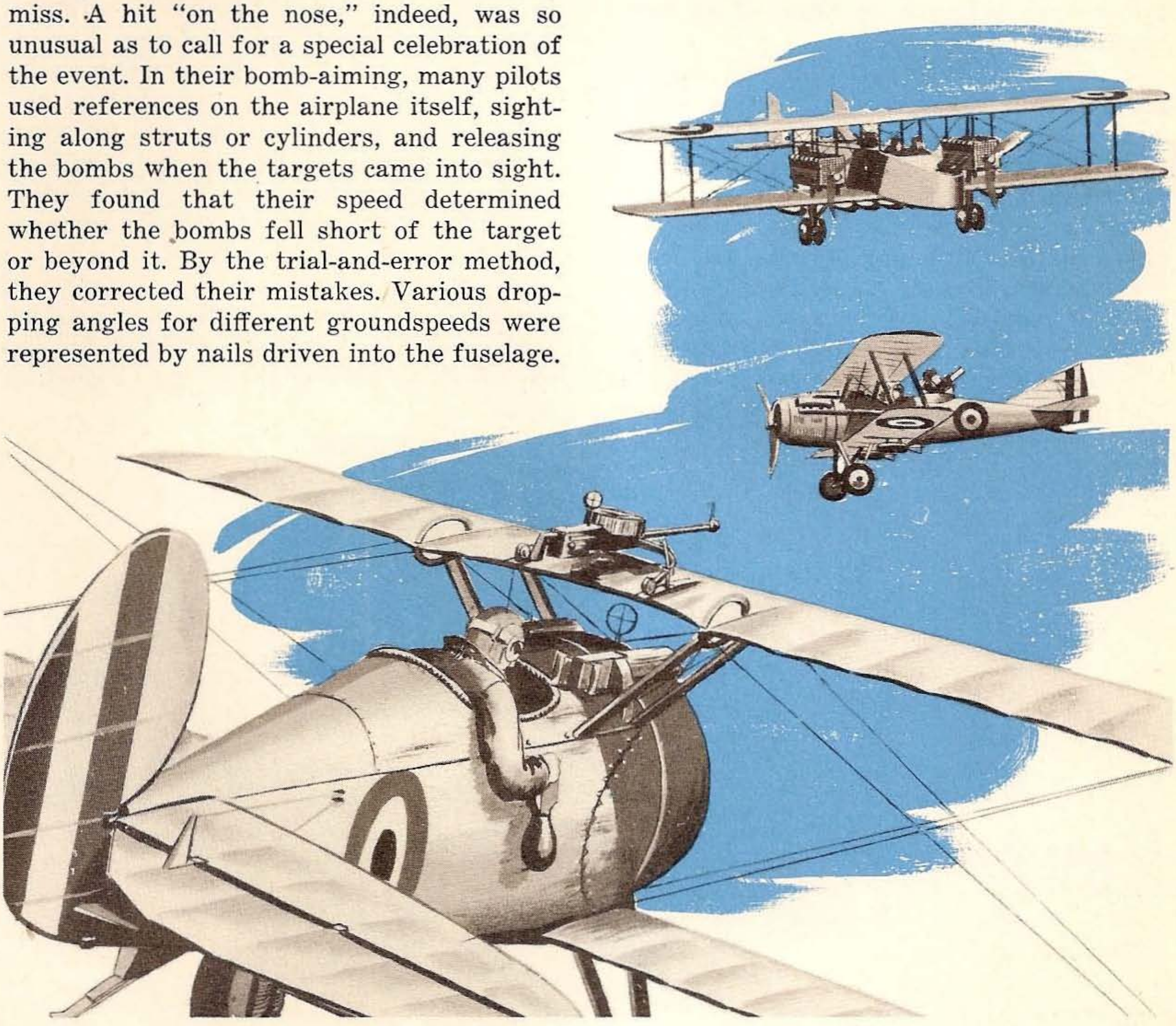
Pilots experimented for a time with steel darts, which were dropped on ground personnel. The next development, small shells were guided to their marks not by fins, as modern bombs, but by small ropes which dangled behind them like kite tails. Before the end of World War I pilots began using fragmentation and incendiary bombs which weighed 15 to 18 pounds.

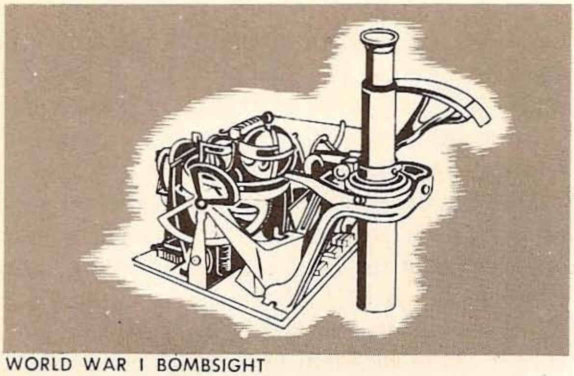
The pilot acted also as bombardier, and his aiming methods were hit-and-miss—mostly miss. A hit "on the nose," indeed, was so unusual as to call for a special celebration of the event. In their bomb-aiming, many pilots used references on the airplane itself, sighting along struts or cylinders, and releasing the bombs when the targets came into sight. They found that their speed determined whether the bombs fell short of the target or beyond it. By the trial-and-error method, they corrected their mistakes. Various dropping angles for different groundspeeds were represented by nails driven into the fuselage.

There was no allowance for drift. So the bombing runs were made either with the wind or against it. Most pilots used a headwind, because it slowed their groundspeed. This made it possible for them to get closer to the target before releasing their bombs.

Engineers increased the bombload capacity of airplanes by developing more powerful engines. But this did not help solve a basic problem: how to find the point in space at which to release the bomb, in order to hit the target. This problem became more acute, as improved ground defenses forced the bombing airplanes to go higher and faster.

AAF officers saw that they would have to find an accurate sighting device — and men who could use such a device with consistent efficiency—in order to make bombing effective.





WORLD WAR I BOMBSIGHT

Improvement in Bombsights

By the end of World War I, engineers had developed simple bombsights. These sights were not comparable to the present synchronous sights, but they produced results accurate enough to insure the future of air bombardment.

It is impossible to outline briefly the improvements that have been made in bombsights and other bombing equipment in the past 25 years. Volumes would be needed to tell only of one great achievement—how brilliant American engineers, mathematicians, physicists, and airmen solved the problem of designing an accurate bombsight. This task in itself required years of trials and tests. Discouragements were many, progress slow.

With the bombsight completed it took the best efforts of American industry to learn how to build these intricate devices to the close tolerances required, and in the large numbers called for by global war.

Avoid the common impression that the bombsight is a super-human, magic-brain device. True, it is an ingenious, precision mechanism; but it definitely is not a miracle machine which requires a miracle man to operate it. Nor is it a device which relieves its user of all responsibility. What it does is to solve understandable problems in an understandable manner.

Other equipment you will use includes the electronic co-pilot, which holds the airplane on its course; the computers, which save the time and trouble of making paper-and-pencil calculations; the intervalometer, which enables you to drop a train of accurately-spaced bombs, and oxygen equipment which makes it possible for you to ascend to altitudes higher than man ever went before.

You can match the excellence of this equipment only by cultivating your skill in handling it. This skill will qualify you for membership in that great group of men, the bombardiers, who have proved beyond question the ability of the AAF to pin-point ammunition dumps on tiny atolls in the Pacific, to destroy ships at sea, to blast bridges and communication lines far beyond artillery range, and to lay a ruinous pattern of fire and explosives on ANY of the enemy's industrial areas.

THEORY OF BOMBING

INTRODUCTION

Before the invention of airplanes, the principal means of dropping explosives upon the enemy was the long-range cannon. An airplane, in effect, advances the range of a cannon. Bombing is really aerial artillery.

In order to make a shell drop on a certain point, a cannon must hurl it up into the air, so that the path of the shell, or the trajectory, describes a wide arc in its flight through the air. The essential difference between firing a shell and dropping a bomb is that the airplane carries the bomb up into the air and releases it at the highest point of the trajectory. From that point on, the bomb follows the same downward path as the shell.

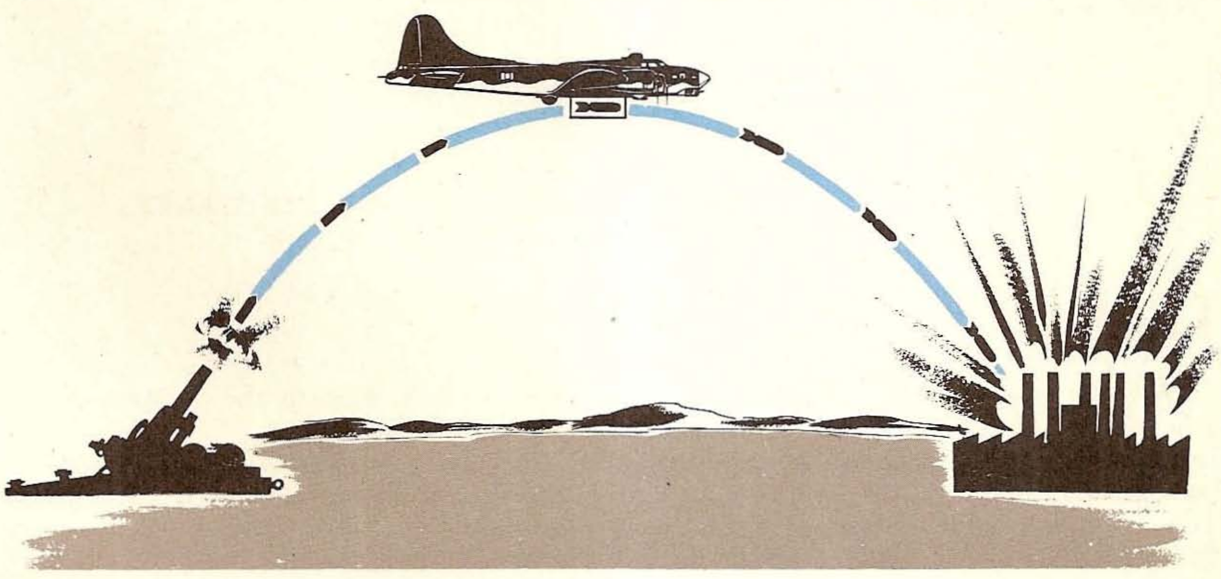
To make your bomb hit the target, the only thing you have to do is find the proper point in space from which to release it. Actually, the bombsight will find this point and release the bomb for you, provided that you put the proper data into it.

A thorough study of bombing theory, however, will enable you to understand what data must be set into the sight, how you set it in, and how the bombsight uses it to solve the bombing problem.

The bombing problem has two parts: the **course** problem and the **range** problem. **Course** means that the bomb must travel in the right direction, that is, toward the target. **Range** means that it must be released the correct distance back from the target, so that it will not fall short of the target or over it.

The course problem is fairly simple. A bomb always falls in the direction in which the airplane is headed at the moment of release. Therefore you solve your course problem by putting your airplane on the correct heading.

To understand the range problem, you must know something about falling bodies.



FORCES ACTING ON THE BOMB

The moment a bomb is released from an airplane, a number of forces begin acting upon it. These forces are: (1) gravity, (2) airspeed, (3) air resistance, and (4) wind. The result of these forces determines the path the bomb will follow and the point of impact.

Gravity

Gravity pulls the bomb toward the earth at a continually increasing speed. It exerts the same force on all bodies, whatever their size, shape, or weight.

True Airspeed

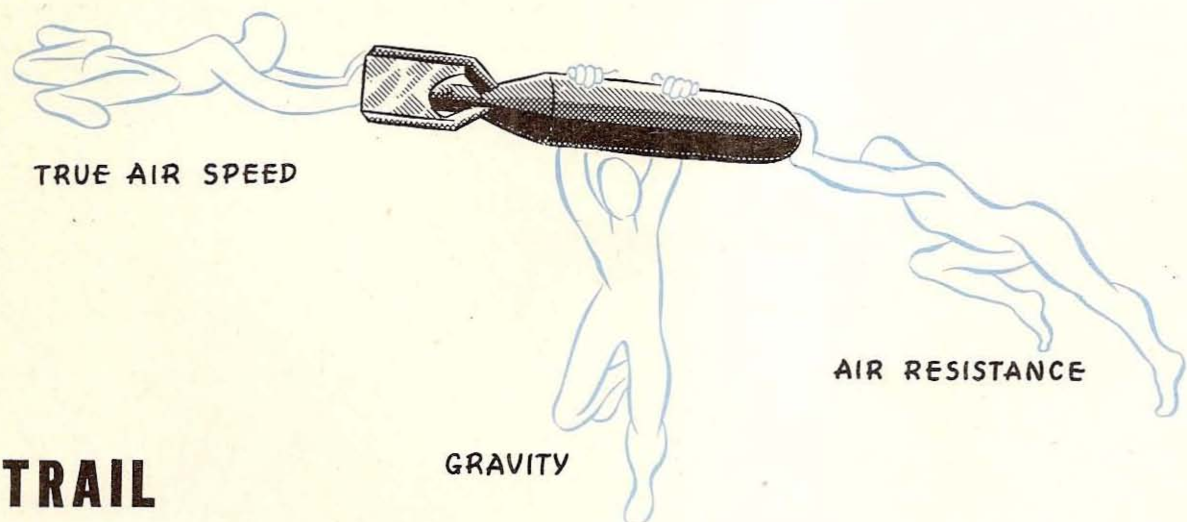
At the same time that gravity is pulling the bomb downward, velocity is driving it forward. Remember that the airplane is traveling at a definite speed with respect to the air. Since the bomb is a part of the airplane up to the moment of release, it leaves the airplane with the same forward velocity. In bombing, this forward velocity of the airplane and the bomb relative to the air is called true airspeed (TAS).

Remember that gravity and true airspeed are acting on the bomb at the same time. During the time between release and impact the bomb follows a path between the direction of these two forces. This time is called the **actual time of fall** (ATF).

Air Resistance

The third force affecting the bomb in its flight is one which acts against the first two. This force is **air resistance.** While true airspeed is driving the bomb forward, the air through which the bomb moves is resisting this motion. In other words, the air pushes back against the bomb, causing it to lag behind the airplane. The distance on the ground resulting from this resistance to the forward motion of the bomb is called horizontal lag.

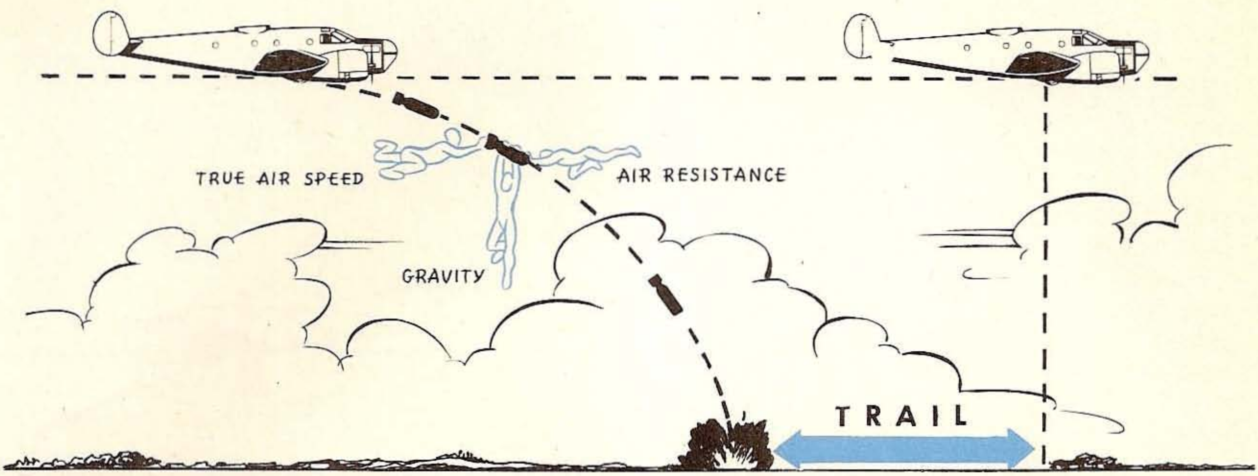
In the same way, air resistance acts against the force of gravity. This resistance tends to keep the bomb in flight longer. During the extra time required for the bomb to fall, the airplane continues to move forward. The distance on the ground over which the airplane travels during this extra time is called vertical lag.



TRAIL

The sum of these two distances on the ground is called **trail** (T). This is a good name for it, since it is the distance the bomb has trailed behind the airplane that dropped it. Trail is the horizontal distance measured on the ground from the point of impact to a point directly beneath the airplane at the instant of impact.

The amount of trail for various bombing altitudes, true airspeeds, and types of bombs has been determined by trial and error and is given in your bombing tables.



Remember that trail is the result of several forces which are acting on the bomb. While true airspeed is driving the bomb forward, air resistance is tending to hold it back; while gravity is pulling it down, air resistance is tending to hold it up. If true airspeed increases, the resistance of the air increases; thus the horizontal lag is greater. Therefore:

As true airspeed **increases,** trail **increases.**

In the same way, if the downward velocity increases, the resistance of the air to that force increases and the vertical lag is greater. Since the downward velocity depends on the bombing altitude from which the bomb is dropped:

As bombing altitude **increases,** trail **increases.**

The amount of resistance which the air offers to the bomb depends on the size and shape of the bomb. Ordnance engineers classify bombs into different types according to the **ballistic coefficient** of the particular bomb, which means the relative amount of resistance the air offers to it. A bomb with a high ballistic coefficient falls faster and with less trail than a bomb with a low ballistic coefficient. Therefore:

As ballistic coefficient **increases,** trail **decreases.**

ACTUAL TIME OF FALL

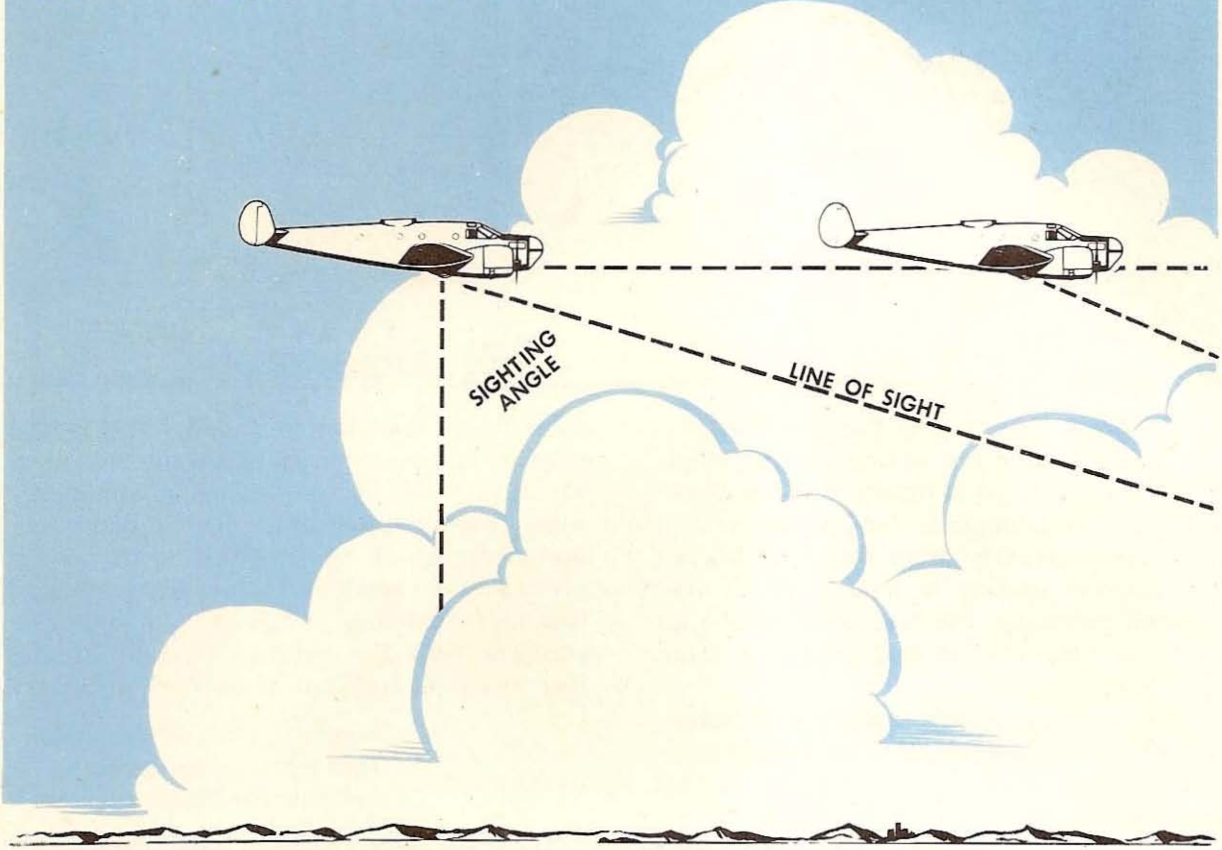
The **actual time of fall** (ATF) of the bomb depends primarily on the exact height of the airplane above the target, or the vertical distance which the bomb must fall, but it is also affected by true airspeed and bomb ballistics. The actual time of fall for each bombing altitude, true airspeed, and type of bomb has been determined by trial and error and is given in your bombing tables. Whenever you look up actual time of fall in your tables, be sure you have the correct bombing altitude, true airspeed, and type of bomb. Remember:

ATF **increases** as
- bombing altitude **increases.**
- true airspeed **increases.**
- ballistic coefficient **decreases.**

Trail and **actual time of fall** are the two factors you must set into your bombsight. You set actual time of fall into the **M-Series** Bombsight as a **disc speed,** but when using some sights you set in the **actual time of fall** directly. You set trail into the bombsight as a mil value. The tables give you the correct actual time of fall or the correct disc speed for each bombing altitude, true airspeed, and type of bomb. Similarly, the tables give you the correct trail for each bombing altitude, true airspeed, and type of bomb.

Therefore, before your sight can do anything for you, YOU MUST KNOW ACCURATELY your **bombing altitude, true airspeed, and type of bomb.** Once you have obtained from the tables your correct **trail** and **actual time of fall** and have set them into the bombsight, you must **synchronize** for course and range. If you do these few things correctly, the bombsight will automatically solve the bombing problem. It will find the correct point in space for the bomb release, and will **release** the bomb at that point.

BOMBING TERMS



Before considering wind, the fourth and final force on the bomb in its downward flight, you must understand certain fundamental bombing terms. Be sure that you get them thoroughly. They are terms you must use every day.

Whole Range and Groundspeed

In the first place, you must understand the term **whole range** (WR). Whole range is the horizontal distance traveled by the airplane from the moment the bomb is released until the bomb strikes the ground. To measure the distance covered by a moving object in a given time, you multiply the time by the rate at which the object is moving. Whole range is measured on the ground. Therefore, the rate you use is the rate at which the airplane is moving with respect to the ground. This rate is called **groundspeed** (GS), and in computing whole range, groundspeed must be in feet per second. The time used is the actual time of fall, and it is given in seconds. Therefore:

$$WR = GS\ (\text{ft/sec}) \times ATF$$

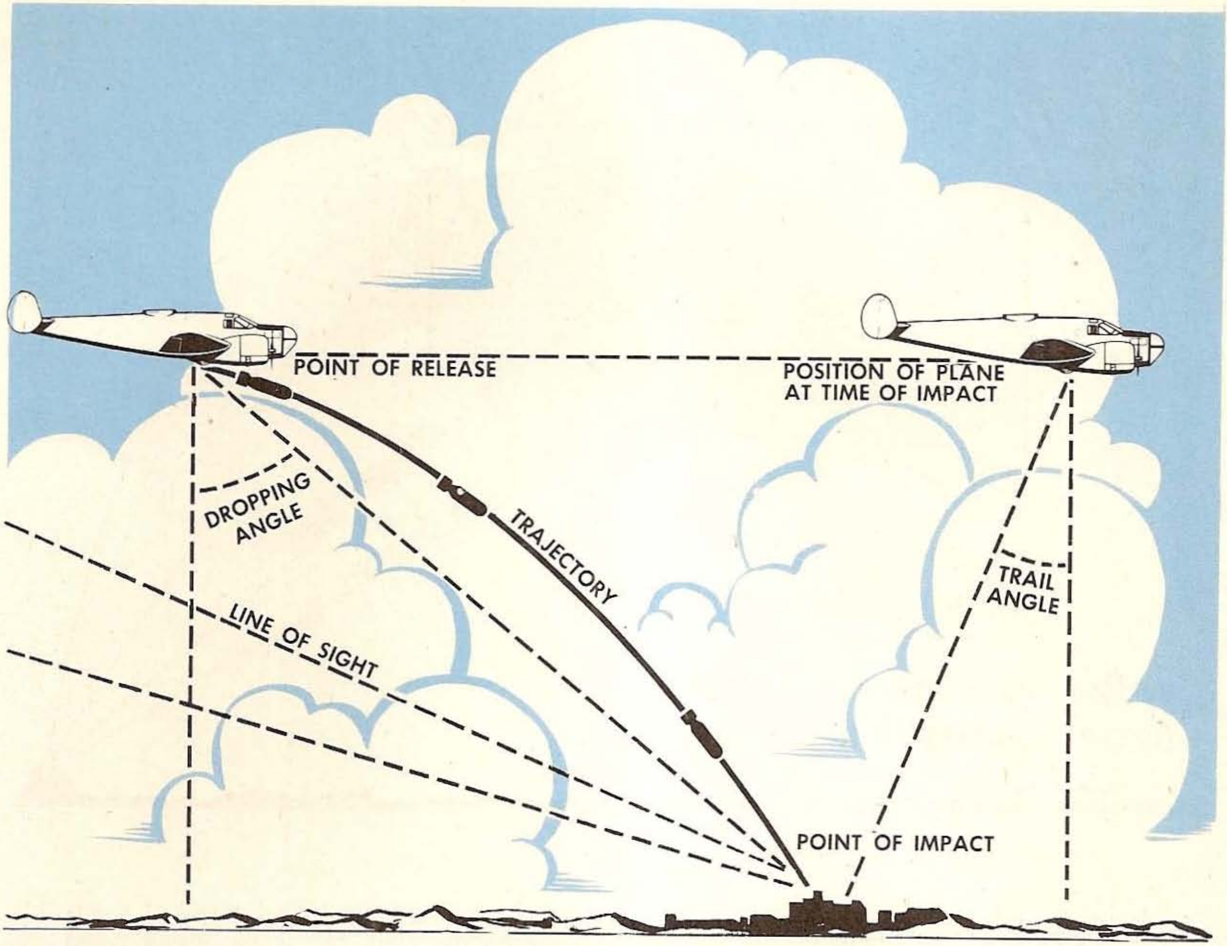
Suppose that a bomb is dropped from an airplane traveling at a groundspeed of 150 mph, and that the bomb takes 20 seconds to reach the ground. In order to find the whole range, you must first change your groundspeed of 150 mph to feet per second. To do this, multiply 150 by

$$\frac{5{,}280\ (\text{ft. in a mile})}{3{,}600\ (\text{sec. in an hr.})},\ \frac{88}{60}\ \text{or}\ \frac{22}{15}$$

The groundspeed in this problem is therefore 220 feet per second. Then $220 \times 20 = 4{,}400$ ft. whole range. In other words, the airplane flies 4,400 ft. while the bomb is falling.

Actual Range

Actual range (AR) is the horizontal distance that the **bomb** travels from the moment



of release until the moment of impact. Since the bomb lags a certain distance behind the airplane (trail), you can find actual range by subtracting trail from whole range.

$$AR = WR - T$$

If your whole range is 4,400 ft. and you find by using your bombing tables that your trail is 270 ft., your actual range is 4,130 ft. While your airplane is traveling 4,400 ft. forward, the bomb travels only 4,130 ft. forward.

Line of Sight

Whenever you look at the target through your bombsight, you are looking along a line, from bombsight to target, which is called the **line of sight.** As your airplane moves toward the target, of course your line of sight changes.

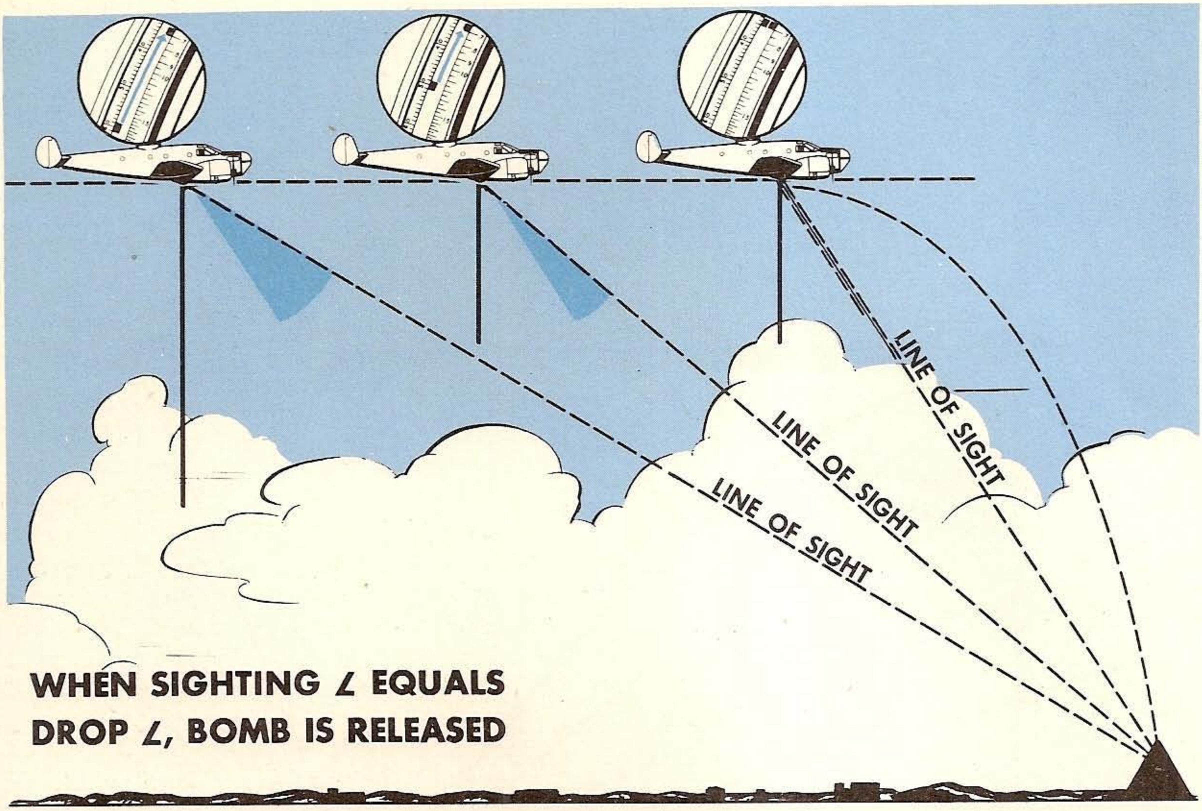
When you have set up the proper course toward the target, you have yet to find the actual range, that is, the correct distance back from the target that the bomb must be released in order to score a hit. If you set the proper data into the bombsight, it solves this problem for you automatically. It measures an angle which subtends actual range, thereby locating the proper point in space for the bomb's release.

Sighting Angle

To do this, the bombsight sets up a vertical line of reference between itself and the ground. The angle between this vertical reference and the line of sight at any instant is called the **sighting angle.** As the airplane approaches the target, the line of sight sweeps toward the vertical and the sighting angle grows smaller.

Dropping Angle

The particular sighting angle set up by the bombsight at the instant of release is called the **dropping angle** (Drop ∠). The dropping angle is the angle formed between the line of



sight and the vertical reference at the instant the bomb drops from the airplane.

True Vertical and Bombsight Vertical

If you operate the bombsight correctly, it will establish as the vertical line of reference a line which is the **true** vertical, that is, a line which is exactly perpendicular to the ground. If you do not operate the bombsight correctly, the line of reference it sets up will not be true vertical. But remember that the sighting angle and the dropping angle are measured from the vertical reference set up by the bombsight, whether this is the true vertical or not.

Range Angle

The **range angle** is the angle between the line of sight and the true vertical. At the instant of release, this angle differs from the dropping angle by the amount the vertical reference is out of the true vertical.

Actual Range Angle

The **actual range angle** (AR∠) is the angle which subtends the actual range of the bomb. This means that the lines which form the angle strike off on the ground the actual range distance. If the bombsight sets up a true vertical reference and the bombing problem has been properly solved, the dropping angle is the same as the actual range angle and also subtends the actual range of the bomb.

Whole Range Angle

The **whole range angle** (WR∠) is the angle which subtends whole range. It is measured from the true vertical at the instant of release.

Trail Angle

The angle which subtends trail is called the **trail angle** (T∠). In bombing, trail is given and used in terms of mils.

Tangent Values of Angles

Angles can be measured by using what is called the **tangent** of the angle, and this is the method the bombsight uses. The tangent of an angle in a right triangle is the number you get when you divide the length of the side opposite the angle by the length of the side adjacent to the angle.

$$\text{Tangent} = \frac{\text{opposite side}}{\text{adjacent side}}$$

Reading Angles from the Bombsight

The particular tangent which you can read from the bombsight is the tangent of the dropping angle (Tan Drop ∠). The side opposite the dropping angle is the actual range, and the side adjacent to the dropping angle is bombing altitude (BA).
Therefore,

$$\text{Tan Drop} \angle = \frac{\text{AR}}{\text{BA}}$$

In the same way,

$$\text{Tan T} \angle = \frac{\text{T (in ft.)}}{\text{BA}}$$

Since the trail angle is comparatively small, it is measured in **mils** (m̸) rather than in degrees. A mil is an angle whose tangent is 0.001. An angle of 3 mils has a tangent of 0.003; an angle of 35 mils has a tangent of 0.035. One mil subtends a distance on the ground equal to 1/1,000 of the BA. At 1,000 ft. BA, 1 mil of trail subtends 1 ft. on the ground. At 8,000 ft., 50 mils of trail subtends 400 ft. Therefore:

$$\text{Tan T} \angle = \frac{\text{T (in mils)}}{1{,}000}$$

$$\text{T (in ft.)} = \text{T (in mils)} \frac{\text{BA}}{1{,}000}$$

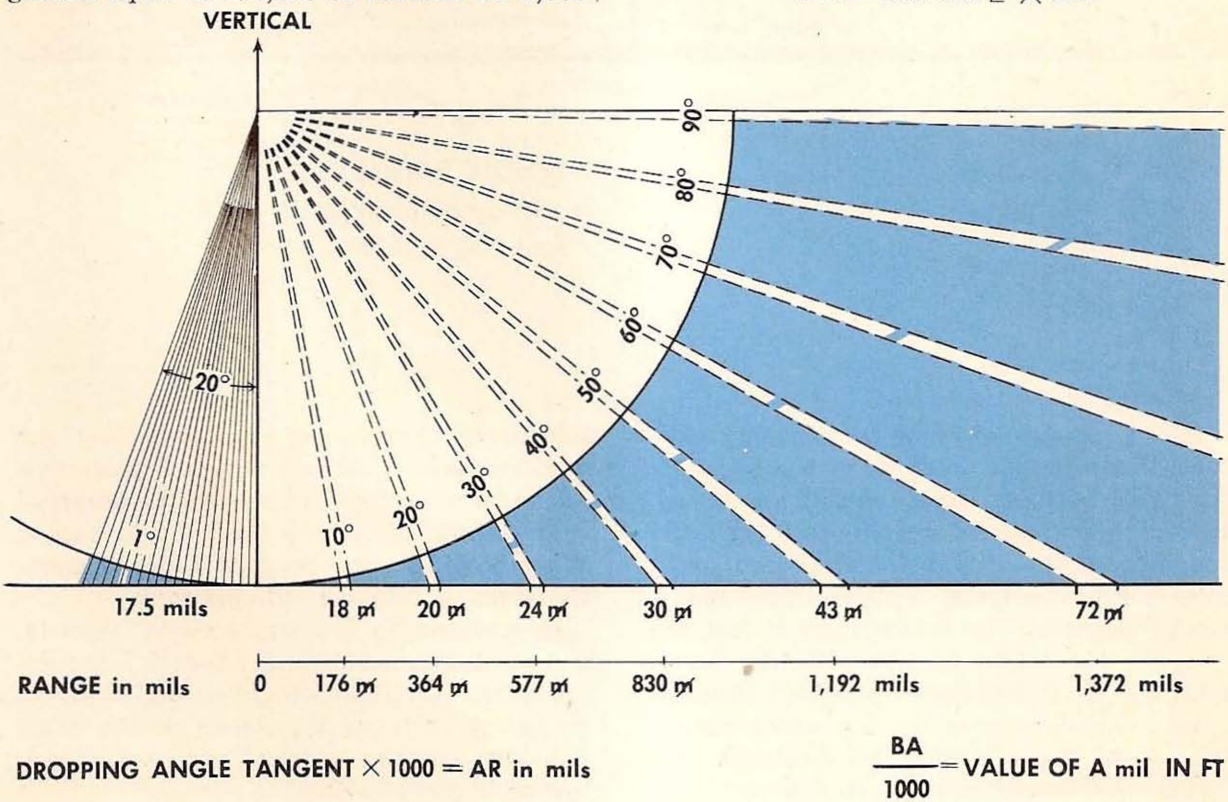
Since whole range equals actual range plus trail, then:

$$\frac{\text{WR}}{\text{BA}} = \frac{\text{AR}}{\text{BA}} + \frac{\text{T}}{\text{BA}} \text{ Therefore:}$$

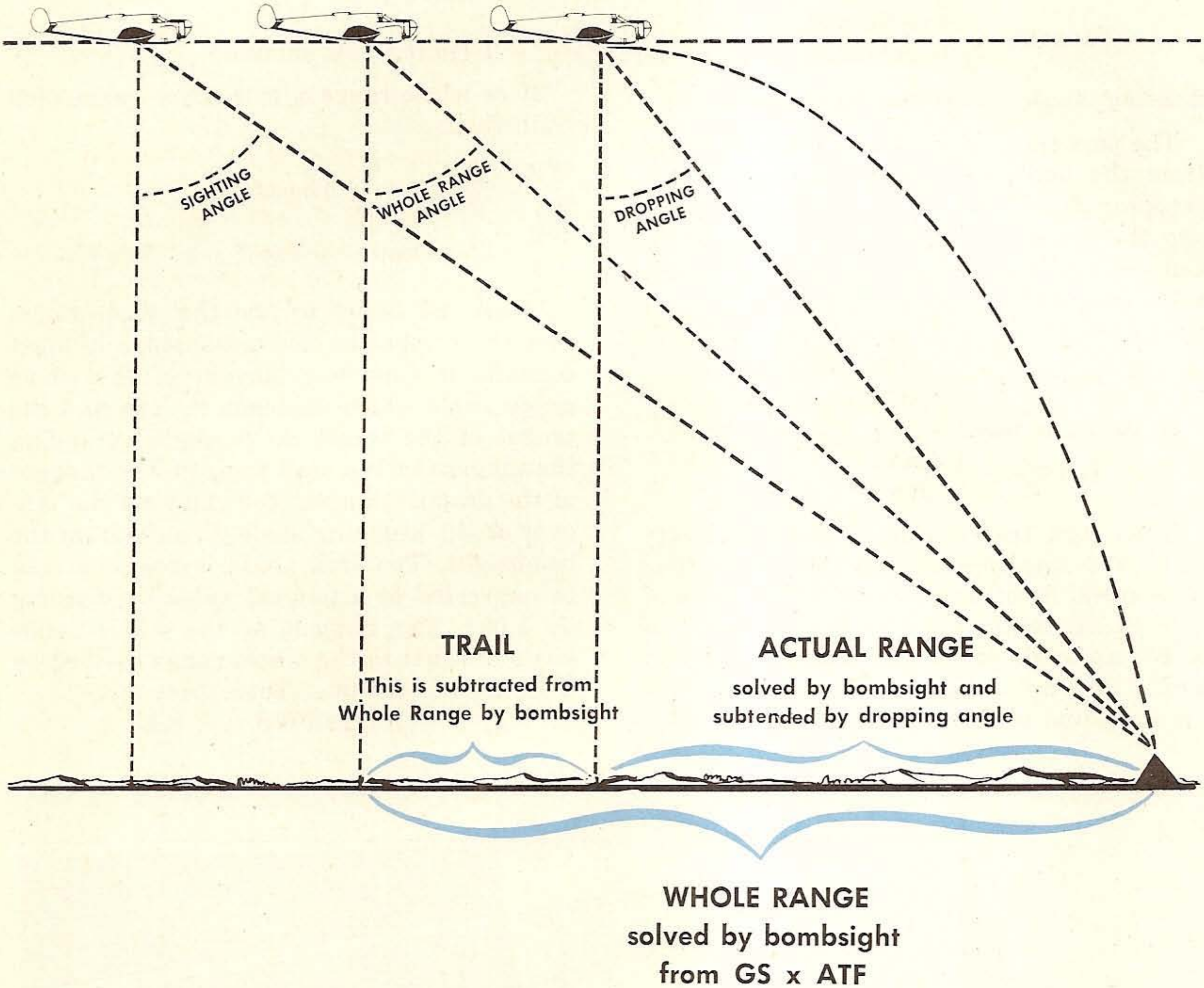
$$\frac{\text{WR}}{\text{BA}} = \text{Tan Drop} \angle + \text{Tan T} \angle = \text{Tan WR} \angle$$

When you desire to find the whole range that the bombsight has measured, you must compute it from the tangent of the whole range angle which subtends it. You find the tanget of the whole range angle by adding the tangent of the trail angle to the tangent of the dropping angle. You can read the tangent of the dropping angle directly from the bombsight. The trail angle is read and can be converted to a tangent value by dividing by 1,000. The tangent of the whole range angle is equal to the whole range divided by the bombing altitude. Therefore:

$$\text{WR} = \text{Tan WR} \angle \times \text{BA}$$



SOLUTION OF THE RANGE PROBLEM



It is necessary to know the bombing altitude, true airspeed, and type of bomb to find from your bombing tables the **trail** and **actual time of fall** to set into your bombsight. By keeping the line of sight on the target, you solve for groundspeed. This is called **range synchronization.** The actual time of fall set into the bombsight is automatically multiplied by the groundspeed obtained through synchronization to solve for **whole range.** During this operation the trail that was previously set into the sight is automatically subtracted from whole range, leaving the measurement of **actual range.** During this operation the bombsight sets up the **dropping angle** which subtends this actual range. When sighting angle reaches dropping angle, the bomb is released automatically.

In addition to gravity, forward velocity, and air resistance, there is a fourth force acting on the bomb in its flight and affecting its trajectory. This is the speed of the wind. Consider first the simplest wind conditions: tailwinds and headwinds.

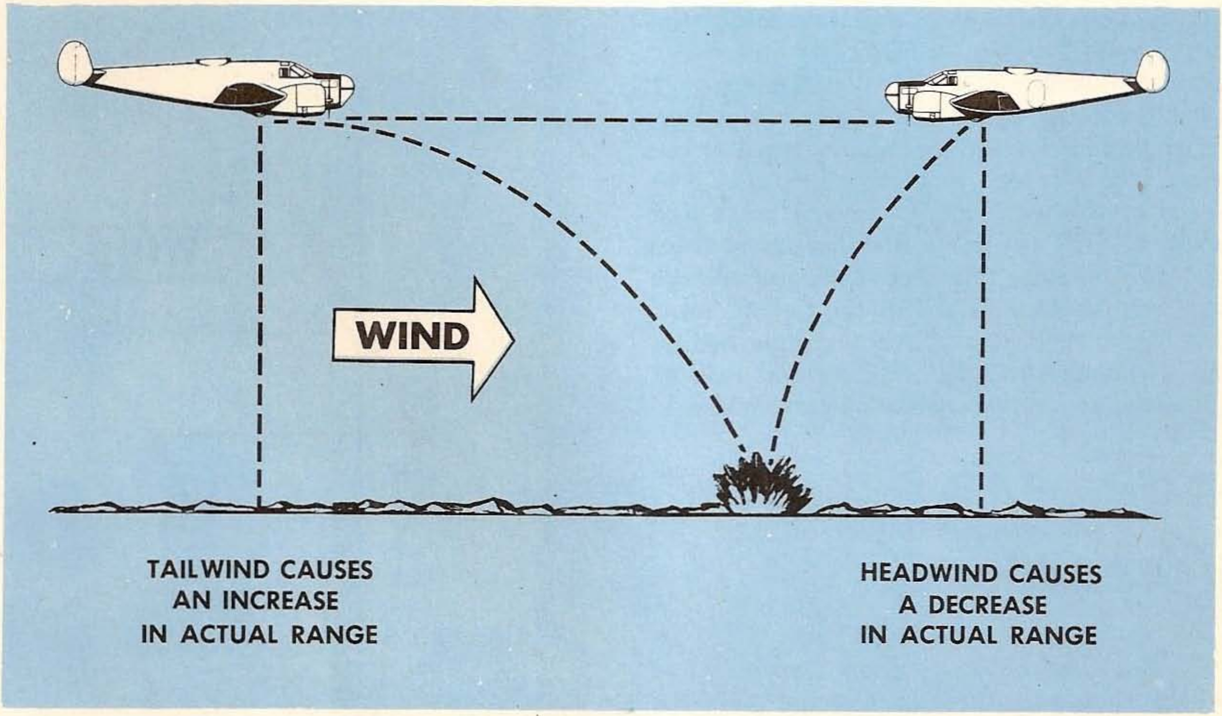
HEADWINDS AND TAILWINDS

The first thing to notice about a headwind or tailwind is that it does not affect the true airspeed of the airplane. Sin^e trail depends only on true airspeed, bombing altitude, and type of bomb, neither a headwind nor a tailwind has any effect on the amount of trail.

Groundspeed is the factor which is affected by a headwind or a tailwind. If your airplane is flying at a true airspeed of 150 mph, with a tailwind which pushes the air forward at 10 mph, then the airplane's speed over the ground is 160 mph. Since whole range is found by multiplying groundspeed (in feet per second) by the actual time of fall, an increase in groundspeed causes an increase in whole range. Actual range is also increased, since actual range is found by subtracting trail from whole range. Therefore, a tailwind causes an increase in whole range and a corresponding increase in actual range.

When your actual range is increased, you must drop your bomb at a greater distance from your target in order to hit it. This means that the dropping angle must be greater. When there is a tailwind your bombsight sets up a dropping angle with a larger tangent.

When your airplane flies directly into a headwind, all these results are reversed. The groundspeed is less, and your actual range is smaller. Your bombsight therefore sets up a smaller tangent of the dropping angle.



Wind Does Not Effect
The Amount of Trail!

CROSSWINDS

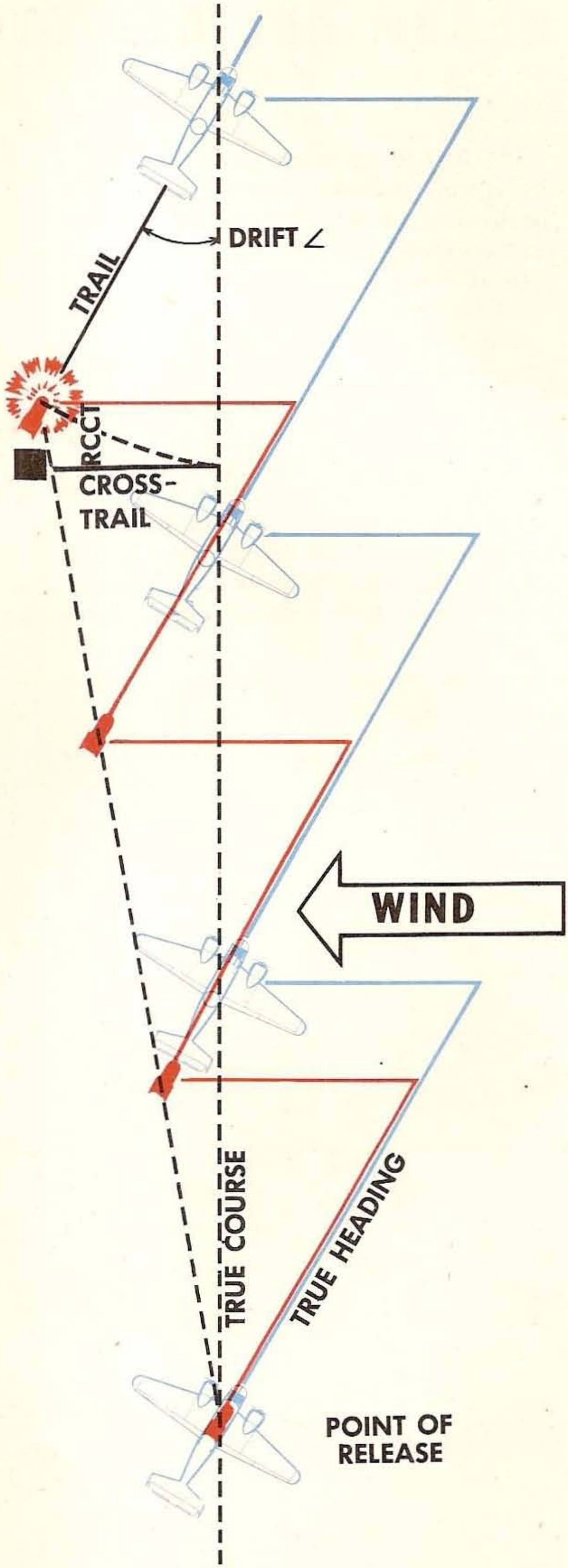
When you have a wind from any direction except from dead ahead or directly behind the airplane, **drift** enters the bombing problem. Wind is the movement of the entire body of air surrounding the airplane. When the wind moves to the right, the airplane moves to the right. This is called **right drift.** Similarly, if the body of air is moving to the left, the movement of the airplane is described as **left drift.**

In order to make good a certain path over the ground (true course) when there is a crosswind, the pilot crabs the airplane into the wind. That is, he heads the airplane upwind sufficiently to compensate for the effect of drift. The angle formed between true heading and true course is called the **drift angle.**

At the moment of release, true airspeed is driving both the airplane and the bomb in the direction of heading. Immediately on release, air resistance begins to reduce the forward velocity of the bomb. The engines, however, continue to drive the airplane forward at the same true airspeed as at bomb release. The speed of the wind causes both airplane and bomb to drift the same distance away from the true heading. Therefore the bomb always lags behind the airplane in the line of heading. The bomb will strike the ground behind the airplane, along the longitudinal axis of the airplane, and downwind of true course.

Crosstrail

If the airplane made good a true course which would pass directly over the target (**a collision course**), the bomb would strike the ground downwind of the target. The airplane must therefore make good a true course upwind of the target. The distance between the true course of the airplane and the collision course is called **crosstrail** (CT). Crosstrail is measured from the point of impact to the true course.



The bombsight automatically measures crosstrail for you. Crosstrail depends on **trail** and drift. To make its computation, the bombsight uses what is called the **sine** of the drift angle. The sine of an angle in a right triangle is the number you get when you divide the opposite side by the hypotenuse. The side opposite the drift angle is the crosstrail; the hypotenuse is the trail. Hence the sine of the drift angle is the crosstrail divided by trail. Therefore:

$$CT = T \times \text{Sin Drift} \angle$$

The bombsight can compute crosstrail because you have set trail into it and have automatically set up the drift angle when you set up your course. Naturally, if there is no drift there will be no crosstrail. In the same way, if you forget to set in trail, the bombsight cannot compute crosstrail for you. Therefore you MUST remember to set in trail, because if you do not your bomb will fall not only short but also downwind of the target.

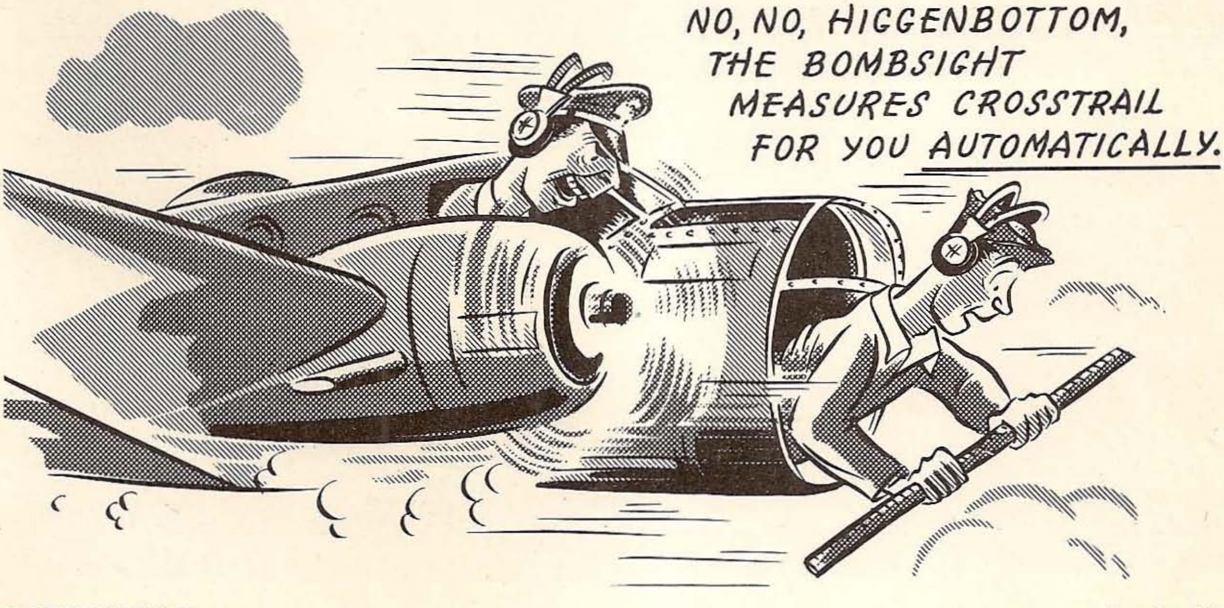
RCCT

You must notice one final fact about the effect of crosswind on the bombing problem. In the crosstrail drawing, the point of impact of the bomb is shown a small distance over the target. Although the distance is exaggerated in the drawing, nevertheless this error is always present in all computations performed by modern bombsights whenever a crosswind is present. The error is called **range component of crosstrail** (RCCT). It results from the fact that the bombsight measures trail along the course of the airplane, whereas when there is a crosswind, trail actually occurs along the line of **heading.**

When there is no crosswind, heading and course coincide; there is no crosstrail and no RCCT. But when wind and crosstrail exist, the bombsight still measures trail along the course. If you measure from a point on the ground directly beneath the airplane at the moment of impact back along the course to a point opposite the target, you have the trail as solved for by the bombsight. But if you measure this same distance back along the heading of the airplane, you find that this trail distance does not reach the target. Instead, it reaches to a point on the collision course ahead of the target. The distance from the target to this point of impact ahead of the target is the range error "over," known as RCCT. The equation for computing RCCT is:

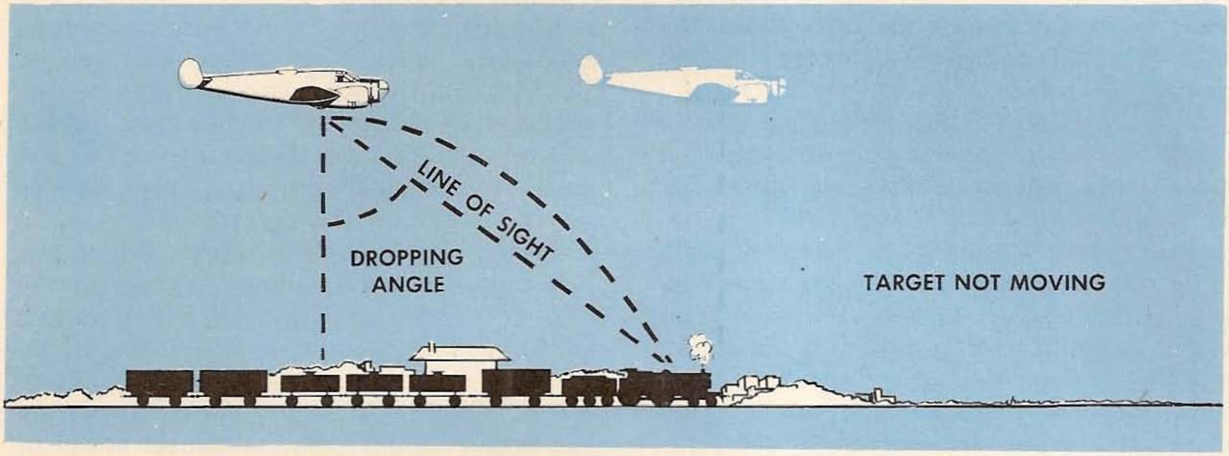
$$RCCT = T(1 - \text{Cos Drift} \angle)$$

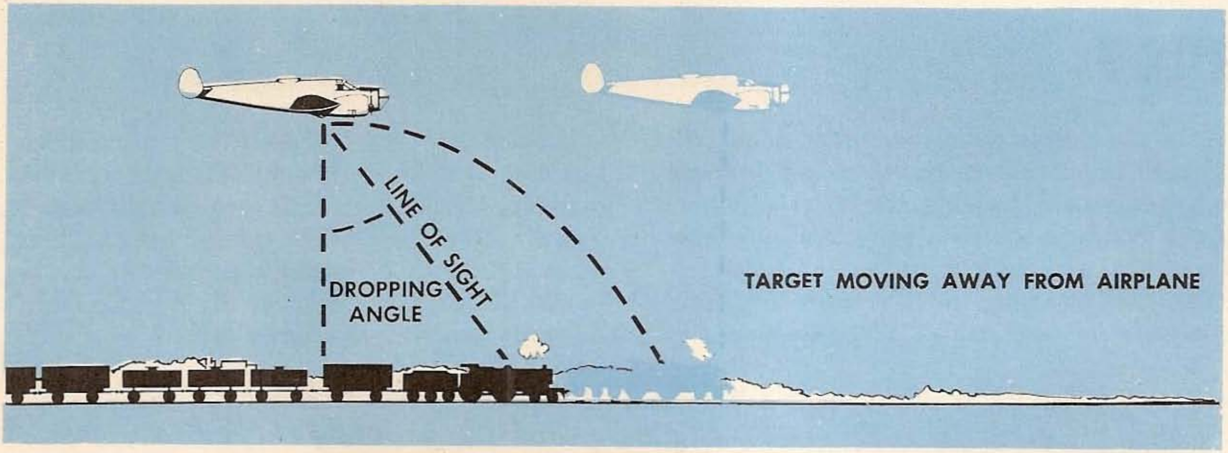
Notice that RCCT depends on trail and the amount of drift. In low and medium altitude bombing, trail and drift are usually small enough that the "over" caused by RCCT is negligible. RCCT produces significant errors when a high-speed bomber, flying at a high altitude, encounters a large drift.

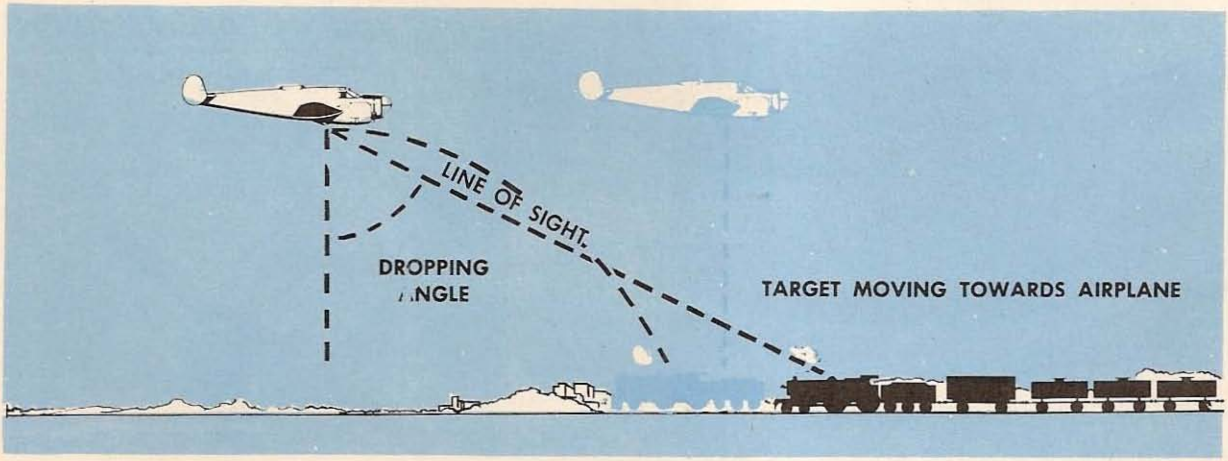


THE MOVING TARGET

A moving target is often the object of attack. If you attack a target which is moving in a straight line at a constant speed, no new element is introduced into the bombing problem. A **target moving away** from the airplane in the same line as the airplane's course presents the same problem as a stationary target when a **headwind** is blowing. Similarly, a **target moving toward** the airplane along the course is like a stationary target when a **tailwind** is blowing. Also a target moving in







a straight line across the course presents the same problem as a stationary target with a crosswind blowing from the direction opposite to that in which the target moves.

Remember that a bombsight develops whole range, actual range, and dropping angle by analyzing the **speed of closure** between itself and the target, that is, the speed at which the distance between them is closed. When the target is stationary, the speed of closure is the same as the groundspeed of the airplane. When the target is moving, the speed of closure is the groundspeed of the airplane plus or minus the groundspeed of the target.

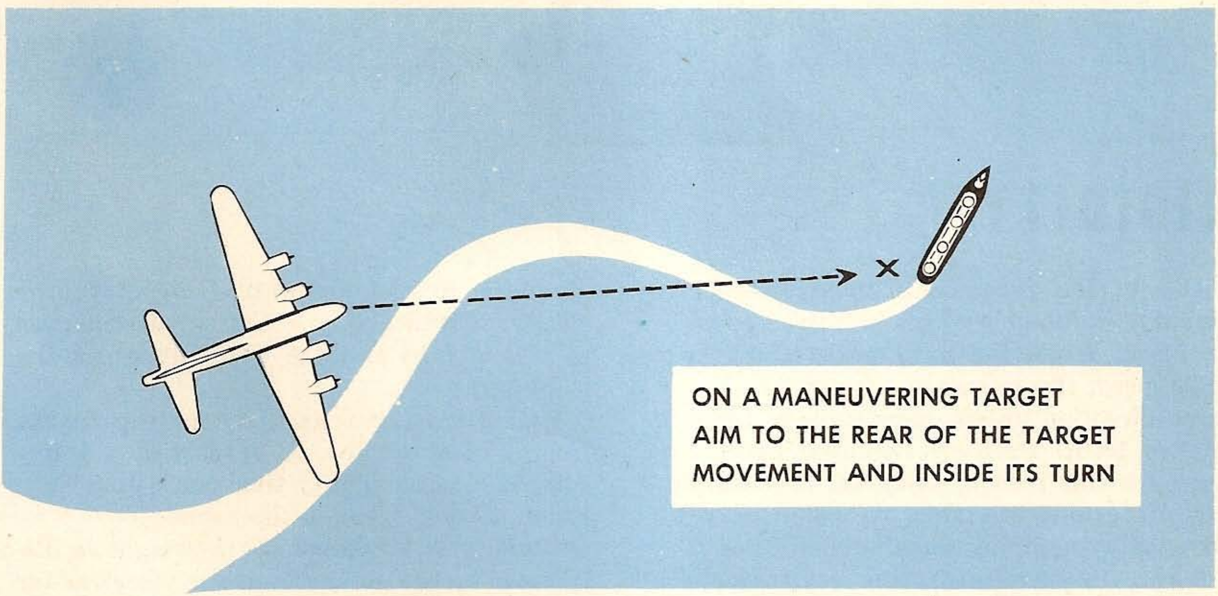
When an airplane traveling at a groundspeed of 150 mph is overtaking a train retreating at 50 mph, the airplane is actually closing with the train at a speed of 100 mph. The bombsight solves for this speed of closure in setting up the dropping angle. When the train approaches the airplane, the speed of closure is 200 mph and consequently the dropping angle is larger.

If the train moves in a straight line **across** the track of the airplane, the bombsight handles the situation just as if the target movement were drift caused by a crosswind. In fact, in setting up your course you could not tell the difference between a left drift and an actual target motion to the right. In either case you must crab the airplane to the right and set up a course to right of target.

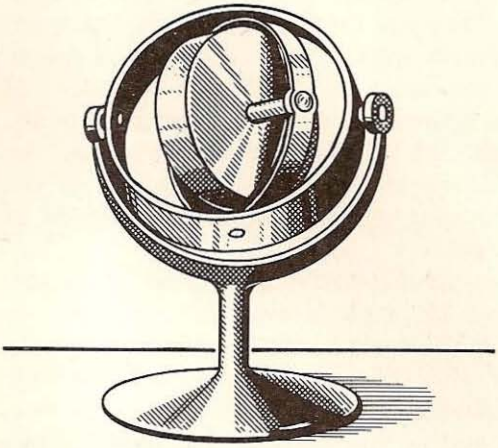
If you had a target moving diagonally across the course and at the same time a crosswind blowing, it would be very hard to determine the speed of closure mathematically. But, you do not have to worry about such a problem. The bombsight automatically solves it and determines the correct course and dropping angle.

However, there are two situations involving moving targets which the bombsight cannot handle adequately. First, if the target keeps changing its speed, the bombsight cannot synchronize for rate or determine the amount of crab required, and thus cannot set up the correct course or dropping angle. Second, if the target does not move in a straight line, the bombsight cannot set up either course or dropping angle accurately, since it has no means of predicting where the target will be at the time of impact.

If you try to bomb a target which is maneuvering, the only thing you can use in solving your bombing problem is the experience of AAF bombardiers. They have discovered that to hit a maneuvering target you must aim to the **rear of the target movement and inside its turn.** The only way to become proficient in bombing targets of this sort is to put in a great deal of practice on the bombing trainer and have actual bombing experience.

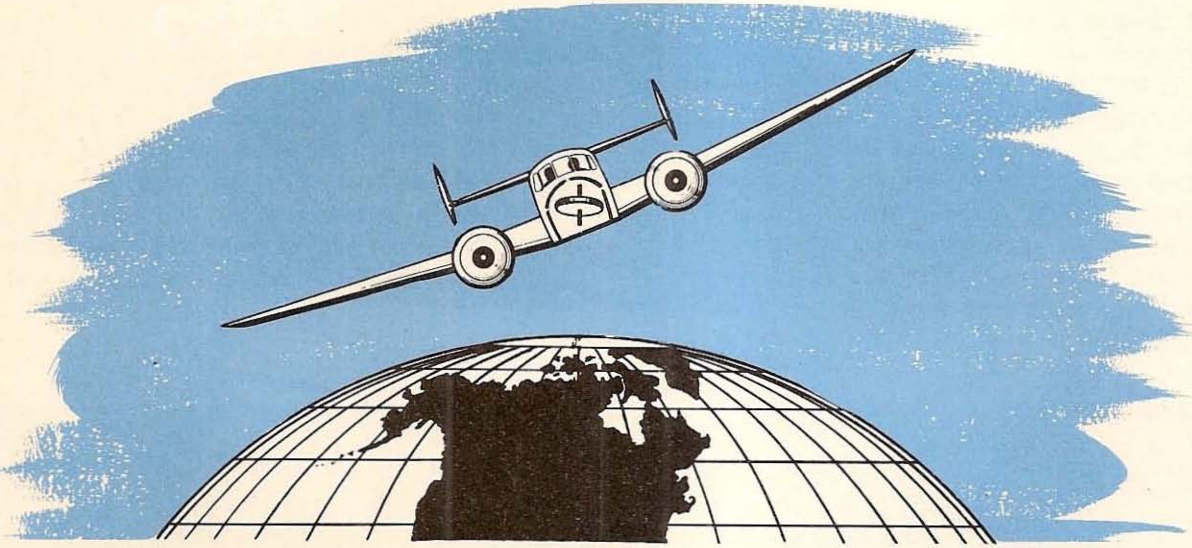


THE GYROSCOPE



Your airplane pitches, turns, and rolls. You couldn't synchronize your bombsight with precision, if you did not have some means for holding the sight in a steady, fixed position relative to the earth. The gyroscope is the only device that will hold your sight in a firm, stable position, regardless of the movements of your airplane.

A gyroscope is simply a spinning flywheel. Well balanced, this wheel revolves around its only fixed point, its center of gravity. It is free to turn or tilt in any direction about this point.



RIGIDITY

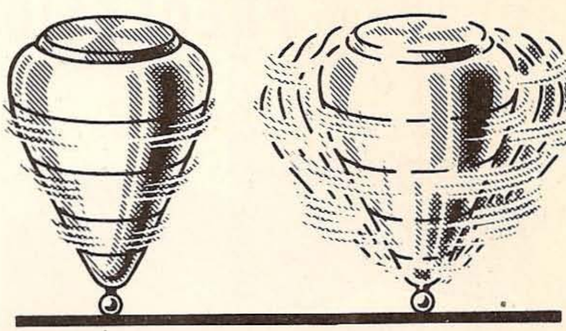
One of the gyroscope's characteristics is rigidity: its tendency to hold a fixed position in space. When the gyro wheel spins at a high speed, the spinning axis remains in the same direction unless some outside force is applied to it. Properly mounted gyros are used, for this reason, as an aid in maintaining direction; but this direction may be changed by applying some outside force.

Three factors determine a gyroscope's strength or the amount of rigidity: the weight of its wheel or rotor, the distribution of this weight and the speed at which the rotor spins.

Rigidity is increased by adding to the weight of the rotor. A gyro with a heavy rotor has more rigidity than one with a light rotor, if their speed is the same.

Rigidity is increased if the weight is distributed on the outer rim of the wheel, as far from the spin axis as possible.

Finally, rigidity increases as the speed of the rotor increases. A slowly spinning rotor gives the gyro little or no rigidity. An example is a boy's top which wobbles and then falls over on its side when its speed of rotation decreases.



APPARENT PRECESSION

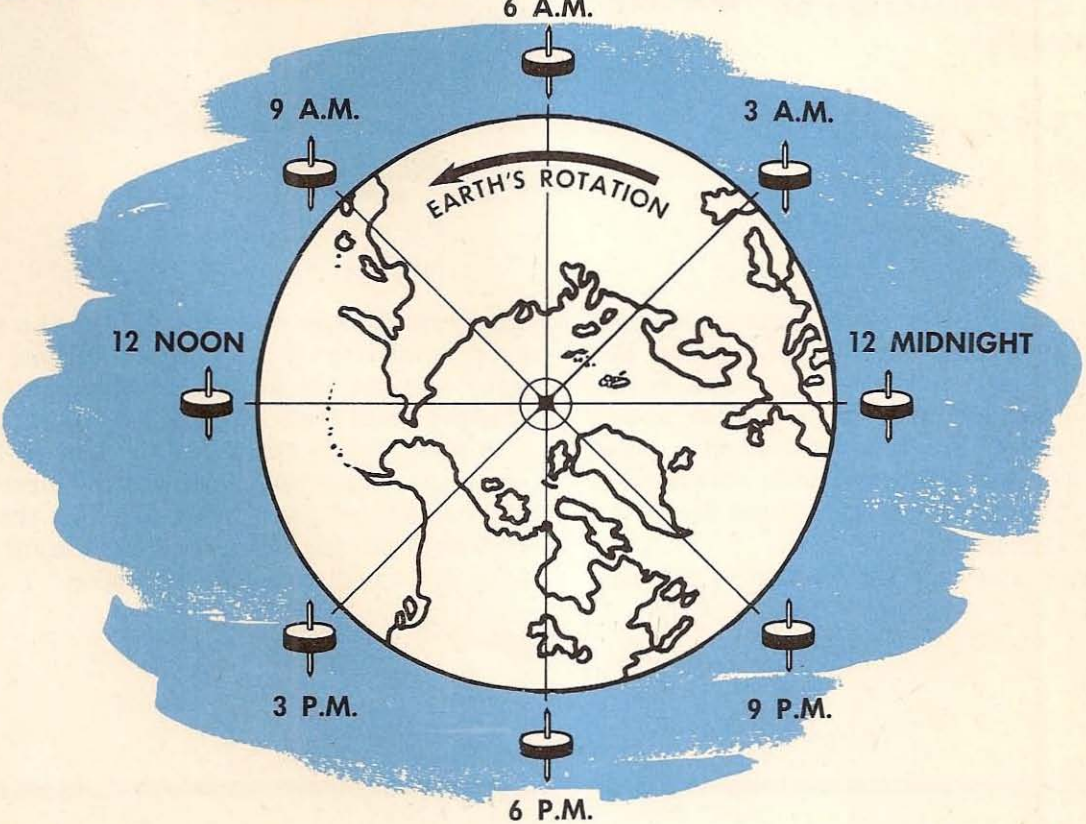
Rigidity causes the gyro's spin axis to point in a fixed direction. However, as the earth turns under the gyro, the axis of the gyro **appears** to tilt.

Suppose you have a gyro at the equator. At noon its spin axis is horizontal. At 6 P.M., the axis is vertical to the earth. By midnight the gyro is upside down from its noon position. It appears that the gyro has turned over; this is an illusion. The earth has turned, not the gyro's spin axis, which is the same at midnight as it was at noon.

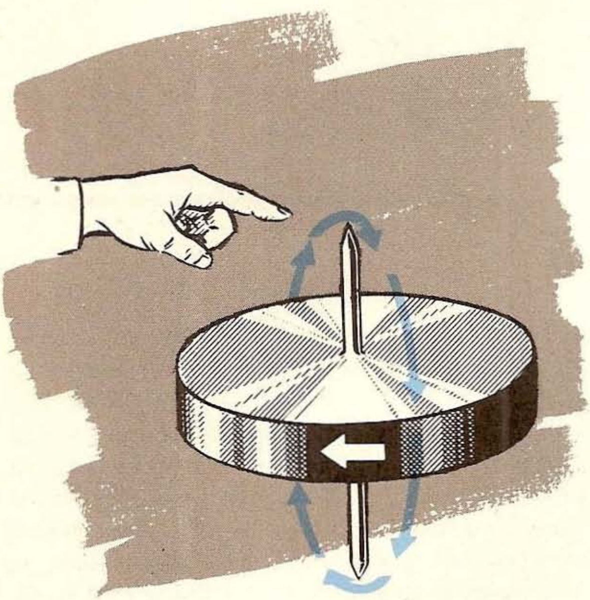
This movement of the earth in relation to the gyro is called **apparent precession.**

The greatest amount of apparent precession is at the equator. There, in 4 minutes, a gyro will apparently precess 17.45 mils. The amount of apparent precession decreases as you move from the equator toward the north or south poles where apparent precession is zero. You can determine, in mils, the amount of apparent precession that takes place in 4 minutes in any latitude, by using this equation: $17.45 \times$ cosine of the latitude.

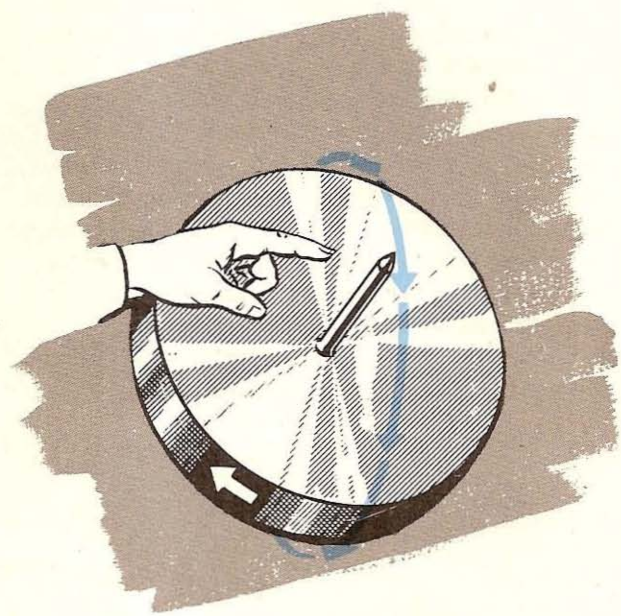
Remember that in apparent precession, the earth moves in relation to the gyroscope. Induced precession, however, means movement of the gyro in relation to the earth.



INDUCED PRECESSION



GYRO PRECESSES 90° FROM POINT OF APPLIED PRESSURE IN THE DIRECTION OF ROTATION.



To change the position of a gyro, you apply enough force to overpower its rigidity. But the gyro's spin axis does not move in the direction in which the force is applied, as you would expect. Instead, it moves at a right angle to the applied force and in the direction of the gyro's rotation. This is known as the Law of Precession.

Suppose you have a gyro that is spinning clockwise. If you push the top of the spin axis toward the 3:00 o'clock position, the gyro does not tilt in that direction. Instead, it tilts toward the 6:00 o'clock position.

A good way to remember the Law of Precession is: Place your fingers in the direction of rotation and point index finger in the direction of the applied force, your thumb will extend in the direction of precession.

BOMBING ERRORS

INTRODUCTION

A good bombing team is one that constantly improves with practice and study. If you are a good bombardier you do not make the same error over and over again. When your bomb misses its mark, you must try to find out **why**. You will have to study all the data you have recorded for that particular release.

It is only by first determining the cause of a bombing error that you can prevent it from happening again.

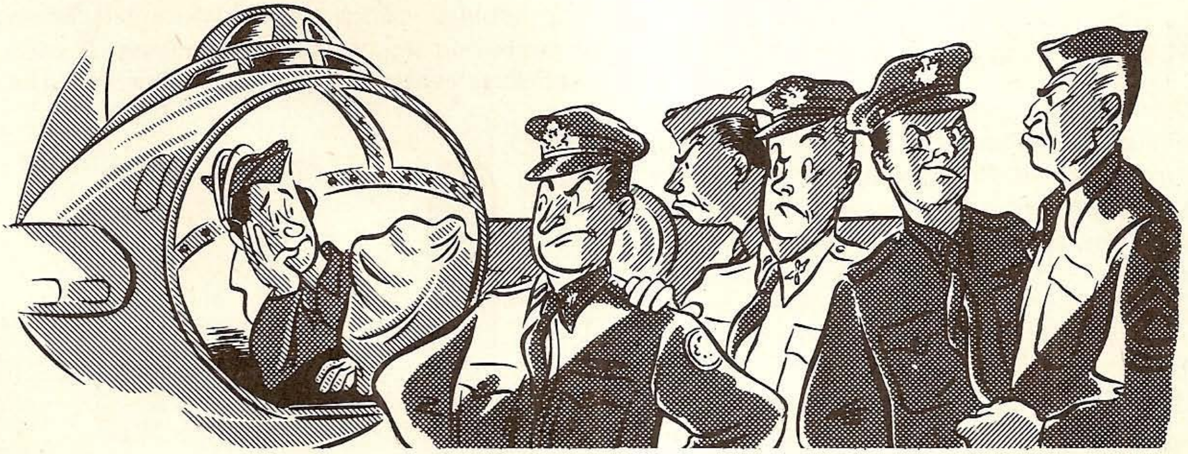
Remember, your job is to hold bombing errors to a minimum and to eliminate them wherever possible. Your team is only as good as you are. Your mission is not successful unless your bomb hits the target. When it misses, your pilot, your navigator, your gunners, the ground crew, the ordnance men who loaded your bombs—everyone who had anything to do with your mission—might just as well have taken the day off and stayed home in bed!

When you cut your probable errors in half, you become **four** times as valuable a bombardier!

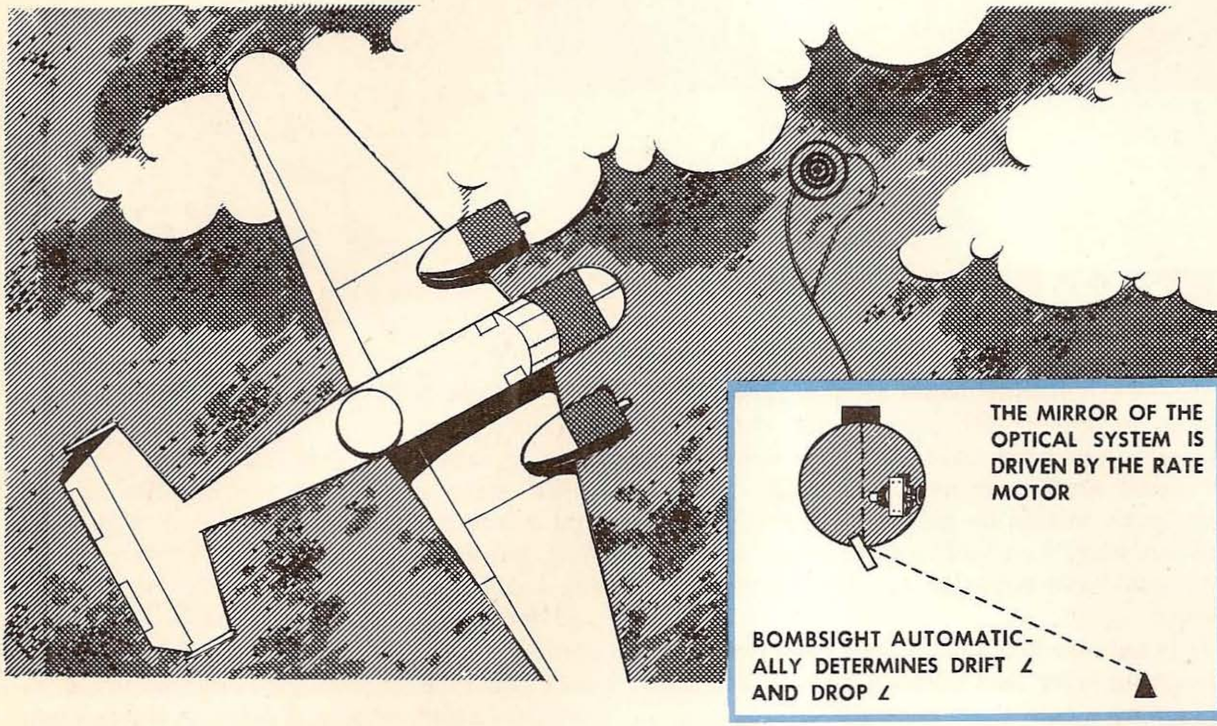
With experience, you learn what causes a given error merely by viewing the impact and reading the data from your sight. At first, however, you will do most of your bombing analysis on the ground, after the mission, and from data which you yourself have recorded on the 12C form. For this reason, your data must be as complete and accurate as possible. Start writing it down as soon as you call "Bomb away."

Record ALL the Data on 12C CORRECTLY.

There are two methods of bombing: **(1) synchronous** and (2) **fixed-angle.** Errors, for the most part, are the same in each type. In certain cases, however, the thing which causes a given error in synchronous bombing causes an error in just the opposite direction in fixed-angle bombing. For this reason, the errors associated with each method will be discussed separately.



Errors In Synchronous Bombing



In synchronous bombing the bombsight automatically solves your groundspeed and dropping angle. Most of the errors occur when you compute incorrect data, when you operate the bombsight incorrectly, or when your bombsight does not function properly. There are six major causes of errors in synchronous bombing: (1) improper vertical, (2) improper actual time of fall, (3) improper trail, (4) improper course, (5) improper rate, and (6) improper release.

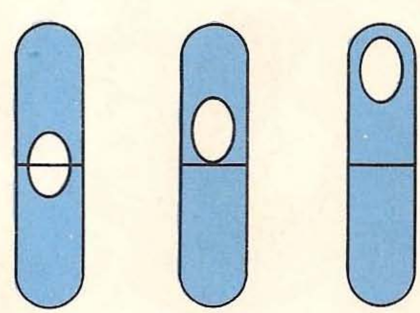
IMPROPER VERTICAL

The vertical gyroscope in the M-Series bombsight stabilizes the optics against the roll and pitch of the airplane. It establishes a vertical reference to the ground from which to align the course and measure the dropping angle.

To establish a vertical reference to the ground, you try to align the spin axis of the sight gyro with the true vertical. Your accuracy in this operation has much to do with the accuracy of your bombs. Your dropping angle must be measured from the true vertical reference line for your bomb to hit the target.

But when you do not align the spin axis with the true vertical — that is, when you establish an **improper vertical** — your bomb misses. It misses because the bombsight has measured the dropping angle from the wrong reference line. The effect is the same as if you had set incorrect data into your sight.

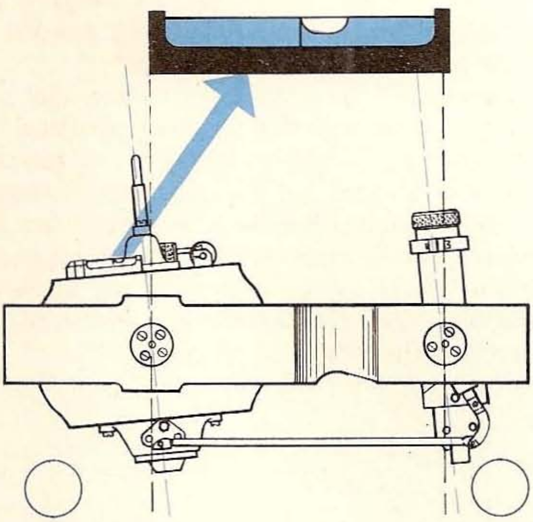
You can tell whether your gyro is in the true vertical by looking at the position of the bubbles, which are in two spirit levels mounted on top of the gyro housing. If each bubble is centered under its lubber line, the



gyro gives a true vertical reference. When properly centered, the bubble is cut in half by the lubber line. If one end of the bubble is under the lubber line, the bubble is one-half bubble length off. To read the bubbles accurately, be sure the airplane is flying **straight and level and at a constant airspeed.**

You use the leveling knobs to center the bubbles. Once the gyro is leveled during the bombing run, it will tend to remain level. Likewise, the gyro is out of the vertical when the bubbles are not centered, and it will tend to remain out of the vertical until they are centered.

LATERAL BUBBLE



The lateral bubble indicates the position of the gyro when the airplane is flying straight and level. When the gyro tilts, the bubble moves toward the higher side of the gyro. If the top of the spin axis of the gyro tilts to the right, the bubble moves to the left. You can measure the amount of tilt by the amount the bubble deviates from the lubber line. Experience with many sights shows that when the bubble is one-half length off, the deviation of the spin axis is approximately 18 mils.

If the bubble is one-half length to the right, the top of the spin axis of the gyro and the axis of the optics are tilted 18 mils to the left. If you set it up this way, you fly too far to the left in sighting the target. Therefore, your bomb hits left of the target.

How to Calculate Deflection Errors Resulting From Improper Vertical.

To compute the amount of an error resulting from an improperly centered lateral bubble, or the actual distance by which the bomb misses the target, you multiply the number of mils of deviation by 1/1,000 of the BA. Therefore the deflection error is:

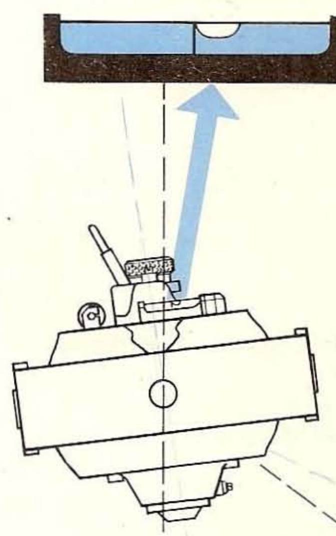
DE = (bubble error in mils) × BA/1,000.

FORE AND AFT BUBBLE

Just as the lateral bubble shows the position of the gyro when the airplane is flying straight and level, so the fore and aft bubble shows the gyro's position when the airplane is flying at a constant airspeed and not climbing or diving. Under these conditions, a perfectly centered fore and aft bubble shows that the vertical reference set up by the bombsight is the true vertical.

If this bubble is one-half length **forward,** the top of the vertical reference is tilted **back,** and the bombsight sets up a false sighting angle.

You must center the fore and aft bubble **when the airplane is maintaining a constant speed and is not climbing or diving.** Once the true vertical is established, the gyro tends to hold it. If thereafter the airplane speeds up or slows down, the bubble moves forward or back because of the inertia of the liquid.



Therefore, once you have established the true vertical, DO NOT attempt to re-center the bubble each time it moves off.

A gyro spin axis tilted forward or back produces an error in range. The error is due to the fact that tilting the gyro also tilts the telescope and mirror.

If the gyro top is tilted to the rear (bubble to the front), the line of sight is swung upward **without moving the sighting angle index.** The range angle will then be larger than the angle indicated by the sighting angle index. Consequently, the sighting angle index will reach coincidence with the dropping angle index too soon, and the bomb will hit **short.** If the gyro top is tilted to the front, the range angle will be smaller than that indicated by the sighting angle index. This index will therefore reach coincidence too late, and you will get an **over.**

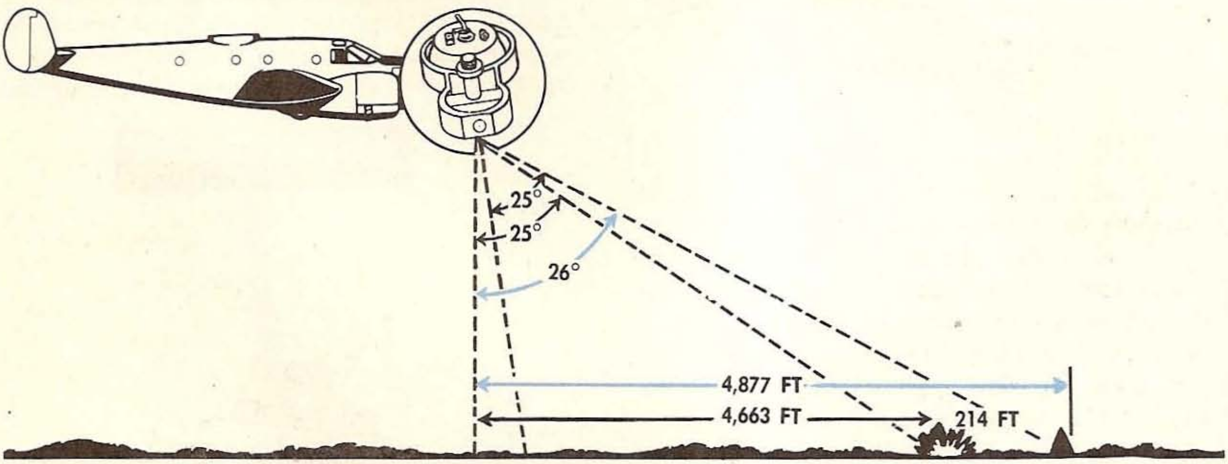
How to Calculate Range Errors Resulting From Improper Vertical.

The amount of this range error is primarily affected by the difference between the range angle and the indications of the sighting angle index. Consider, for example, a mission on which the correct dropping angle is 25° (Tan is .4663). If your bombing altitude is 10,000 feet, the actual range of the bomb will be 4,663 feet (Tan 25° × BA). Now assume that your gyro top becomes tilted 1° to the rear. The range angle will now be 26° when the sighting angle index reaches coincidence at 25°. Since the Tan of 26° is .4877, the bomb will be released 4,877 feet short of the target. But its actual range is only 4,663 feet, hence it will hit 214 feet **short.**

This calculation is more simply expressed by the equation: (Tan Dropping Angle – Tan Range Angle at Release) × Bombing Altitude = Range Error. A plus error here means an over. A minus error is a short.

On a synchronous mission the error as calculated above is not exact, due to the fact that the shift in the line of sight requires re-synchronizing. This results in a changed dropping angle. The change in dropping angle varies in amount, but always tends to compensate to some extent for the range error caused by the difference between the range angle and the sighting angle.

Because of the complexity of an exact calculation, you will find it most practical on synchronous bombing missions to assume that fore and aft bubble errors are the same in size as lateral bubble errors. And remember—a bubble to the **front** causes a hit **short,** and a bubble to the **rear** causes a hit **over.** The direction of the **error** is **opposite** to the direction the **bubble** is off center.



IN SUMMARY:

1. Lateral bubble to the *left* — bomb impact to the *right.*
2. Lateral bubble to the *right* — bomb impact to the *left.*
3. Fore and aft bubble to the *front* — bomb impact *short.*
4. Fore and aft bubble to the *rear* — bomb impact *over* . . . Remember if the bubble is off, the bomb impact is in the opposite direction.

Causes and Cures OF INCORRECT VERTICAL

WAS IT YOUR ERROR?

1. Did you chase the bubbles?
2. Did you try to level when the airplane was skidding?
3. Did you over-correct when leveling?
4. Did you try to see your bubbles from an angle?

1. Take your time.
2. Wait for a good level.
3. Use the **inner** knob to make more accurate corrections.
4. Take a good look **straight down.**

WAS IT CAUSED BY YOUR INSTRUMENTS?

1. Did your leveling knobs stick?
2. Did your gyro precess excessively?
3. Was the C-1 Autopilot improperly adjusted?

1 and 2. You should have caught these in your preflight inspection.

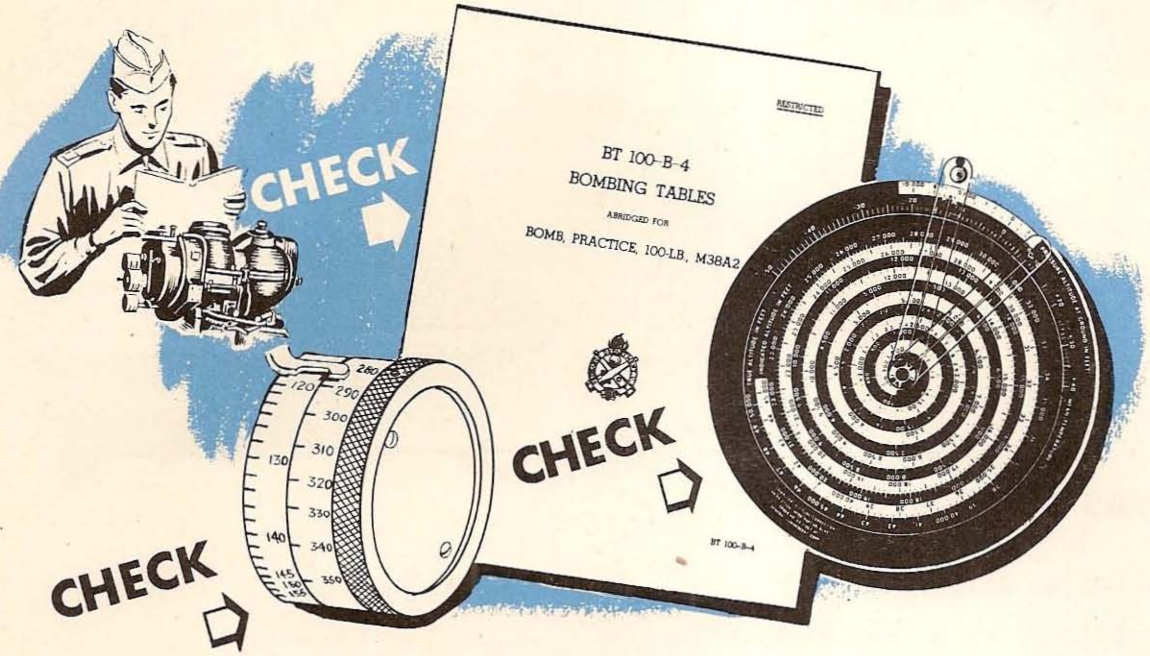
3. Be sure airplane is trimmed to fly straight and level, "hands off" before beginning C-1 adjustment.

WAS IT THE PILOT'S ERROR?

1. Did he skid or turn the airplane while you were leveling bubbles?
2. Did he speed up or slow down while you were leveling?

1. Check PDI center and airplane level before leveling bubbles.
2. Keep an eye on your own airspeed indicator.

IMPROPER ACTUAL TIME OF FALL



From any given BA, a bomb requires a definite length of time to hit the ground. This length of time, or **actual time of fall,** has been determined for most bombing altitudes and true airspeeds. Neither you nor the bombsight can change the time it will take a bomb to fall from a given BA and true airspeed.

If you know your bombing altitude and your type of bomb, you can readily find the actual time of fall from your bombing tables. For M-Series bombsights, this actual time of fall is given as a disc speed setting. Always remember that disc speed is inversely proportional to actual time of fall. In other words, the higher you fly, the smaller is your disc speed setting.

Your bombsight computes whole range for whatever actual time of fall you set into it. The bombsight has no way of "knowing" whether or not this is the **correct** time of fall. Naturally, if you set in an improper actual time of fall, the bombsight cannot accurately compute whole range. Your bomb is destined to miss the target before it ever leaves the airplane.

If you set in too small an actual time of fall, the disc speed is too fast. When synchronizing for rate, with the disc rotating too fast, you do not move the roller far enough from the center of the disc. As a result, the actual range computed is too small. The dropping angle which subtends this incorrect actual range is likewise too small. The bomb is carried too close to the target; the bomb is still in the air when the actual time of fall set in the sight expires, and the bomb falls over.

One thing which might cause you to set an improper actual time of fall into the sight is an incorrect computation of your bombing altitude. If you compute your bombing altitude as 6,800 ft. when it is actually 7,000 ft., you set into the bombsight the disc speed for 6,800 ft., which is too fast.

Several things may cause you to compute an incorrect bombing altitude. Reading the computer incorrectly or making simple mistakes in addition and subtraction are the most common errors.

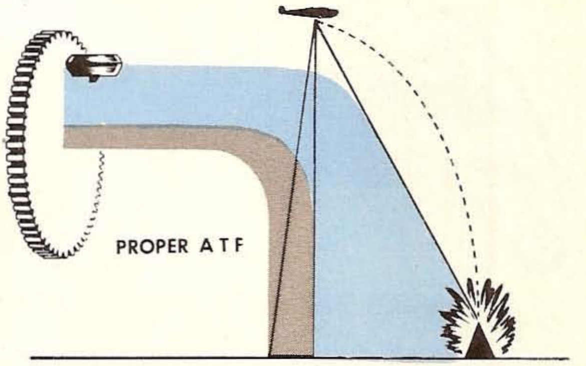
Sometimes the fault is in the free air temperature gage. When the gage reads too high, for example, you compute too high a bombing altitude. As a result, you set into the sight too slow a disc speed. With the disc rotating too slowly, you move the roller too far from the center of the disc when synchronizing for rate. Accordingly, the actual range computed is too large. The dropping angle which subtends this incorrect actual range is likewise too large. The bomb is released too far from the target; it hits the ground before the actual time of fall set in the sight expires, and it falls short.

Improper actual time of fall also can result from a change in BA after the data has been set into the sight. If the bombing altitude is 10,000 ft. and if the airplane is actually flying at a bombing altitude of 9,800 ft. at the moment of release, then the disc speed set into the sight is too slow for the actual bombing altitude. The sight computes an actual range too large for the actual time of fall, and the bomb falls short.

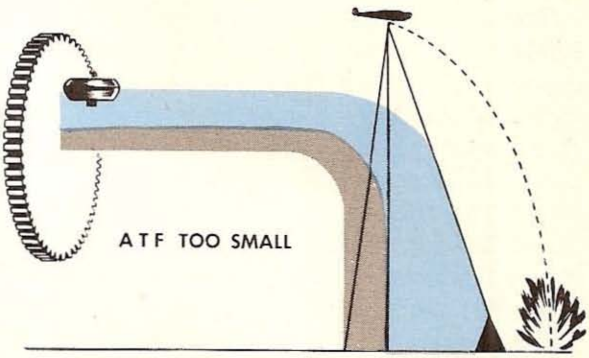
For synchronous bombing, remember the following relationships:

Flying at too high BA
Using too small ATF } **Bomb impact over.**
Using too fast a DS

When these conditions are reversed the bomb impact will be short.



ACTUAL RANGE COMPUTED CORRECT



ACTUAL RANGE COMPUTED TOO SMALL

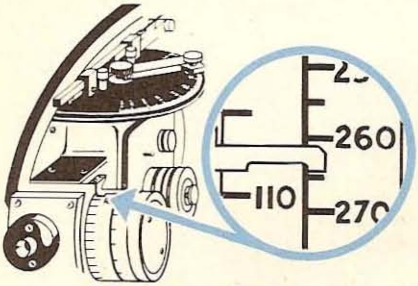
HOW TO CALCULATE ERRORS RESULTING FROM IMPROPER ATF

After you set the correct actual time of fall into the bombsight, you synchronize for groundspeed. If you do this correctly, the bombsight automatically computes the correct whole range.

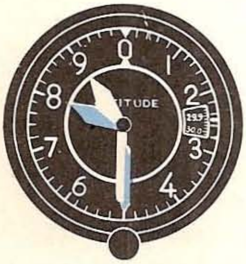
Suppose that your bombing altitude is 6,000 ft. and the actual time of fall is 20.12 seconds. You set the corresponding disc speed, 263.4, into the sight. The groundspeed is 200 ft/sec., and the trail set into the sight is 46 mils. This is the correct trail for 6,000 ft., if groundspeed is proportional to true airspeed.

The whole range solved for by the bombsight is groundspeed (ft/sec) $\times$ actual time of fall, or $200 \times 20.12 = 4{,}024$ ft. If no trail were set into the sight, you would release the bomb 4,024 ft. from the target. With 46 mils of trail, you release the bomb $46 \times 6 = 276$ ft. closer. The bomb travels a horizontal distance equal to groundspeed $\times$ actual time of fall minus trail, or $200 \times 20.12 - 276 = 3{,}748$ ft. and hits the target.

Now, with this same data set into the bombsight, suppose you release the bomb from a BA of 7,000 ft. instead of 6,000 ft. Since 46 mils at 7,000 ft. subtends 322 ft., the bomb is released 322 ft. beyond the whole range vertical line. After the bomb travels 6,000 ft. downward from this point, it has used up all the actual time of fall set in the sight. Since it still has 1,000 ft. to fall, it must continue to travel forward an additional horizontal distance. This carries it over the target. You can compute the distance by subtracting the whole range solved for by the sight from the whole range of the bomb. In other words: (GS $\times$ ATF at 7,000 ft.) – (GS



CORRECT DISC SPEED



ALTITUDE TOO HIGH

BOMB HITS OVER.

$\times$ ATF at 6,000 ft.). Then $(200 \times 21.82) - (200 \times 20.12) = 4{,}364 - 4{,}024 = 340$ ft.

The approximate error is then 340 ft. It is called "approximate" because the bomb slows down somewhat in falling the last 1,000 ft. You can find the exact error by considering that since you have used data for 6,000 ft. you have set insufficient trail into the bombsight. The trail for 7,000 ft. at the true airspeed flown (assumed to be equal to GS) is 47 mils, whereas the trail for 6,000 ft. is 46 mils. The trail deficiency is therefore 1 mil, which results in a 7 ft. error short. Thus your exact error is 340 ft. minus 7 ft., or 333 ft. over.

In analyzing your errors, it is not necessary to be accurate to the exact foot. For ordinary purposes you can ignore the small trail deficiency and compute the range error as:

$$\text{RE} = (\text{Difference in ATF}) \times \text{GS (ft/sec)}$$

Since this solution requires a computation of groundspeed, you may find it easier to calculate a range error by figuring it as an error of actual time of fall in the bombsight, that is, as an error in disc speed. The equation is a simple proportion:

$$\frac{\text{Range Error}}{\text{WR of Sight}} = \frac{\text{Error in DS}}{\text{DS Used}}$$

From a concrete example you can see how to use this equation.

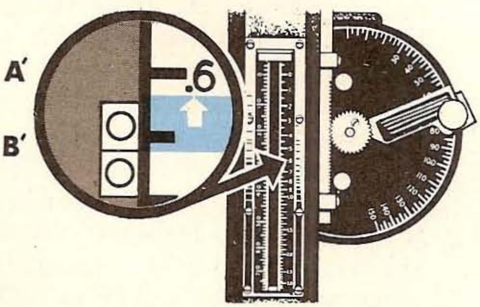
Suppose that for a bombing altitude of 10,000 ft. you set in a disc speed of 190 rpm. The correct disc speed for this altitude is 201 rpm. You have, therefore, a disc speed error of 11 rpm.

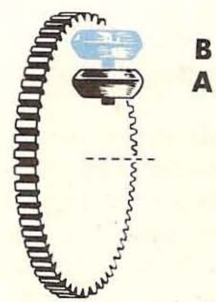
Since you have set in a disc speed of 190 rpm, the roller will be at position B on the disc when you have synchronized, and the dropping angle index will be at position B′ on the tangent scale. If you had set in the correct disc speed of 201 rpm, the roller and dropping angle index would have been at positions A and A′, respectively. Notice that position B′ of the dropping angle index indicates a larger tangent of the dropping angle than position A′. With the incorrect disc speed, the dropping angle is too large; your bomb is dropped too soon, and hits short of the target.

To calculate the distance short, you must first compute whole range. You read the Tan Drop $\angle = 0.660$ from the position B′ of the dropping angle index. If you have set 60 mils trail into the sight, the Tan T$\angle$ is 0.060. Then the Tan WR$\angle$ is $0.660 + 0.060 = 0.720$. Hence, $\text{WR} = 10{,}000 \times 0.720 = 7{,}200$ ft.

Now you can substitute in your equation:

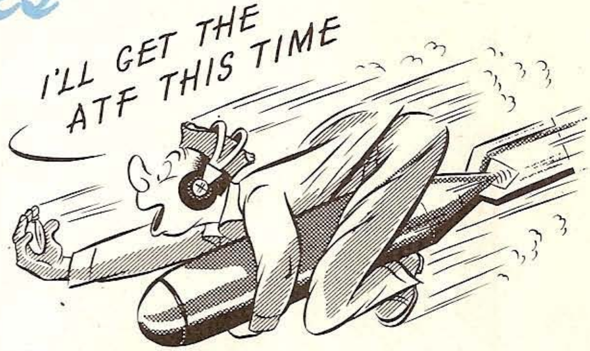
$$\frac{\text{RE}}{7{,}200} = \frac{11}{190}, \text{ or RE} = 417 \text{ ft. short.}$$





Causes and Cures

OF INCORRECT ATF



WAS IT YOUR ERROR?

1. Did you compute a false bombing altitude?
   Did you fail to correct temperature for airspeed compression error?
   Did you read your DS tables incorrectly?

1. Check those computations.
   Remember that all thermometer readings must be corrected.
   Be sure you get into the right column and row.

2. Did you fail to check DS at bombing altitude?

2. Always use your tachometer at bombing altitude.

3. If you used a stop watch to check disc speed, did you have trail set in the sight?

3. When using stop watch to check disc speed, ALWAYS use **zero** trail setting.

4. Did you knock the disc speed gear shift out of position?
5. Did you knock the disc speed drum off the correct setting?

4 and 5. Always check these positions at the beginning of each run. When operating the bombsight, be careful with your hands.

WAS IT CAUSED BY YOUR INSTRUMENTS?

1. Is your disc speed erratic?
2. Is the roller slipping?

1 and 2. Always check for these in your preflight inspection.

3. Is your tachometer or stopwatch inaccurate?
4. Does your altimeter:
   read too high and cause a short? or
   read too low and cause an over?
5. Does your thermometer:
   read too high and cause a short? read too low and cause an over?

3, 4 and 5. Have these instruments inspected and calibrated by instrument specialists.

WAS IT THE PILOT'S ERROR?

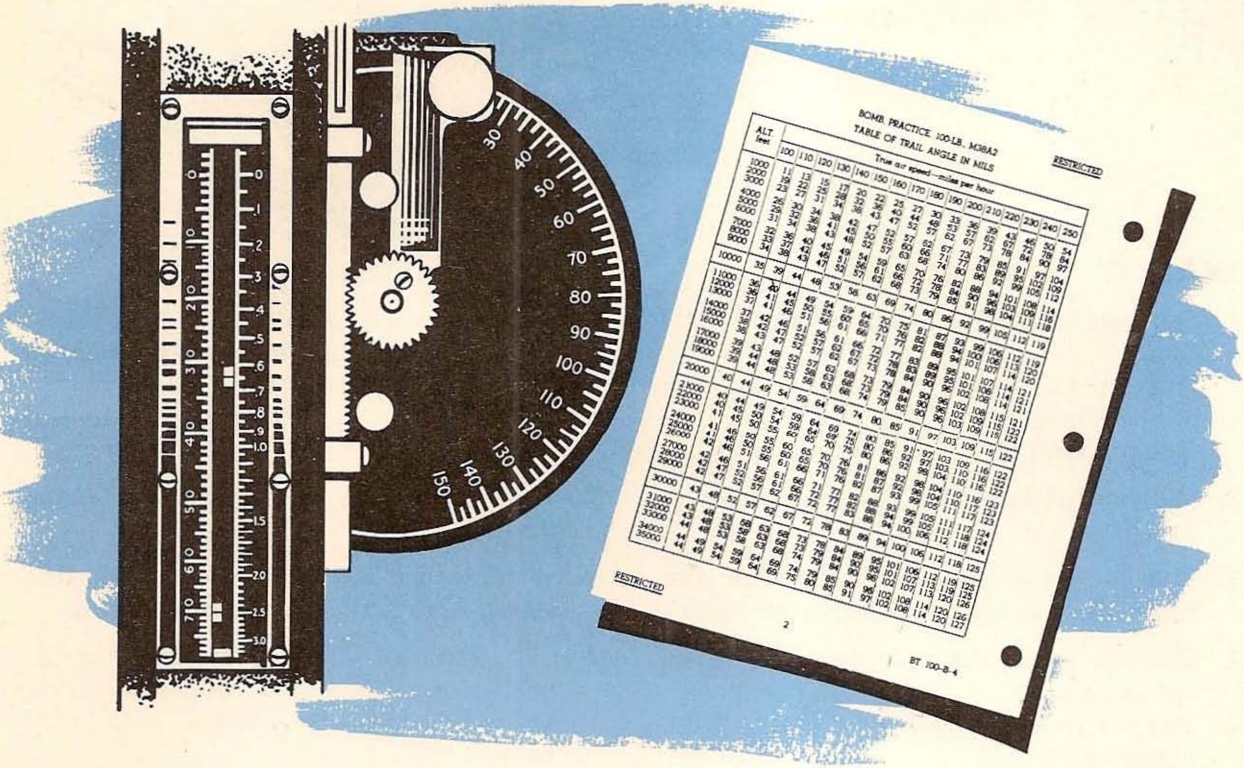
1. Did he fly too high or too low?

1. Watch your own altimeter, and ask the pilot to fly at the correct bombing altitude.

2. Did he climb at the instant of release, increasing ATF and causing an over?
3. Did he dive at the instant of release, decreasing ATF and causing a short?

2 and 3. This will seldom happen if you cooperate fully with the pilot. Cultivate team work.

IMPROPER TRAIL



For every different bombing altitude and true airspeed, a given type of bomb lags a definite distance behind the airplane. This distance, called **trail,** has been determined and is given in your bombing tables.

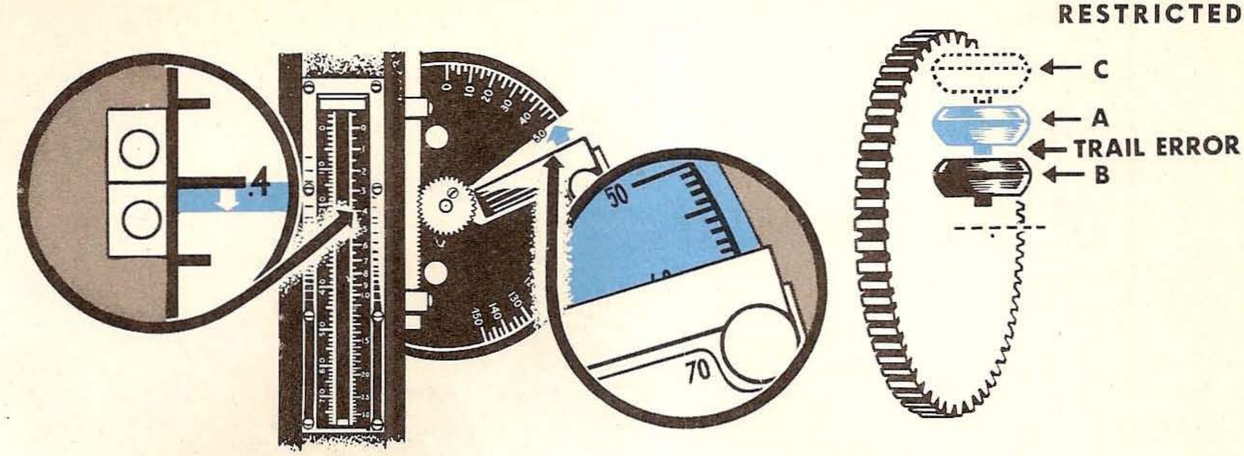
Trail is entered into the M-Series sights by setting the trail arm on the trail plate to the correct trail value, which is given in mils. When you move the trail arm, trail is set into the rate end and into the crosstrail mechanism at the same time. If you put the wrong trail into the rate end, you get a range error. At the same time, this improper trail in the crosstrail mechanism causes a deflection error. Thus if you set in too much trail, your bomb falls over and upwind. If you set in too little trail, it falls short and downwind.

There are several reasons why you might set improper trail into the bombsight. Since trail depends on bombing altitude and true airspeed, you must make both these computations correctly in order to arrive at the proper trail.

On the other hand, suppose you compute the correct trail for the true airspeed you are flying and set it into the bombsight. Now if your pilot slows down or speeds up, the trail set into the bombsight becomes improper for the **new** true airspeed. A range error results.

How to Calculate Range Error Resulting from Improper Trail in Rate End.

When the dropping angle index is set at zero and the trail arm is set at zero trail, the roller is positioned at the center of the disc. If you now enter 60 mils trail in the rate end, the roller moves up to position A. When you synchronize on the bombing run, you move the roller from position A to position C. This automatically moves the dropping angle index to 0.400. With the roller and the dropping angle index in these positions, the bombsight computes the actual range for a 60-mil trail setting.



The correct trail is 50 mils. If you had entered this correct trail, the roller would have been at position B at the beginning of the run. When you synchronized, it would have moved from B to C, and the dropping angle index would have moved from zero to 0.410.

The distance AB is equal to the trail error of 10 mils, and is proportional to the range error on the ground. To find the range error in feet, **multiply the trail error by 1/1,000 of the bombing altitude.** If at 9,000 ft. you set 60 mils trail into the sight when the correct trail is only 50 mils, your bomb falls 90 ft. over.

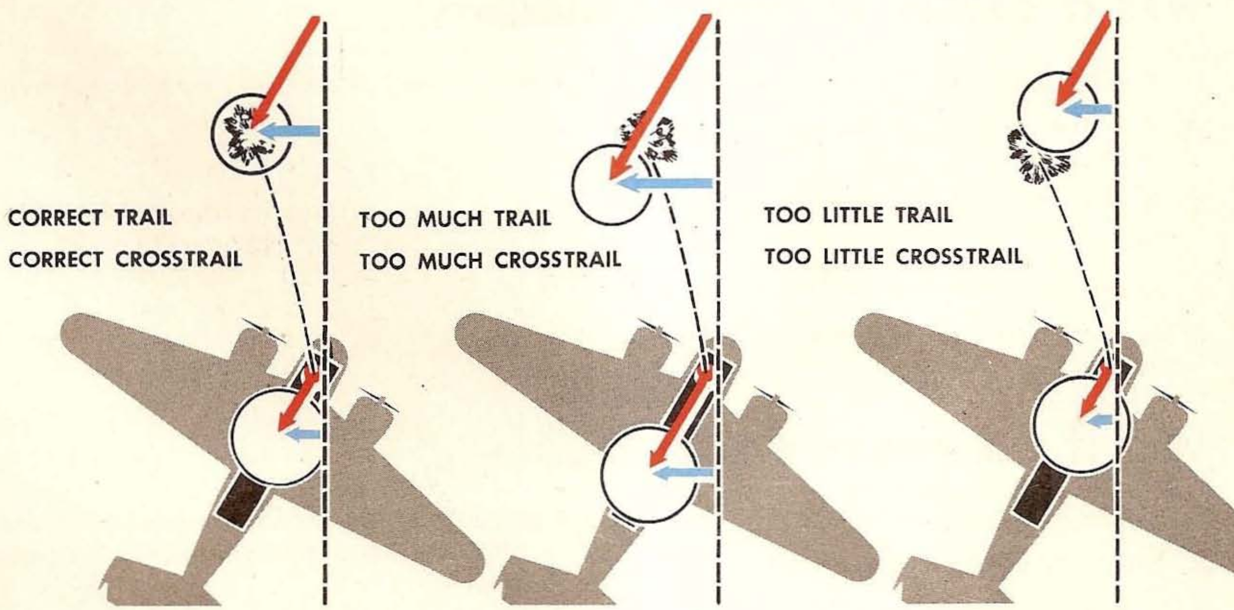
How to Calculate Deflection Error Resulting from Incorrect Trail in Crosstrail Mechanism.

If you set the trail arm at zero trail, the concentric stud and disc is centered over the top of the crosstrail shaft. When you move the trail arm to the correct trail value, the concentric stud and disc moves toward the rear of the sight. The distance it moves depends on the amount of trail you set in.

When you set up your course, the concentric stud and disc swings through the drift angle. Its lateral displacement is proportional to crosstrail. The amount of this lateral displacement will depend on the distance the concentric stud and disc was back of the center of the crosstrail shaft when it began to swing. In other words, the crosstrail computed by the sight depends on the amount of trail you set in. If you enter too much trail, the bomb impact is upwind; if you enter too little trail, it is downwind.

Since the crosstrail depends on trail and the drift angle, you can compute the amount of the deflection error by using the equation:

$$DE = \text{Trail Error in ft.} \times \text{Sin Drift} \angle$$



Causes and Cures

OF INCORRECT TRAIL

WAS IT YOUR ERROR?

1. Did you forget to correct temperature readings?
2. Did you make a mistake in computing bombing altitude or airspeed?
3. Did you set the wrong trail?
4. Did you forget to check for pre-set trail in your sight?
5. Did you knock trail setting off?

1. Remember to subtract compression error.
2. MASTER your computers.
3. Use your bombing tables carefully.
4. NEVER neglect your preflight checks.
5. Check your settings at the beginning of each approach.

WAS IT CAUSED BY YOUR INSTRUMENTS?

1. Was there pre-set trail in the sight?
2. Was the dovetail or the stabilizer misaligned?
3. Does your airspeed indicator register too high or too low?
4. Is your altimeter inaccurate?
5. Is your free air temperature gage in error?

1 and 2. Catch these errors in your preflight check.

3, 4 and 5. Have these instruments inspected and calibrated by instrument specialists.

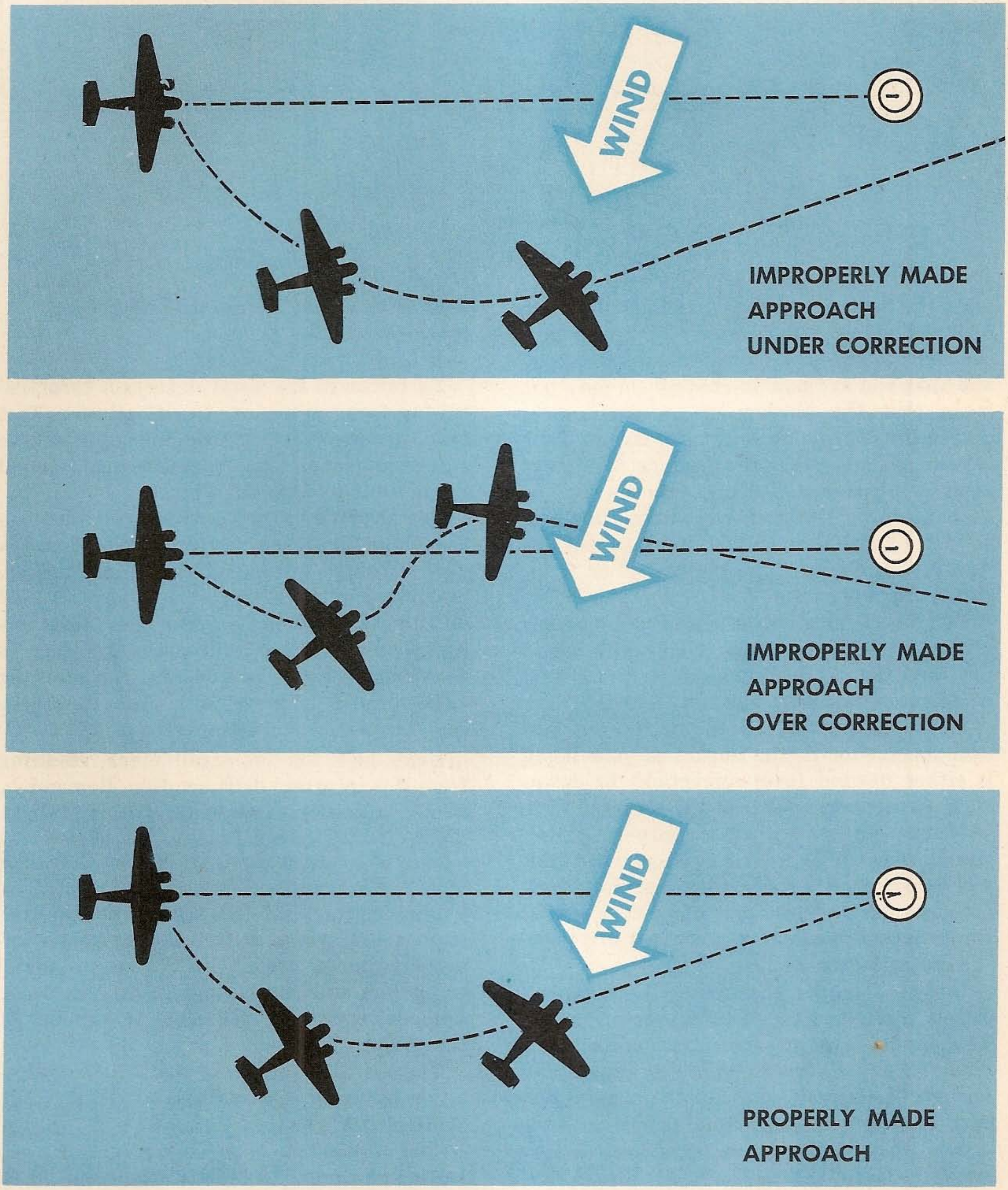
WAS IT THE PILOT'S ERROR?

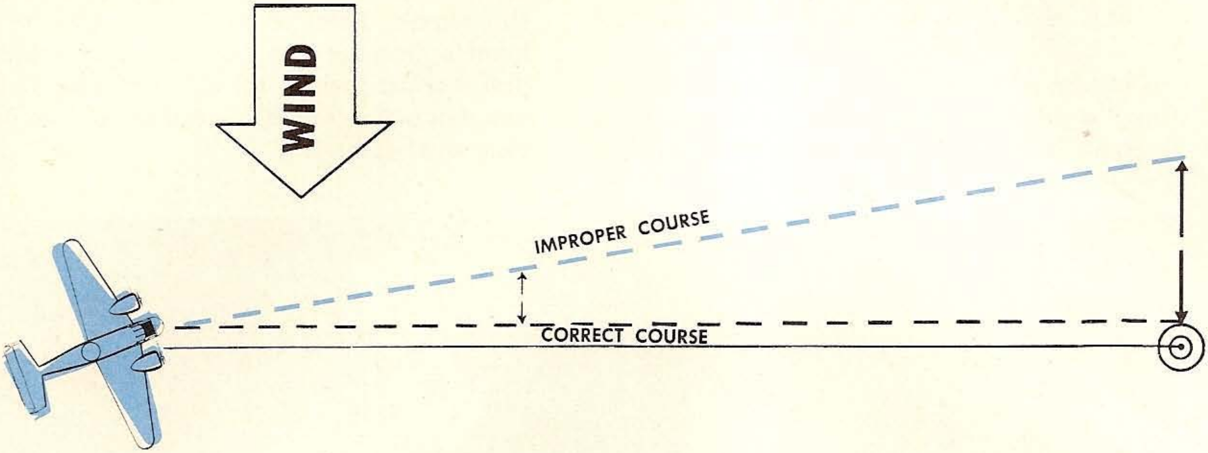
1. Did he fly too fast or too slow?
2. Did he fly too high or too low?

1 and 2. Watch your airspeed indicator and altimeter. Work toward complete cooperation.

IMPROPER COURSE

As you remember from "Theory of Bombing," wind is one of the four forces acting on a bomb from the instant of its release. Drift has a definite effect on a bomb, depending on the wind's direction and speed and on the bomb's airspeed and altitude. Your job is to predetermine what this effect will be, so that you can make proper allowances before dropping the bomb.





At the beginning of any bombing run your pilot will signal "On course." He means that the airplane is headed straight for the target and that you are now in charge. He does not mean that the airplane is on the **correct** course for your bomb to hit the target. That is your job, and your very first one. You must head the airplane sufficiently into the wind so that it will fly the proper crosstrail distance upwind of the target. You speak of this as "setting up course," "killing drift," or "synchronizing for course."

You direct the airplane's heading by means of the course knobs on the bombsight. When the fore and aft hair "rides" on the shack, it indicates that drift has been killed.

If you do not kill all the drift or if you over-correct for it, the impact of your bomb is either upwind (over-correction) or downwind (under-correction) of the target.

When you set up an improper course, you automatically cause two errors. First, you make good an incorrect course, which accounts for the large part of your deflection error. Second, you set an incorrect drift into the crosstrail mechanism.

Incorrect drift in the crosstrail mechanism causes the optics to tilt at the wrong angle. This results in an incorrect solution for crosstrail. These two errors, improper course and incorrect crosstrail, work in the same direction. In other words, the total deflection error equals the SUM of the two contributing errors.

How to Calculate Errors Resulting from Improper Course.

To calculate the total deflection error resulting from an incorrect drift solution, first find the error due to the improper course of the airplane. This distance equals actual range $\times$ sine of the drift error.

The airplane in the accompanying drawing is crabbed too much into the wind. It makes good a course upwind of the proper course. Suppose you have headed the airplane 10° into the wind, whereas you should have corrected only 6°. The drift error, therefore, is 4°. If actual range is 4,000 ft., you multiply $4{,}000 \times 0.070$ (Sin of 4°). This improper course causes a deflection error of 280 ft.

Next find the crosstrail error resulting from this incorrect drift solution. Remember, two factors affect crosstrail: trail and drift. Since $CT = T \times \text{Sin Drift} \angle$, it follows that $CT\ \text{Error} = T \times \text{Sin Drift Error}$. If trail is 300 ft., CT Error is: $300 \times 0.070 = 21$ ft.

Because the total deflection error resulting from an incorrect drift solution equals improper course error PLUS the crosstrail error, you add 280 ft. and 21 ft. The bomb dropped, therefore, falls 301 ft. upwind of the target.

The overall error can be found in one calculation by using: Course Error $=$ WR $\times$ Sin Drift Error. Thus, $WR = AR + T = 4{,}000 + 300 = 4{,}300$ ft.

Deflection Error $= 4{,}300$ ft. $\times\ 0.070 = 301$ ft.

Causes and Cures

FOR IMPROPER COURSE

WAS IT YOUR ERROR?

1. Did you still have drift to kill at the end of the run?	1. Make your large course corrections at the beginning.
2. Did you over-correct for drift?	2. Wait till your pilot takes out one course correction before making another.
3. Did you make too many displacement corrections?	3. Stop apparent motion as soon as possible by **double-gripping** your course knobs.
4. Were your corrections jerky?	4. Make them smooth, so your pilot can follow the PDI.
5. Did you forget the PDI or the torque motor switch?	5. Check your switches before starting on a bombing run.

WAS IT CAUSED BY YOUR EQUIPMENT?

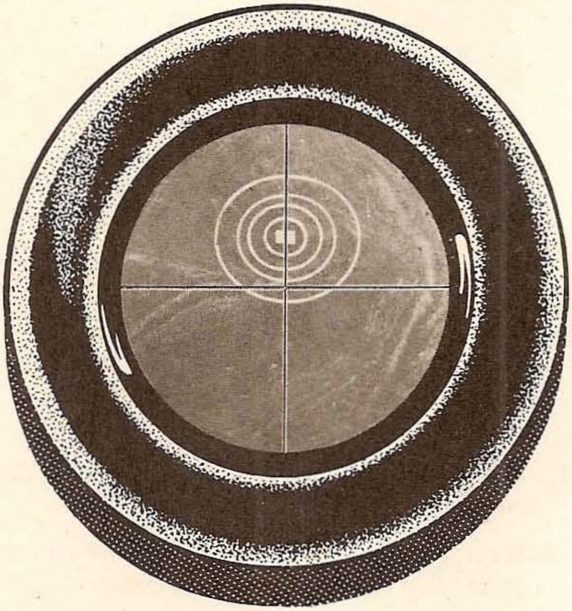
1. Did your course knobs stick?
2. Was your PDI erratic?
3. Did your bombsight clutch slip?
4. Did your directional gyro or torque motor fail to operate?

1, 2, 3 and 4. Catch these in your preflight inspection. They must be remedied by Bombsight Maintenance.

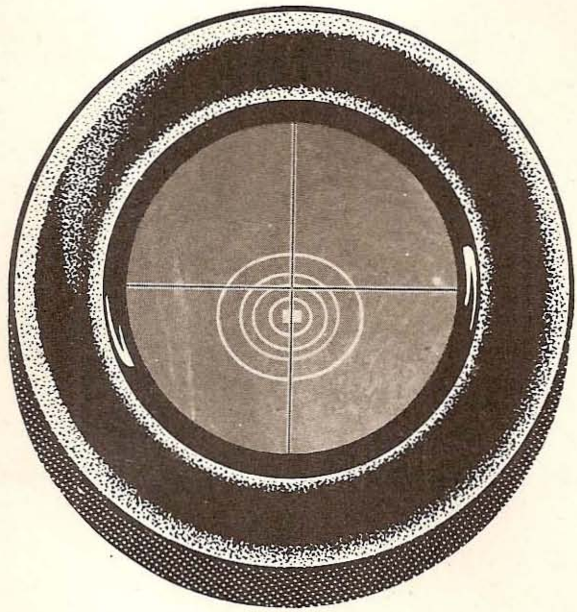
WAS IT THE PILOT'S ERROR?

1. Did he fail to follow the PDI correctly?	1. Make **smooth** and **slow** course corrections which will be easy to follow. Pilot should make course corrections with smooth coordinated turns.
2. Was C-1 Autopilot out of adjustment?	2. Before adjustment, pilot should trim ship for "hands off" straight and level flight.

IMPROPER RATE



RATE TOO FAST



RATE TOO SLOW

After you set up course, you must synchronize for groundspeed or rate of closure. Remember, groundspeed varies with the heading of the airplane, since it is the wind which causes the difference between true airspeed and groundspeed. The airplane must be on the correct heading before you can solve for rate.

You use the rate knob on the bombsight when synchronizing for rate. This knob causes the roller to move out on the disc until it picks up a rate of spin proportional to groundspeed. You have then synchronized for rate, and the lateral crosshair remains stationary.

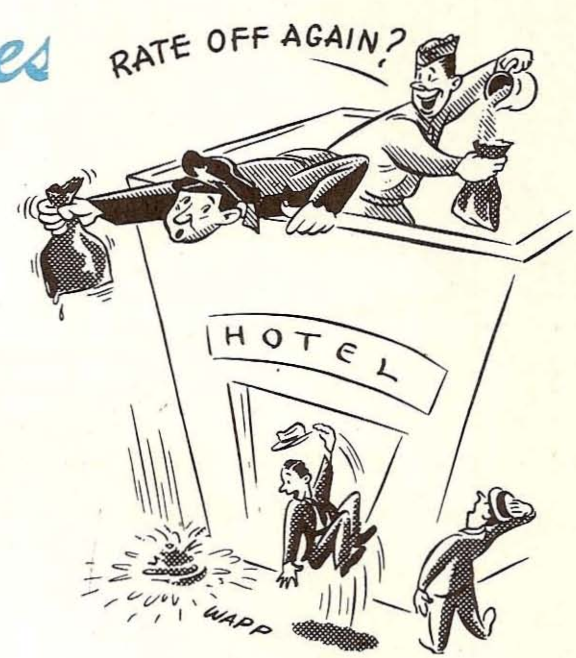
If the lateral crosshair moves short of the target, or toward you, your rate synchronization is said to be "fast." You have solved for a faster groundspeed than actually exists. On the other hand, if the lateral crosshair moves away from you, your rate synchronization is said to be "slow." You have solved for a slower groundspeed than actually exists.

How to Calculate Errors Resulting from Improper Rate.

To calculate errors caused by fast or slow rate synchronization, remember that your bomb is released short of the target a distance equal to the actual range computed by your bombsight. Since $AR = GS \times ATF - T$, it follows that range error = difference between correct and incorrect $GS \times ATF$.

Suppose you synchronize on a given bombing run for a groundspeed of 205 ft/sec. Actually, the groundspeed is only 200 ft/sec. You have solved for a faster groundspeed than the actual groundspeed. You have moved the roller out too far on the disc. Hence, the actual range computed is too large, and so is the dropping angle set up to subtend it. With a 20-sec. ATF, your range error $\doteq 20 \times 5$ (difference between correct and incorrect groundspeeds) or 100 ft. Improper synchronization causes the bombsight to compute WR 100 ft. too large. The bomb is released 100 ft. too soon, and hits 100 ft. short.

Causes and Cures
FOR IMPROPER RATE



WAS IT YOUR ERROR?

1. Did you make rate corrections before you set up course?
2. Did you try to kill rate immediately after making a course correction?
3. Did you make a large last second correction?

1. Kill drift first, then synchronize for rate.
2. Wait until the airplane is flying straight and level.
3. Keep final adjustments small. Double-grip rate knobs for these last **small corrections.**

WAS IT THE FAULT OF YOUR EQUIPMENT?

1. Did your rate knobs stick?
2. Was there roller slippage?
3. Was your disc speed erratic?

1. Catch this in the preflight inspection.

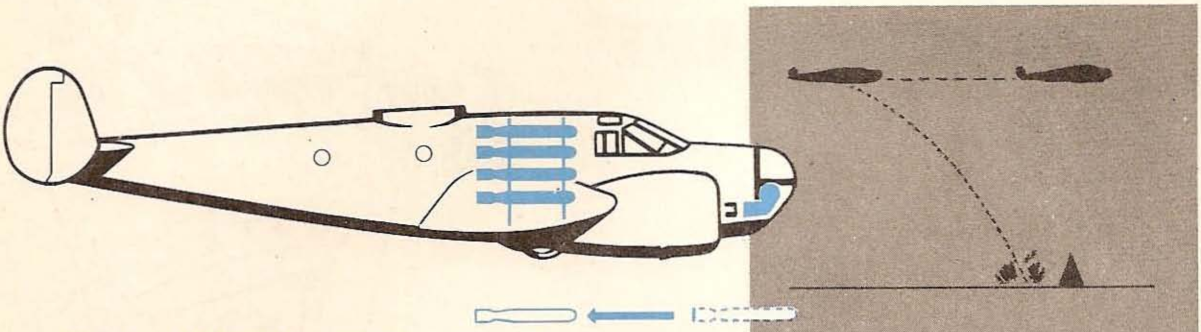
2 and 3. Catch these in your preflight by checking the movement of the sighting angle index with your stop watch.

WAS IT THE PILOT'S ERROR?

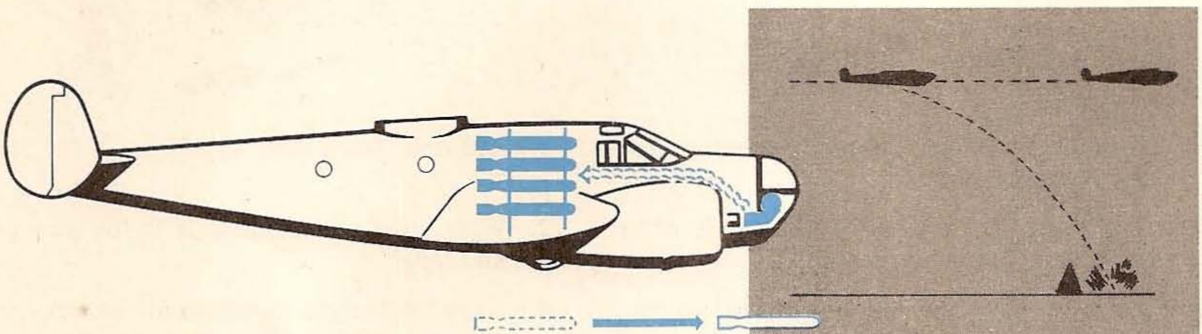
1. Did he vary his airspeed down the run?
2. Did he climb or dive?

1 and 2. Keep an eye on your own altimeter and airspeed indicator. Good bombing requires complete cooperation between pilot and bombardier, and a thorough understanding of each other's problems.

IMPROPER RELEASE



BOMB LOCATION TENDS TO CAUSE BOMB TO HIT SHORT OF TARGET



RACK LAG TENDS TO CAUSE BOMB TO HIT OVER THE TARGET

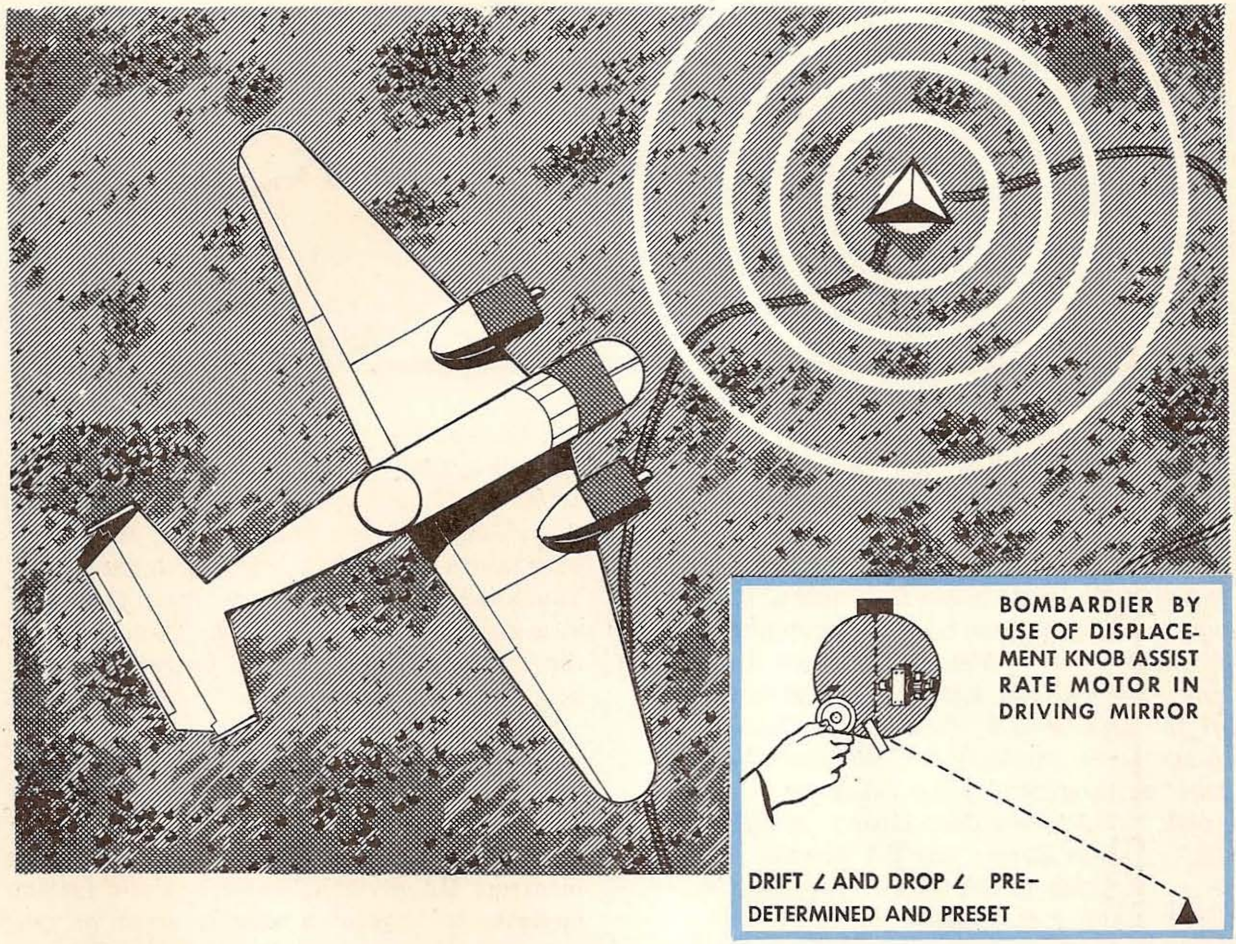
Proper release of a bomb requires these two ideal conditions: (1) the bomb must be directly beneath the bombsight when it is released and (2) the bomb must be released precisely when dropping angle and sighting angle indices meet.

Airplane construction makes it impossible to carry the bombs directly beneath the bombsight. Instead, bombs are carried some distance behind the sight. As a result, they tend to hit the same distance short of the target.

After the release impulse has been sent from the sight to the racks, the bomb is carried for an instant before release actually takes place. This is called **rack lag.** Allowable lag is from 0.03 to 0.06 seconds, depending on the age and condition of the racks. Rack lag tends to give an over, since the bomb is carried longer than the bombsight intended. Errors resulting from rack lag are small unless the lag exceeds the allowable limit.

Improper adjustment of the bombsight's release contacts will cause faulty release. These contacts should close when the dropping angle and sighting angle indices meet. If the two are not properly adjusted, the racks will be energized either too soon, caus- the bomb to hit short, or too late, causing it to hit over.

Errors In Fixed-Angle Bombing



Synchronous bombing with the equipment you have at present is not possible at bombing altitudes below 2,000 ft. The disc does not spin fast enough for you to synchronize for groundspeed, which at low altitudes appears to be much faster than at high altitudes. Therefore, you compute your groundspeed by taking a double-drift and using your E-6B computer to solve for wind. Then you find from special bombing tables the correct dropping angle for your given bombing altitude and groundspeed, and set this dropping angle into the bombsight before you begin the run.

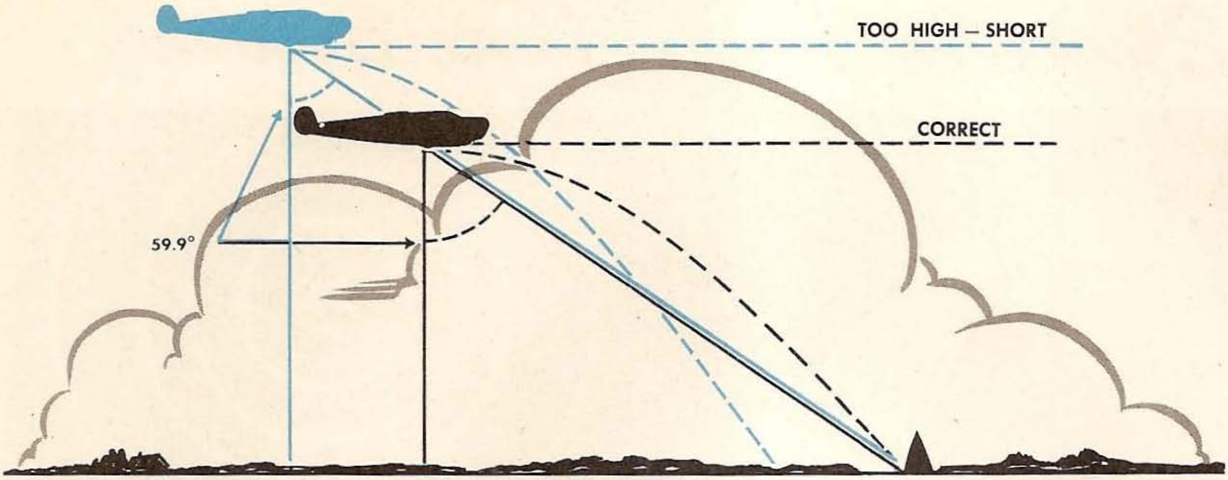
Fixed-angle bombing is subject to many of the errors associated with synchronous bombing. Special attention, however, must be given to errors resulting from improper bombing altitude, improper airspeed, and incorrect use of bombing tables.

INCORRECT ALTITUDE

For bombing altitudes below 2,000 ft., you pre-set the dropping angle for the bombing altitude at which the bomb is to be released. If the bomb is released at that bombing altitude it will strike the target. If you release the bomb at a **higher** altitude it will fall **short** of the target, because the sighting angle coincides with the pre-set dropping angle **too soon.** Similarly, a bomb released at too **low** an altitude falls **over** the target because the airplane reaches the release point **too late.**

How to Measure Errors Caused by Incorrect Altitude.

Suppose that your bombing altitude for a given mission is 1,000 ft. and that you com-



pute your groundspeed at 150 mph. From your tables you find that the correct dropping angle is 59.9° and you pre-set this dropping angle. If at the moment of release your airplane is actually flying at 1,200 ft. bombing altitude, your bomb falls short. The reason is that you have used the dropping angle of 59.9° (Tan 1.657). The correct dropping angle for a BA of 1,200 ft. at a groundspeed of 150 mph is 57.5° (Tan 1.511). To find the range error, multiply the difference between the two tangents by the BA flown.

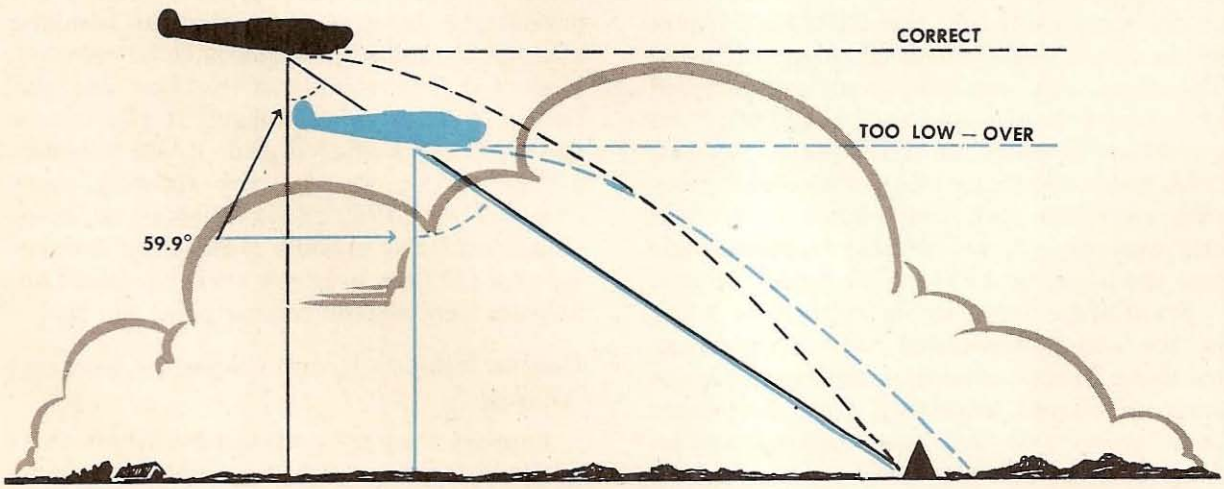
RE = BA flown (Tan Drop ∠ in sight – Tan Drop ∠ for BA flown)
= 1,200 (1.657 – 1.511) = 1,200 × 0.146
= 175.2 ft. **short.**

Suppose that on another occasion you pre-set the same dropping angle for the same intended bombing altitude and groundspeed, but that at the moment of release the airplane is actually flying at a bombing altitude of 800 ft. Your bomb falls over. To compute the amount of the range error, find from your tables the correct dropping angle (62.2°, Tan 1.819) for a bombing altitude of 800 ft. at a groundspeed of 150 mph. Then multiply the difference between the tangents by the bombing altitude flown.

RE = BA flown (Tan Drop ∠ for BA flown – Tan Drop ∠ in sight)
= 800 (1.819 – 1.657) = 800 × 0.162 = 129.6 ft. **over.**

Remember that in fixed-angle bombing an incorrect BA gives an error in the direction **opposite** to that of a similar error in synchronous bombing. In fixed-angle bombing:

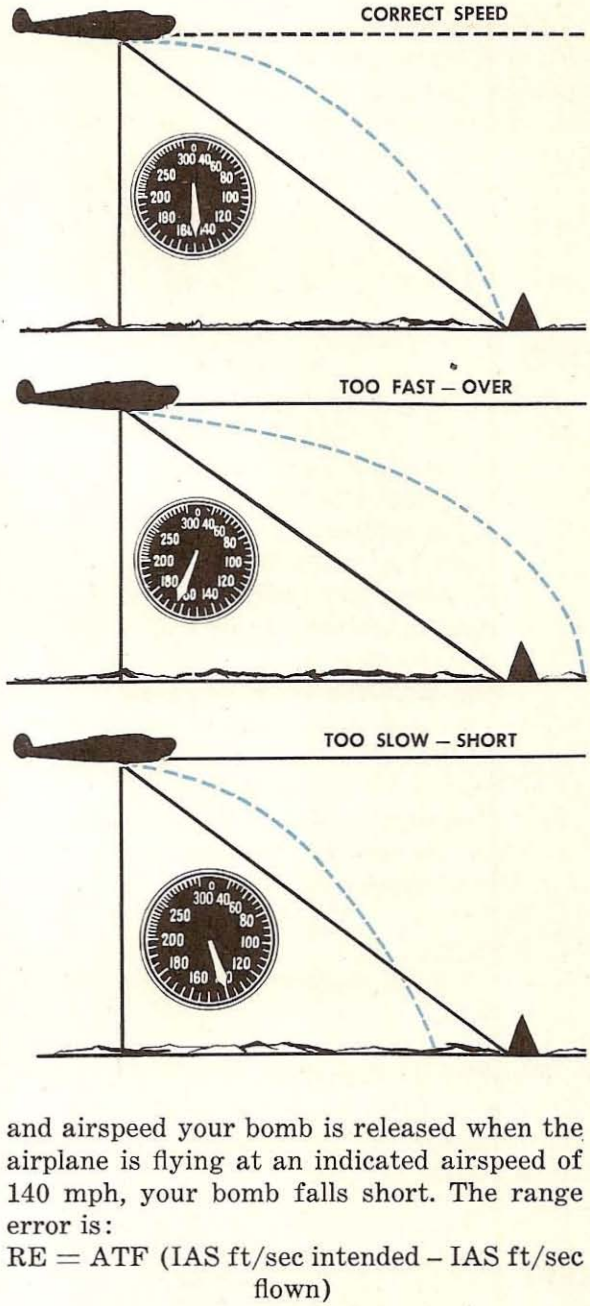
If BA is **too high,** bomb falls **short.**
If BA is **too low,** bomb falls **over.**



INCORRECT AIRSPEED

On a fixed-angle mission, you are given your bombing altitude and your indicated airspeed. You compute your airspeed and your groundspeed, and find from your tables the correct dropping angle for the given bombing altitude and groundspeed. If at the moment of release your airplane is flying at the intended indicated airspeed, your bomb hits the target. If it is flying at a **faster** indicated airspeed, and hence a faster groundspeed, the bomb falls **over.** The pre-set dropping angle is smaller than the correct dropping angle for the groundspeed actually flown.

Similarly, if you release your bomb when the airplane is flying at a **slower** airspeed than the intended one, the bomb falls **short.** You have pre-set a dropping angle too large for the groundspeed actually flown.



How to Measure Errors Caused by Incorrect Airspeed.

Suppose that for a given mission your bombing altitude is 1,000 ft. and your airspeed is 150 mph. If at the moment of release your airplane is actually flying at an indicated airspeed of 165 mph, your bomb falls over. The increase in indicated airspeed has produced a corresponding increase in groundspeed. Since you have pre-set the dropping angle, the bomb has been released at the right point for the intended groundspeed; but the increased groundspeed has given it a larger whole range.

The easiest way to measure the error is to use the equation:

RE = ATF (IAS ft/sec flown – IAS ft/sec intended.)

In using this equation you are actually computing the difference between the actual whole range and the intended whole range, assuming that the difference in airspeed is the same as the difference in groundspeed. The actual time of fall for 1,000 ft. is 8 seconds. Therefore:

$$RE = 8\left\{165 \times \frac{22}{15} - 150 \times \frac{22}{15}\right\}$$

$$= 8\ (242 - 220) = 8 \times 22 = 176 \text{ ft. } \textbf{over.}$$

If with the same intended bombing altitude and airspeed your bomb is released when the airplane is flying at an indicated airspeed of 140 mph, your bomb falls short. The range error is:

RE = ATF (IAS ft/sec intended – IAS ft/sec flown)

$$= 8\ \left\{150 \times \frac{22}{15} - 140 \times \frac{22}{15}\right\}$$

$$= 8(220 - 205) = 8 \times 15 = 120 \text{ ft. } \textbf{short.}$$

Remember that in fixed-angle bombing an incorrect airspeed gives an error in the direction **opposite** to that of a similar error in synchronous bombing. In fixed-angle bombing:

If airspeed is **too fast,** bomb falls **over.**

If airspeed is **too slow,** bomb falls **short.**

INCORRECT USE OF TABLES

In fixed-angle bombing, you always bomb with 20° extended vision locked in. The bombing tables for this type of bombing give you the dropping angle **and** the dropping angle minus 20° for a given groundspeed and bombing altitude. It is the second figure, dropping angle minus 20°, which you must set into the sight.

Summary OF BOMBING ERRORS

OVER

In Synchronous Bombing

I. Drop angle too SMALL, caused by
  1. Disc speed too **fast**, caused by
     Indicated altitude too **high.**
     BA computed too **small.**
     Altimeter reads too **low.**
     Thermometer reads too **low.**
  2. Too **much** trail set in rate end, caused by
     AS too **slow.**
     AS indicator reads too **high.**
     Positive pre-set trail in rate end not allowed for.
  3. Fore and aft bubble to the **rear.**
  4. Synchronized **slow,** or GS solved for by sight **slower** than actually exists.
  5. Mirror drive cable too **short.**

II. RCCT.

III. Rack lag.

IV. Airplane in shallow climb at instant of release.

In Fixed-Angle Bombing

I. Pre-set Drop Angle too **small.**

II. Indicated altitude too **small.**

III. Airspeed too **fast.**

SHORT

In Synchronous Bombing

I. Drop Angle too LARGE, caused by
  1. Disc speed too **slow,** caused by
     Indicated altitude too **low.**
     BA computed too **large.**
     Altimeter reads too **high.**
     Thermometer reads too **high.**
  2. Too **little** trail set in rate end, caused by
     AS too **fast.**
     AS indicator reads too **low.**
     No allowance for negative pre-set trail in rate end.
  3. Fore and aft bubble to the **front.**
  4. Synchronized **fast,** or GS solved for by sight **faster** than actually exists.
  5. Mirror drive cable too **long.**

II. Roller slippage.

III. Airplane in shallow dive at instant of release.

In Fixed-Angle Bombing

I. Pre-set Drop Angle too **large.**

II. Indicated altitude too **large.**

III. Airspeed too **slow.**

LEFT

In Both Kinds of Bombing

1. Lateral bubble **right** of lubber line.
2. Stabilizer twisted counter-clockwise.
3. Over-correction for right drift.
4. Under-correction for left drift.
5. Too much trail set in crosstrail mechanism with right drift.
6. Too little trail set in crosstrail mechanism with left drift.

RIGHT

In Both Kinds of Bombing

1. Lateral bubble **left** of lubber line.
2. Stabilizer twisted clockwise.
3. Over-correction for left drift.
4. Under-correction for right drift.
5. Too much trail set in crosstrail mechanism with left drift.
6. Too little trail set in crosstrail mechanism with right drift.

BOMBING ANALYSIS

INTRODUCTION

"How can I improve my bombing?" You will ask yourself that question many times in your career as a bombardier. One way to improve, of course, would be to drop thousands of bombs, on the theory that you would improve with constant practice.

Unfortunately, you have neither the time nor the large supply of bombs which this method would require. Your only choice is to learn as much as you possibly can from each bomb that you drop. When you return to the field, after the last "bomb away," remember that your mission is not yet complete. Refer to your 12-C form and try to determine why each bomb hit where it did. You can and you will improve your bombing!! Study every bomb-release carefully.

Your 12-C form is all-important. If you make an accurate record of your mission, you can use this data to learn what your errors were. When you understand the "why" of your misses, you can eliminate repetition of those errors and improve your bombing.

It is a fairly simple matter to analyze a bomb's impact. Develop a "sense of error." That is, learn to sense the direction of error and to estimate just how much of the bomb's miss is due to a given error. Study your data thoughtfully and then follow a simple plan of analyzing your errors.

A SUGGESTED PLAN OF ANALYSIS

Wind and Sight Data

(INFORMATION AFFECTING ALL BOMBS)

WIND

Find as nearly as possible the correct wind which was over the target at your bombing altitude and plot this wind on your E-6B computer. One way to do this is to compare notes with other students who were bombing the same target. Another way is to plot, on the E-6B computer, drifts or groundspeeds from two or more of your runs on which you were sure you were synchronized.

BOMBING ALTITUDE AND TRUE AIRSPEED

Check carefully your computed bombing altitude and true airspeed. Work these out again on your computer, to be sure that your original computations were correct.

DISC SPEED AND TRAIL

Make certain that you obtained the correct trail and disc speed from the bombing tables. Check to see if you set them into the sight correctly.

Each Bomb

RANGE

If your error is in range, check the following:

1. Vertical (fore and aft bubble).
2. Actual time of fall (disc speed and bombing altitude).
3. Trail and RCCT.
4. Dropping angle (range synchronization).

DEFLECTION

If your error is in deflection, check these possible causes:

1. Vertical (lateral bubble).
2. Crosstrail.
3. Drift (course synchronization).

For bomb impacts that have errors in both range and deflection, make separate checks, first for range and then deflection.

Your 12-C form contains all of the information pertaining to your bomb release. Shown on the accompanying chart is that part of the data which you must have in order to analyze each bomb and determine what error or errors were responsible for the miss.

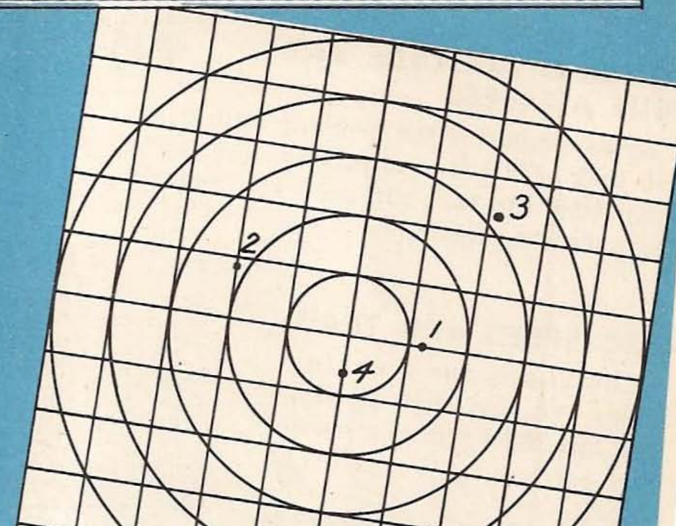
EXAMPLE

Use the figures from the chart in the following suggested analysis of four bombs dropped on a 12,000-ft. mission.

RELEASE NUMBER	PRESSURE ALTITUDE	BOMBING ALTITUDE	INDICATED AIRSPEED	GROUND SPEED	DISC SPEED	TRAIL SET ON SIGHT	LEFT DRIFT	RIGHT DRIFT	TANGENT OF DROPPING ANGLE	SYNCHRONIZATION	COMPASS READING	BUBBLES
1	14,225	12,000	145	166	182.4	78	4	—	.492	R	111°	θ φ
2	14,425	12,200	145	194	182.4	78	—	5½	.483	L	254°	θ ⊢
3	14,225	12,000	155	211	182.4	78	3	—	.674	SR	349°	⊤ ⊣
4	14,225	12,000	145	167	182.4	78	3	—	.515	✓	110°	θ φ

DETERMINATION OF BOMBING ALTITUDE

TARGET	NAME OR DESCRIPTION	N-3	
	ELEVATION	2,450	
	VARIATION	11°E	
	PRESSURE ALTITUDE	2,560	
FLIGHT LEVEL PRESSURE ALTITUDE		14,225	
PRESSURE ALTITUDE ABOVE TARGET		11,660	
BOMBING ALTITUDE		12,000	



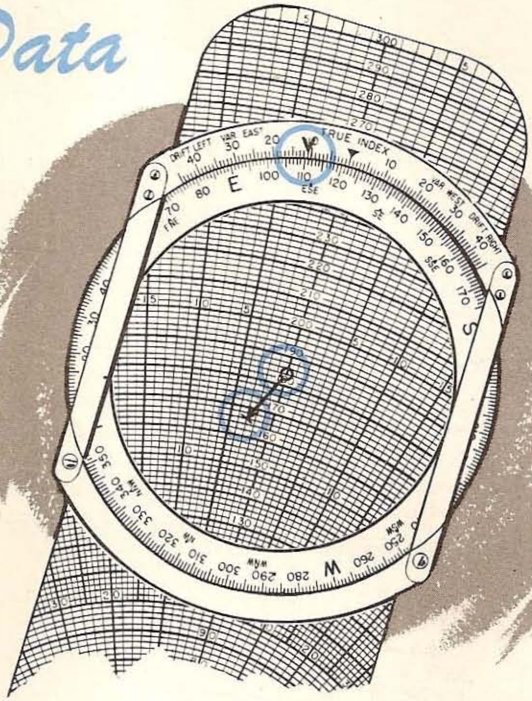
DETERMINATION OF TRUE AIRSPEED

HOUR	1300	
AIRSPEED INDICATED	145	
CALIBRATED INDICATED	145	
TRUE	184	

PRESSURE ALTITUDE	TEMPERATURE Corrected for AIRSPEED Compression Error
14,000	-4
13,000	-2
12,000	-1
11,000	0
10,000	2
9,000	4
8,000	5
7,000	7
6,000	9
5,000	12
4,000	13
3,000	15
2,000	
1,000	
0	
Total	60
Mean	+5°C

RELEASE NUMBER	NUMBER OF BOMBS	BOMBARDIER'S ESTIMATE				
		RANGE		DEFLECTION		CIRCULAR
		SHORT	OVER	LEFT	RIGHT	
1	1	—	—	—	125	125
2	1	—	80	200	—	225
3	1	—	230	—	215	320
4	1	60	—	—	—	60
TOTAL ERRORS		60	310	200	340	730
AVERAGE ERRORS		922		135		182
MPI			62		35	

Wind and Sight Data

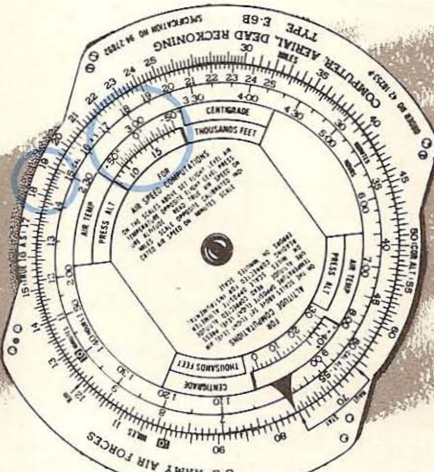


WIND

By checking with other students on the same target and at the same bombing altitude, you find that the wind on your mission was from 149° at 20 mph. You further check the wind you had by using the data recorded for the fourth bomb, on which your synchronization was good and you got a good hit. Plot the wind on your E-6B computer.

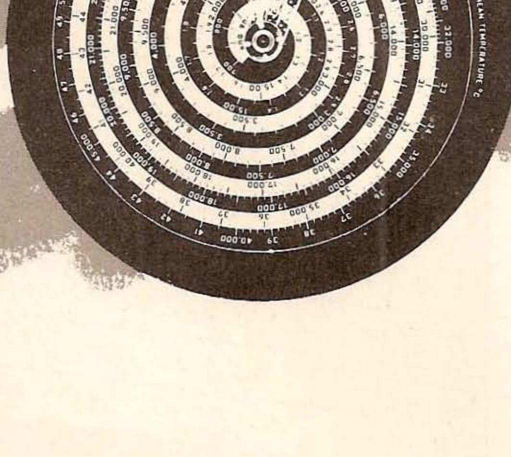
BOMBING ALTITUDE AND TRUE AIRSPEED

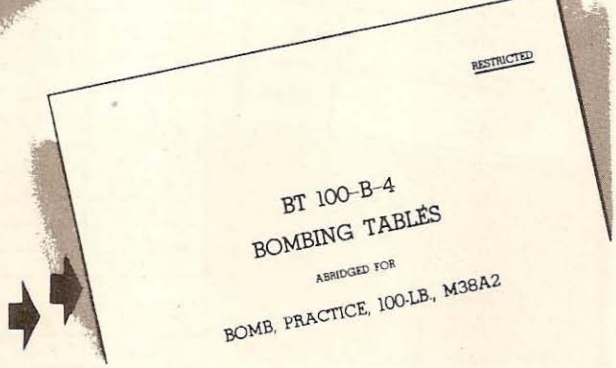
By re-computing the bombing altitude you find that 12,000 ft. was correct. Also, by re-computing the true airspeed you find that 184 mph was correct.



DISC SPEED AND TRAIL

You check the bombing tables and find that 78 mils trail and 182.4 rpm disc speed were correct.





Each Bomb

BOMB NO. 1

Your bomb impact was approximately 125 ft. to the **right** of the target.

Range—From your 12-C form you find:

1. Your fore and aft bubble was centered.
2. The pilot flew the proper altitude. Therefore, the actual time of fall (disc speed) set into the sight was correct.
3. The pilot also flew the proper airspeed. Therefore the trail setting was correct.
4. Your groundspeed compares very closely to the groundspeed found on the E-6B computer for this heading. The range synchronization was good. You now see that you solved your range problem with no appreciable error and the bomb impact was good in range.

Deflection—From your 12-C form you find:

1. Your lateral bubble was centered.
2. Your trail was correct. Therefore, there was no error in crosstrail.
3. Your drift is not the same as the drift found on the E-6B computer for this magnetic heading. The course synchronization was to the **right.**

Referring to the wind you have plotted on the E-6B computer, you see that the correct drift on a magnetic heading of 111° is 3° left. But your 12-C form shows that you solved for a drift of 4° left on a magnetic heading of 111°. Comparing these drifts, you can see that your error in drift contributed to the greater part of the bomb's miss. You solved for 1° too much left drift with the bombsight on the magnetic heading of 111°. For this reason, you know the bomb impact would be upwind, that is, to the **right.**

Now determine from the chart or calculations what part of the error on the ground resulted from this error in drift. Remember that the deflection error caused by a drift error equals: WR $\times$ Sin Drift Error.

To find WR, multiply BA by Tan WR $\angle$.

To find Tan WR $\angle$, add Tan T $\angle$ to Tan Drop $\angle$.

$$\text{Tan WR}\angle = 0.492 + 0.078 = 0.570$$

Then:

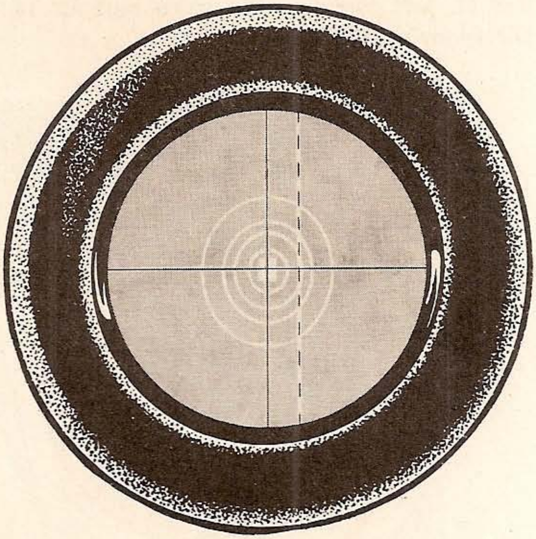
Whole Range $= 12{,}000 \times 0.570 = 6{,}840$ ft.

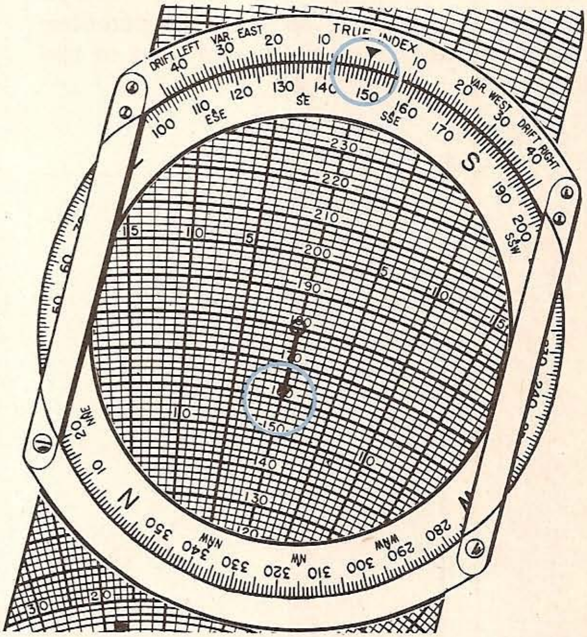
Sin of drift error $= 0.01745$

The deflection error caused by the drift error $= 6{,}840 \times 0.01745 = 119$ ft. **right.**

This shows that your 1° error in drift caused bomb No. 1 to miss the target by about 119 ft.

Your bomb impact was approximately 125 ft. to the **right.** You over-corrected 1° for course and the greater part of your error resulted from this over-correction. The remaining part of the error is so small that for practical purposes you can disregard its cause.





BOMB NO. 2

Your bomb impact was approximately 80 ft. **over** and 200 ft. to the **left** of the target.

Range—From your 12-C form you find:

1. Your fore and aft bubble was centered.
2. The pilot flew 200 ft. too high. This, of course, made the actual time of fall set into the sight too small for the bombing altitude. The disc rotated too fast, the dropping angle was too small, and the bomb hit **over.**
3. The pilot flew at the proper airspeed. Therefore, the trail set into the sight can be considered correct, as the 200-ft. change in altitude has very little effect on trail.
4. Your groundspeed compares very closely to the groundspeed found on the E-6B computer for this heading. The range synchronization was good.

Now determine from chart or calculations what error resulted from the error in bombing altitude. Use the following equation:

Range error due to incorrect bombing altitude = GS ft/sec $\times$ (ATF at 12,200 − ATF at 12,000).

The GS was 194 mph or 284.5 ft/sec. From your bombing tables find the ATF at 12,200 ft. (29.32 sec) and the ATF at 12,000 ft. (29.06 sec).

Then:

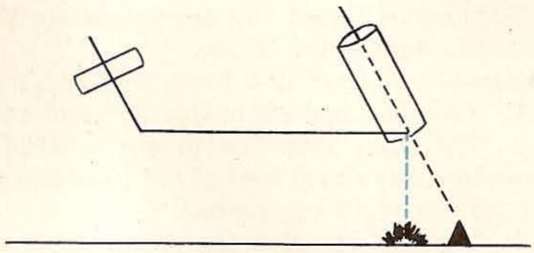
Range error due to incorrect bombing altitude equals:

$284.5\ (29.32 - 29.06) = 284.5 \times 0.26 = 74$ ft.

Thus you see that the error in bombing altitude accounts for the greater part of the range error.

Deflection—From your 12-C form you find:

1. Your lateral bubble was one-half length to the **right.** Thus the optics were tilted 18 mils left of the vertical, causing an error to the **left.**



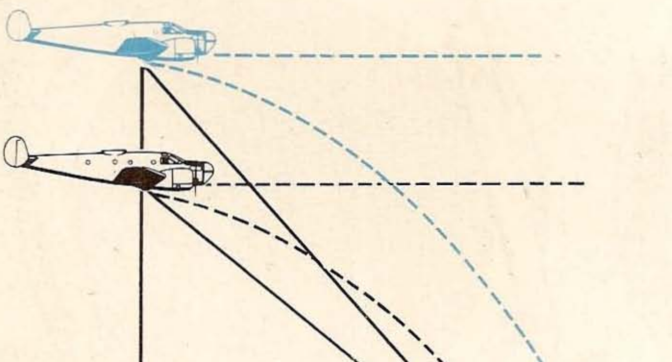
2. Your trail was correct; there was no crosstrail error.
3. Your drift compares very closely to the drift found on the E-6B computer for this heading. Therefore, your drift was correct and you were synchronized for course.

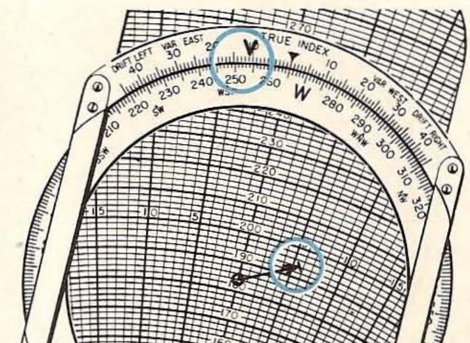
To determine the extent of the error caused by the incorrect level, multiply the bubble error in mils by 1/1,000 of the BA.

Deflection error caused by incorrect level equals:

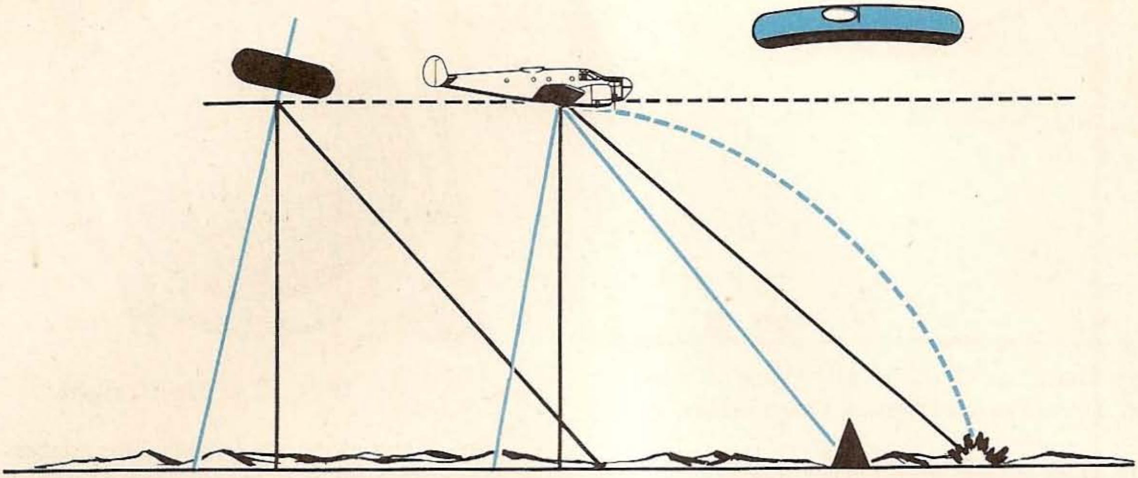
$$18 \times \frac{12{,}200}{1{,}000} = 18 \times 12.2 = 219 \text{ ft.}$$

The deflection error caused by the incorrect level was about 219 ft. **left** and the bomb impact was 200 ft. **left.** The greater part of your error was because your gyro was out of the vertical. Your miss was the result of two errors. Your bomb was 74 ft. **over** because the pilot flew 200 ft. too high. Your bomb was 219 ft. **left** because the gyro had an 18 mil tilt from vertical.





BOMB NO. 3



Your bomb impact was approximately 230 ft. **over** and 215 ft. **right** of the target.

Range—From your 12-C form you find:

1. Your fore and aft bubble was one-half length to the rear. Therefore the top of the optics was tilted to the front of vertical, causing an error **over.**

2. The pilot flew at the proper bombing altitude; the ATF (disc speed) set into the sight was correct.

3. The pilot flew 10 mph too fast an airspeed. Thus, the trail set into the sight was too small and caused an error **short.**

4. Your groundspeed was 3 mph slower than the groundspeed found on the E-6B computer for this heading. Your range synchronization was slow and caused an error **over.**

Analyze the results of these errors one by one, starting with the error caused by the improper fore and aft vertical. Determine this error from the chart or from the following calculations:

The top of the optics was tilted forward 1°, thus making the range angle smaller than the indication of the sighting angle index. The range angle was therefore only 33° when the sighting angle index reached coincidence with the dropping angle index at 34°.

The practical estimate that a bubble one-half length out of the vertical causes an 18 mil range error, may now be used. At 12,000 ft. one mil equals 12 ft. on the ground. Hence, the bubble error is estimated to cause an error of 18×12 or 216 ft. **over.**

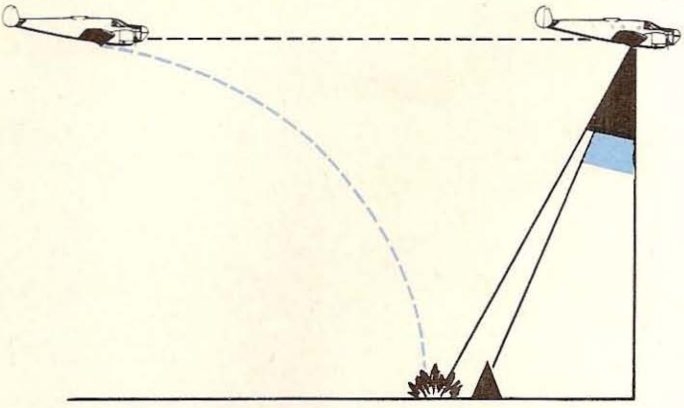
Determine the error caused by the error in airspeed by finding the true airspeed from the indicated airspeed shown on the 12-C form. Find the trail needed for this TAS.

Using your E-6B computer, you find that the true airspeed is 196 mph when the indicated airspeed is 155 mph. From your trail tables, you find that at a bombing altitude of 12,000 ft., at this true airspeed, you should have 86 mils of trail set into the sight. You actually had 78. Thus the trail error is 86 mils less 78 mils, or 8 mils. The resulting range error is then $8 \times \frac{12{,}000}{1{,}000} = 96$ ft. **short.**

When your synchronization for rate is slow, you have not displaced the roller far enough from the center of the disc. The dropping angle set up by the sight is too small; thus the bomb impact is **over.** Comparing the groundspeed from the 12-C form and the E-6B computer, you found that the groundspeed was 3 mph faster than the groundspeed you solved for by the sight. Use the following equation to calculate the range error caused by this error in synchronization:

Range Error caused by incorrect Range Synchronization = ATF $\times$ GS error in ft/sec.

Find ATF (29.06 sec.) from your bombing tables. To solve for GS error in ft/sec, multiply 3 by 88/60.



Range Error $= 29.06 \times 4.4$ ft/sec $= 128$ ft. **over.** You have determined three errors in range:

216 ft. **over** caused by an error in level,

96 ft. **short** caused by an incorrect airspeed, and

128 ft. **over** caused by slow synchronization. Adding these, you get a total range error of 248 ft. **over.** This accounts for your bomb's large range error of 230 ft.

Deflection—From your 12-C form you find:

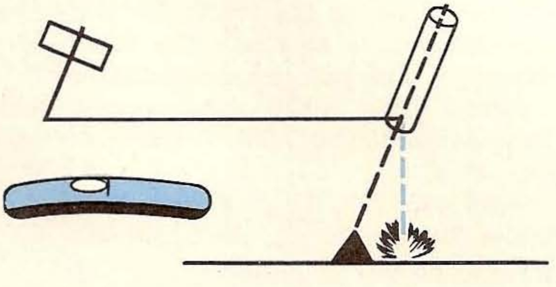
1. Your lateral bubble was one-half length to the **left.** Thus the optics were tilted 18 mils from the vertical, causing an error to the **right.**

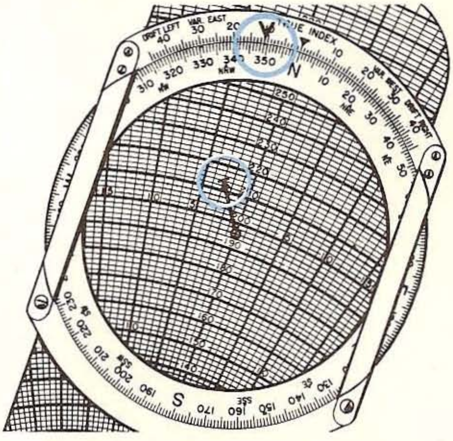
2. Your trail was 8 mils too small. Therefore, there was a small crosstrail error downwind and to the **left.**

3. Your drift compares very closely to the drift found on the E-6B computer for this heading. Therefore, your drift was correct and you were synchronized for course.

Analyze the results of these errors in deflection, starting with the error caused by the improper lateral vertical. To determine the extent of this error, multiply the bubble error in mils by 1/1,000 of the BA.

Deflection error caused by incorrect level equals:





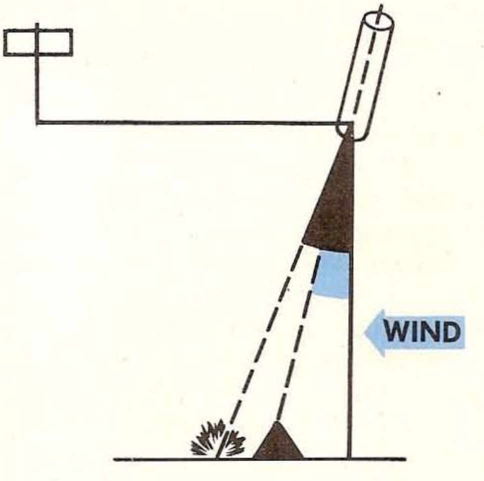
$$18 \times \frac{12,000}{1,000} = 18 \times 12 = 216 \text{ ft. } \textbf{right.}$$

By use of the chart or calculations, determine the extent of the error caused by too little trail set into the crosstrail mechanism of the sight.

Deflection error caused by crosstrail error equals trail error in feet multiplied by the sin of drift angle. Sin $3° = 0.053$

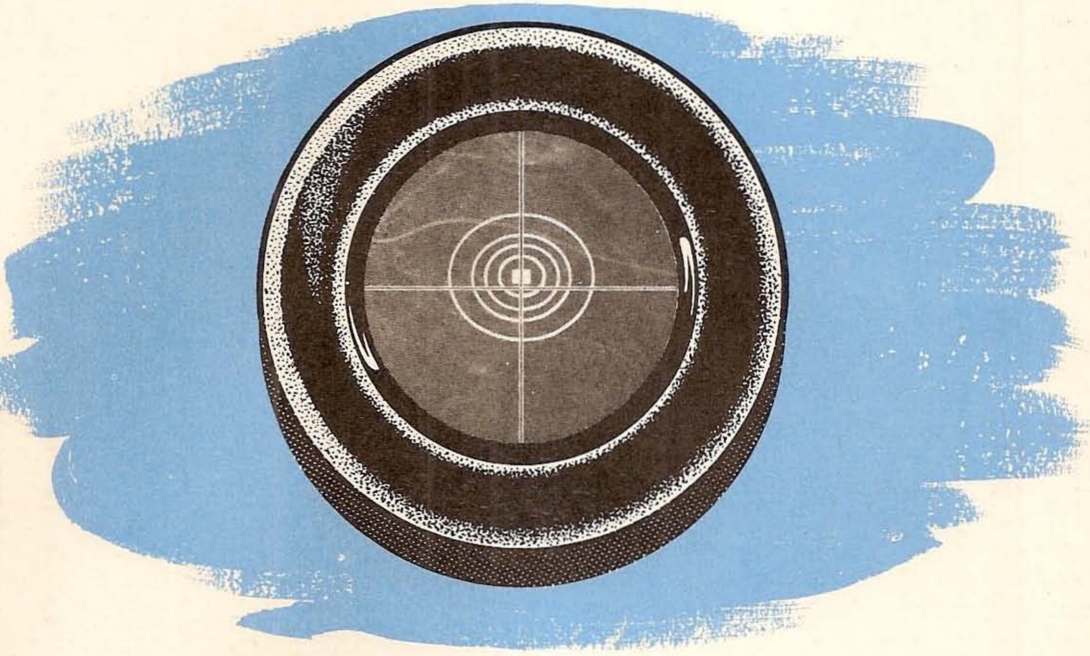
Deflection Error caused by crosstrail error equals

$$8 \times \frac{12,000}{1,000} \times 0.053 = 96 \times 0.053 = 5 \text{ ft. } \textbf{left.}$$



You have determined two errors in deflection. The error caused by the incorrect vertical (216 ft. **right**) was the important one. The error caused by incorrect crosstrail (5 ft. **left**) was very small, but it compensated somewhat for the other error. The calculated error was 211 ft. **right.** This accounts for the large deflection error of 215 ft. in the bomb impact.

BOMB NO. 4



Your bomb impact was approximately 60 ft. **short** of the target.

Range—From your 12-C form you find:

1. Your fore and aft bubble was centered.
2. The pilot flew the proper bombing altitude and the disc speed was correct.
3. The pilot flew the proper airspeed and the trail was correct.
4. Your groundspeed compares very closely to the groundspeed found on the E-6B computer for this heading.

With all of this data correct, your bomb should have hit the shack; or, at least, it should have been a near miss. Thus, with the aid of your 12-C form and E-6B computer, you have eliminated the possibility of any of the more obvious errors. Now, thinking back on your procedure, you recall the position of the lateral crosshair at the instant of bomb release. The lateral crosshair, although its movement was apparently killed, was about 50 ft. short of the target.

Deflection—From your 12-C form you find:

1. Your lateral bubble was level.
2. The trail and crosstrail were correct.
3. Your drift compares very closely to the drift found on the E-6B computer for this heading. The course synchronization was good.

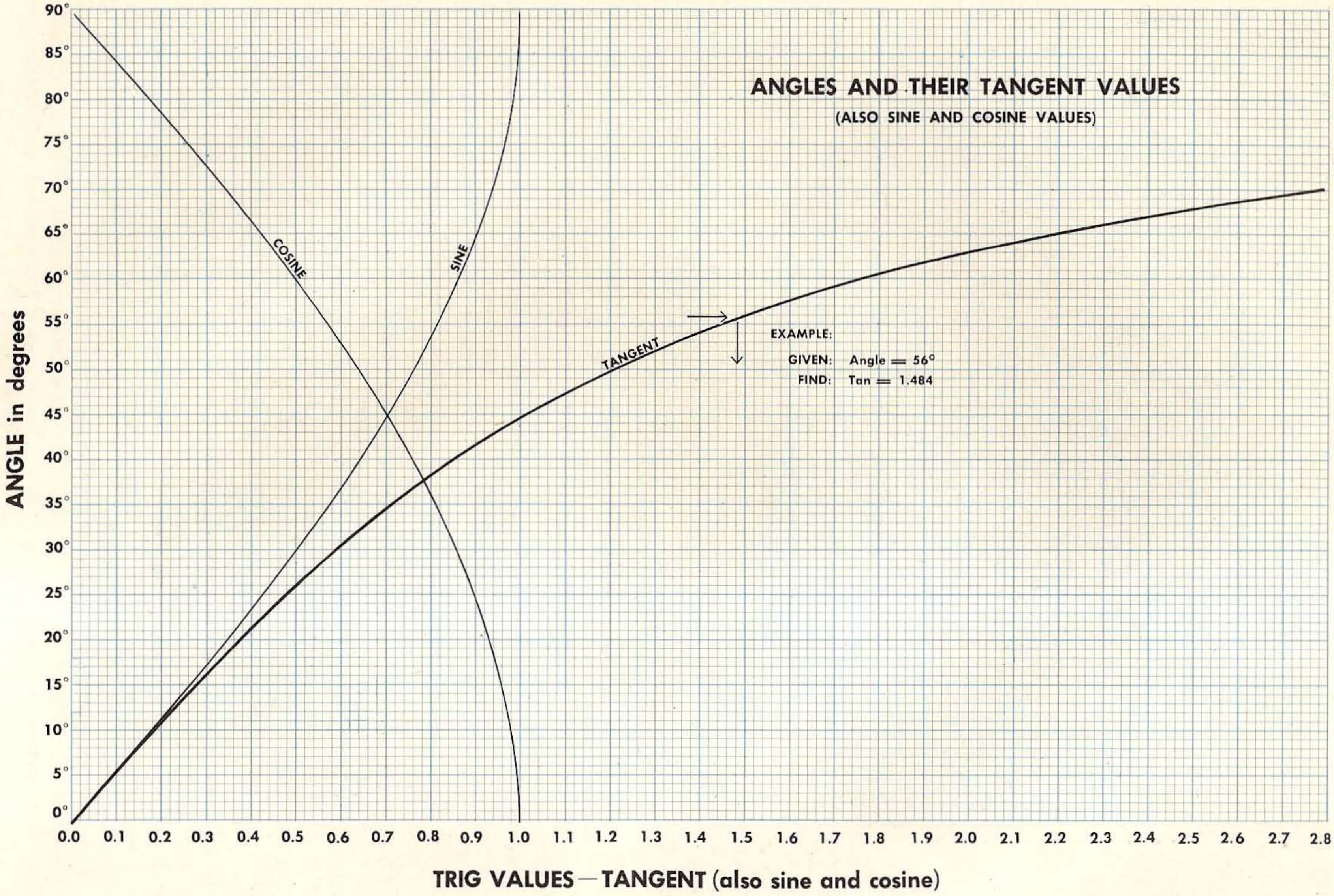
You now know that you set up a good rate and course and had the correct data set into the sight. There was no reason for your bomb to miss the target, except for the fact that the lateral crosshair was 50 ft. short of the target. If the crosshair had been on the target at the instant of release, you would probably have scored a hit.

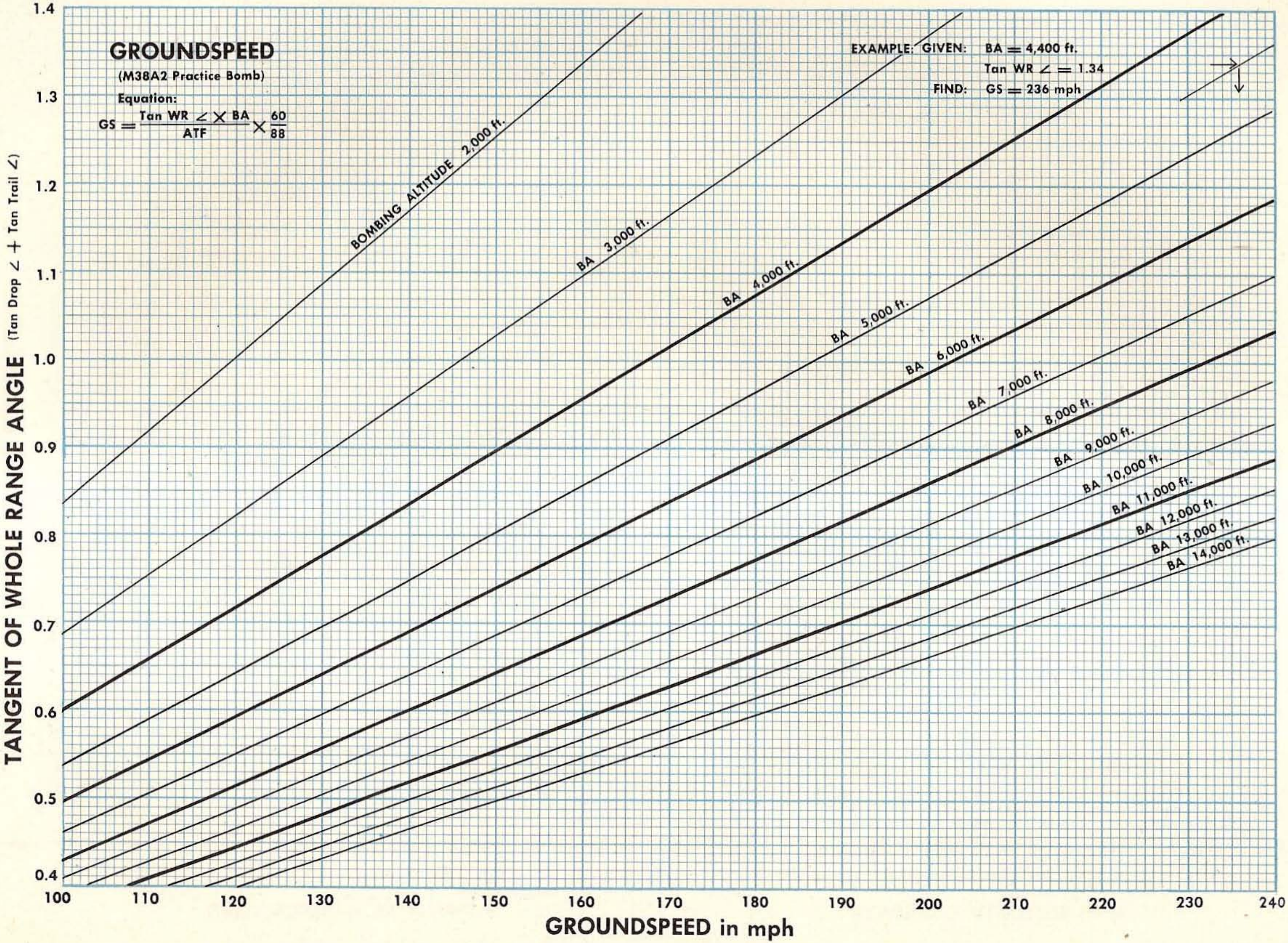
The usefulness of the 12-C form should be extremely clear to you, after you make this type of bomb analysis. You now know the importance of recording your data correctly: so that you can find the reason (or reasons) for every short or over, and every deflection error to left or right.

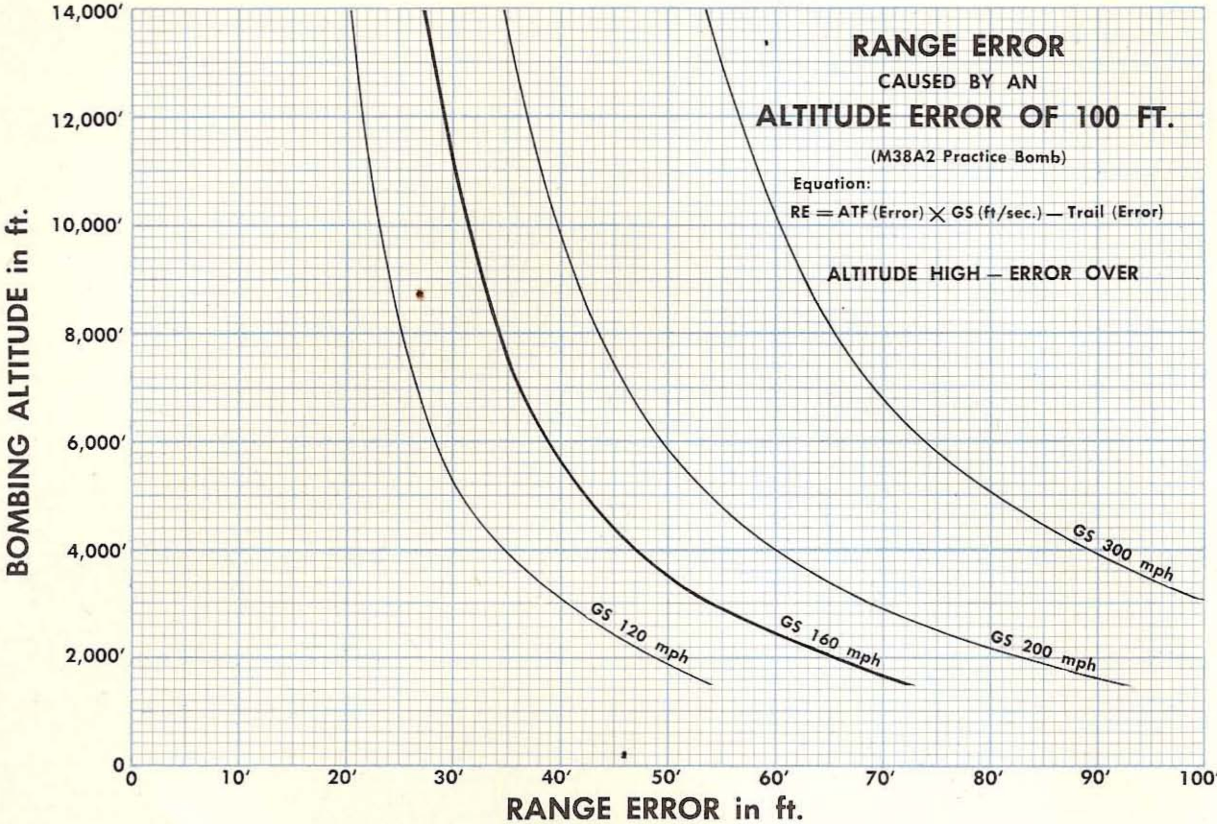
It isn't necessary for you to know your exact error down to a split-hair measurement of feet and inches. But it is important for you to learn to gage the approximate direction and distance of each particular error.

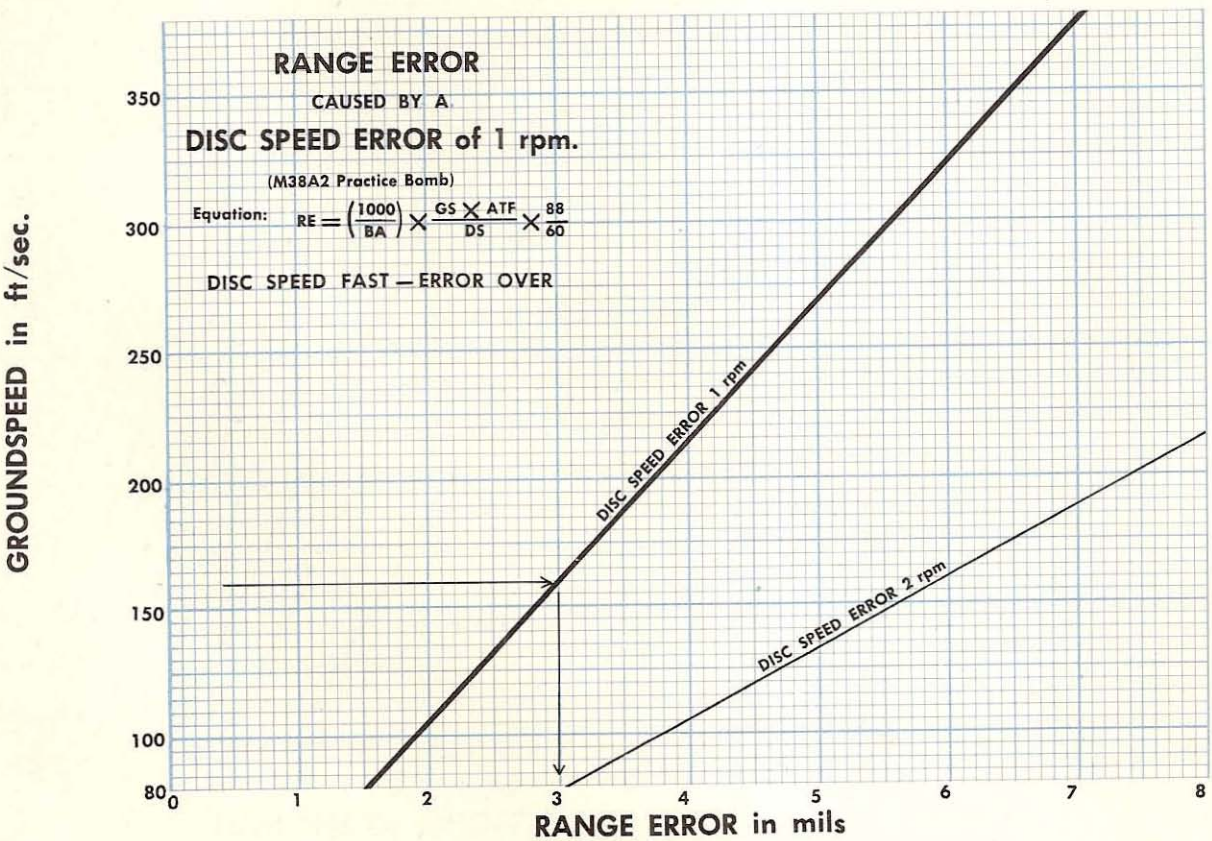
Always remember that your 12-C form is a practical tool to aid you in becoming a better bombardier. You err in judgment, which is worse than a bombing error, if you regard the 12-C form as just "a matter of form" for statistical purposes.

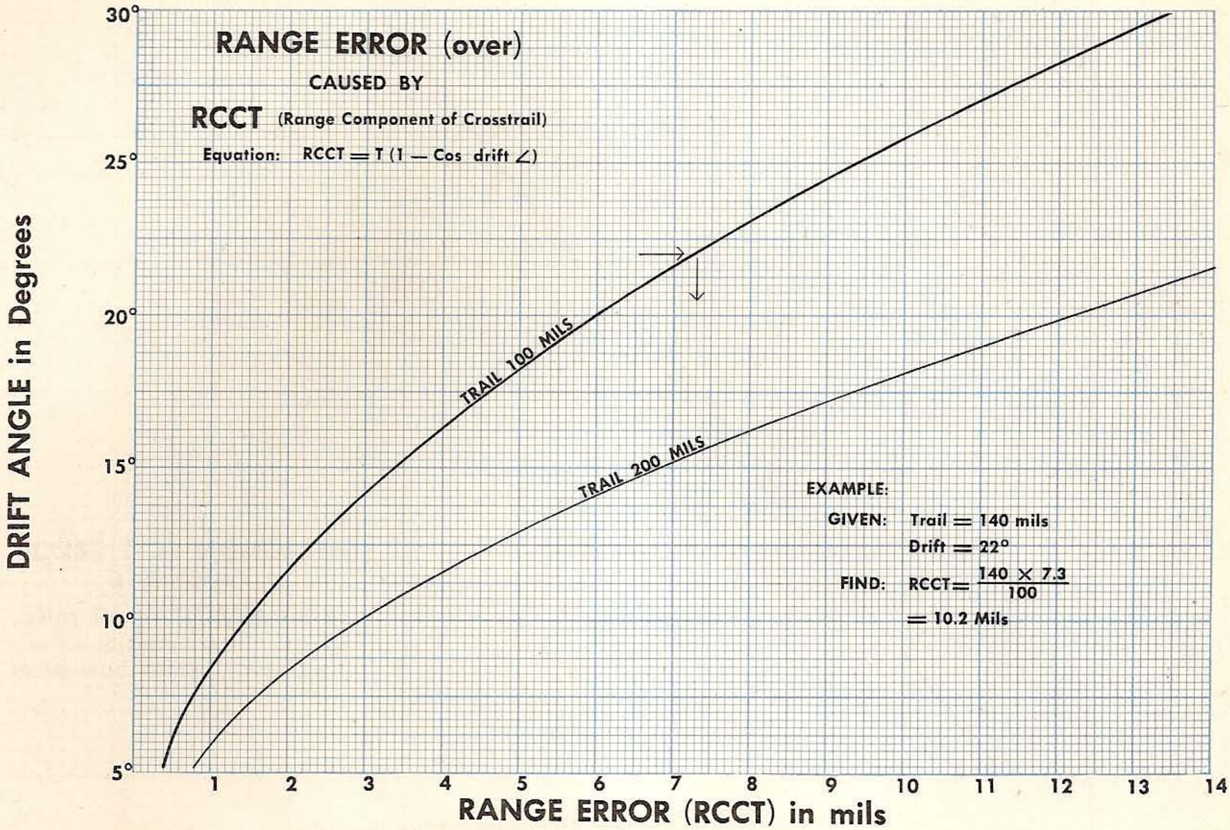
If you take advantage of the 12-C form and analyze each bomb impact, your bombing will be better!


ANGLES AND THEIR TANGENT VALUES
(ALSO SINE AND COSINE VALUES)
EXAMPLE:
GIVEN: Angle = 56°
FIND: Tan = 1.484
COSINE
SINE
TANGENT
ANGLE in degrees
90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25° 20° 15° 10° 5° 0°
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8
TRIG VALUES — TANGENT (also sine and cosine)

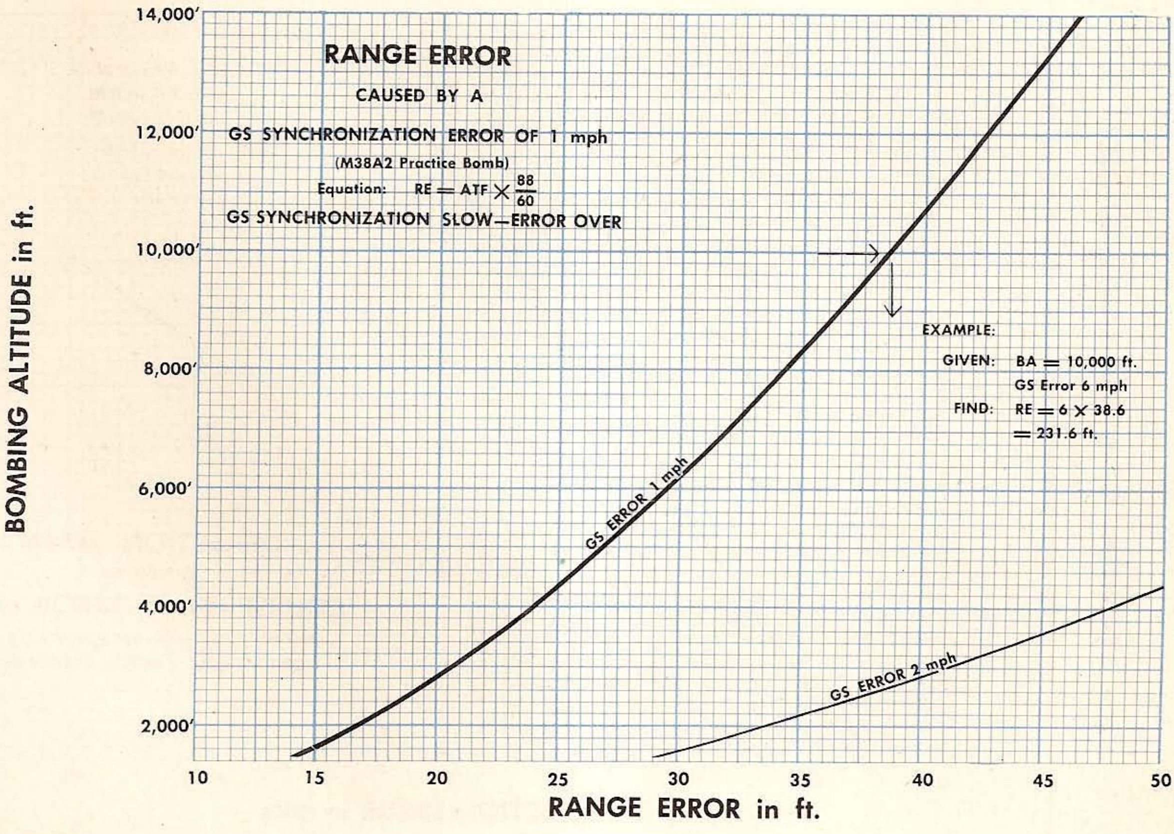

GROUNDSPEED
(M38A2 Practice Bomb)
Equation:
$GS = \frac{\text{Tan WR} \angle \times BA}{ATF} \times \frac{60}{88}$
EXAMPLE: GIVEN: BA = 4,400 ft.
Tan WR ∠ = 1.34
FIND: GS = 236 mph
BOMBING ALTITUDE 2,000 ft.
BA 3,000 ft.
BA 4,000 ft.
BA 5,000 ft.
BA 6,000 ft.
BA 7,000 ft.
BA 8,000 ft.
BA 9,000 ft.
BA 10,000 ft.
BA 11,000 ft.
BA 12,000 ft.
BA 13,000 ft.
BA 14,000 ft.
TANGENT OF WHOLE RANGE ANGLE (Tan Drop ∠ + Tan Trail ∠)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
GROUNDSPEED in mph


RANGE ERROR
CAUSED BY AN
ALTITUDE ERROR OF 100 FT.
(M38A2 Practice Bomb)
Equation:
RE = ATF (Error) × GS (ft/sec.) — Trail (Error)
ALTITUDE HIGH — ERROR OVER
BOMBING ALTITUDE in ft.
14,000'
12,000'
10,000'
8,000'
6,000'
4,000'
2,000'
0
GS 120 mph
GS 160 mph
GS 200 mph
GS 300 mph
0
10'
20'
30'
40'
50'
60'
70'
80'
90'
100'
RANGE ERROR in ft.

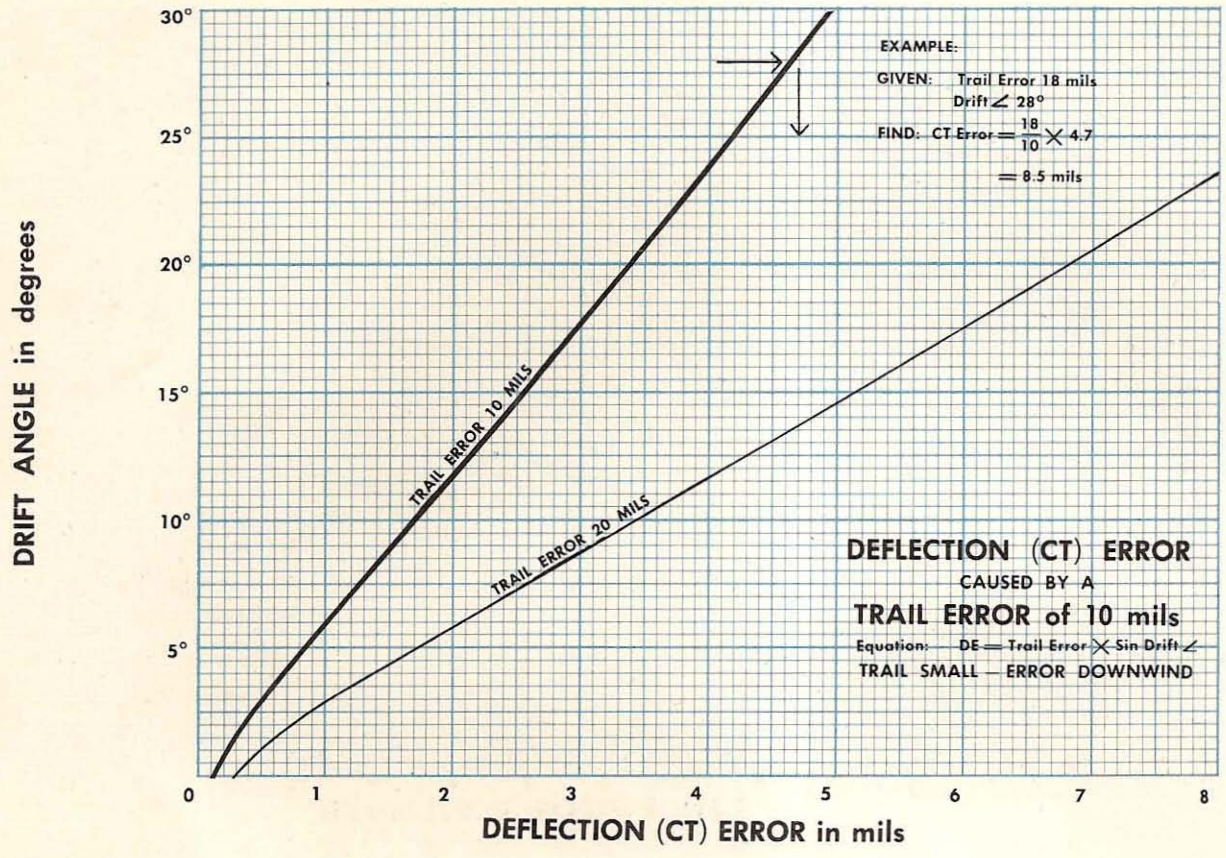

RANGE ERROR
CAUSED BY A
DISC SPEED ERROR of 1 rpm.
(M38A2 Practice Bomb)
Equation: RE = (1000/BA) × (GS × ATF)/DS × 88/60
DISC SPEED FAST — ERROR OVER
GROUNDSPEED in ft/sec.
350
300
250
200
150
100
80
DISC SPEED ERROR 1 rpm
DISC SPEED ERROR 2 rpm
0
1
2
3
4
5
6
7
8
RANGE ERROR in mils



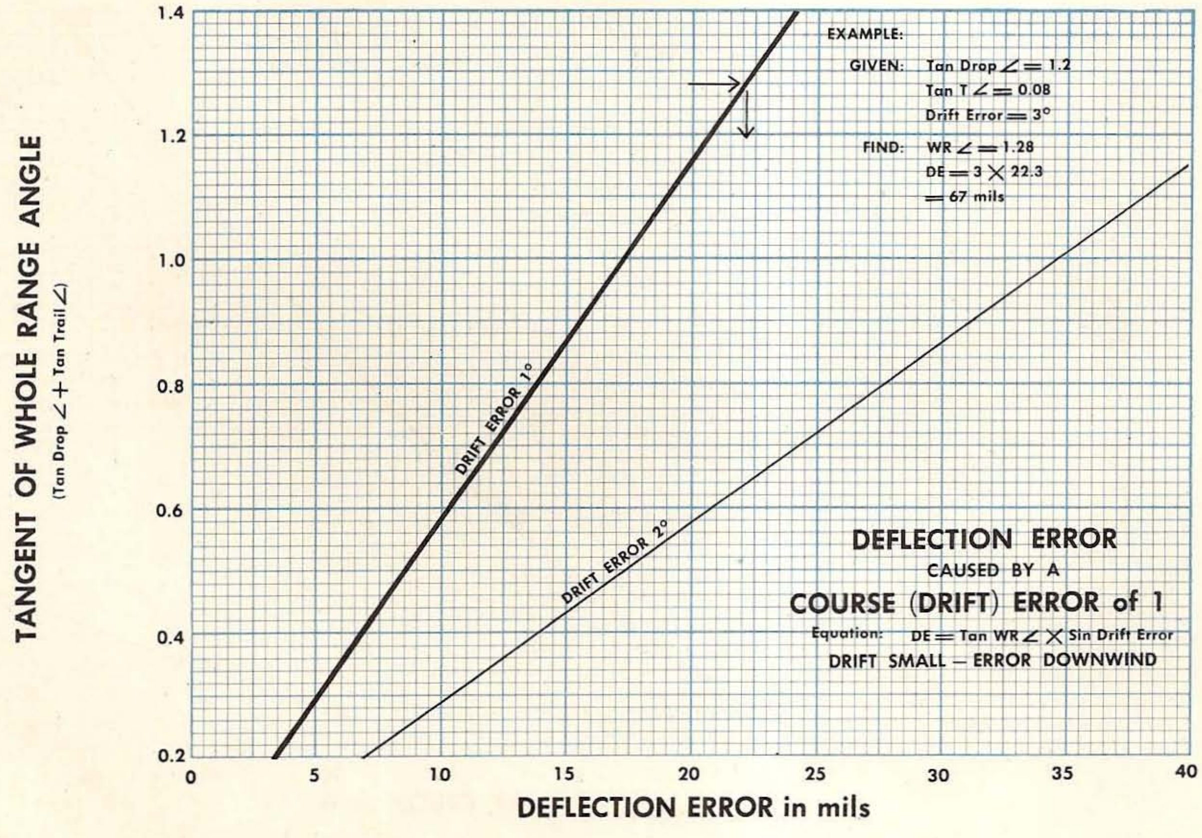
RANGE ERROR (over)
CAUSED BY
RCCT (Range Component of Crosstrail)
Equation: RCCT = T (1 — Cos drift ∠)
TRAIL 100 MILS
TRAIL 200 MILS
EXAMPLE:
GIVEN: Trail = 140 mils
Drift = 22°
FIND: RCCT = 140 × 7.3 / 100
= 10.2 Mils
DRIFT ANGLE in Degrees
30°
25°
20°
15°
10°
5°
1
2
3
4
5
6
7
8
9
10
11
12
13
14
RANGE ERROR (RCCT) in mils



RANGE ERROR
CAUSED BY A
GS SYNCHRONIZATION ERROR OF 1 mph
(M38A2 Practice Bomb)
Equation: RE = ATF × 88/60
GS SYNCHRONIZATION SLOW—ERROR OVER
GS ERROR 1 mph
GS ERROR 2 mph
EXAMPLE:
GIVEN: BA = 10,000 ft.
GS Error 6 mph
FIND: RE = 6 × 38.6
= 231.6 ft.
BOMBING ALTITUDE in ft.
14,000'
12,000'
10,000'
8,000'
6,000'
4,000'
2,000'
10
15
20
25
30
35
40
45
50
RANGE ERROR in ft.



DRIFT ANGLE in degrees
30°
25°
20°
15°
10°
5°
0
1
2
3
4
5
6
7
8
DEFLECTION (CT) ERROR in mils
TRAIL ERROR 10 MILS
TRAIL ERROR 20 MILS
EXAMPLE:
GIVEN: Trail Error 18 mils
Drift ∠ 28°
FIND: CT Error = 18/10 × 4.7
= 8.5 mils
DEFLECTION (CT) ERROR
CAUSED BY A
TRAIL ERROR of 10 mils
Equation: DE = Trail Error × Sin Drift ∠
TRAIL SMALL — ERROR DOWNWIND



TANGENT OF WHOLE RANGE ANGLE
(Tan Drop ∠ + Tan Trail ∠)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25
30
35
40
DEFLECTION ERROR in mils
DRIFT ERROR 1°
DRIFT ERROR 2°
EXAMPLE:
GIVEN: Tan Drop ∠ = 1.2
Tan T ∠ = 0.08
Drift Error = 3°
FIND: WR ∠ = 1.28
DE = 3 × 22.3
= 67 mils
DEFLECTION ERROR
CAUSED BY A
COURSE (DRIFT) ERROR of 1
Equation: DE = Tan WR ∠ × Sin Drift Error
DRIFT SMALL — ERROR DOWNWIND

SECTION 2

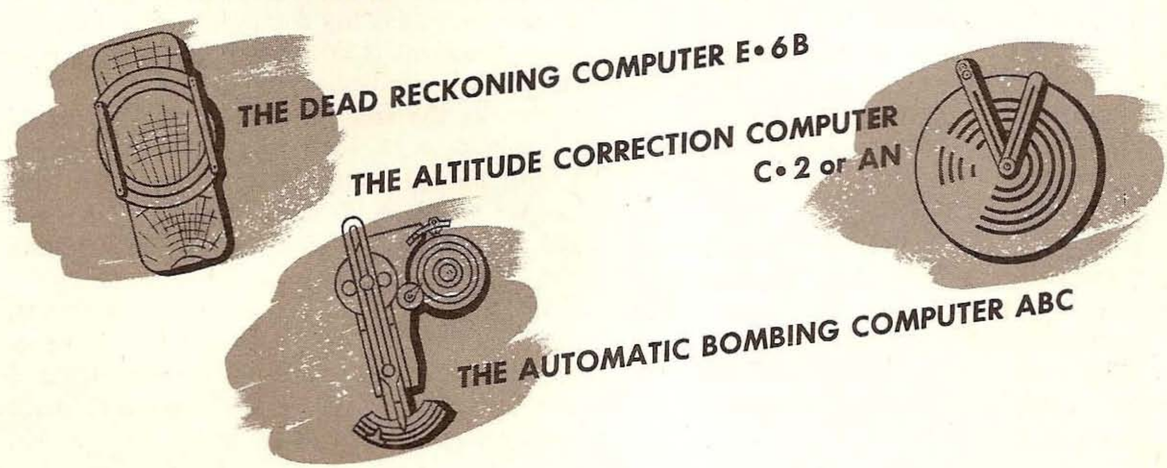
Bombing Computations

INTRODUCTION

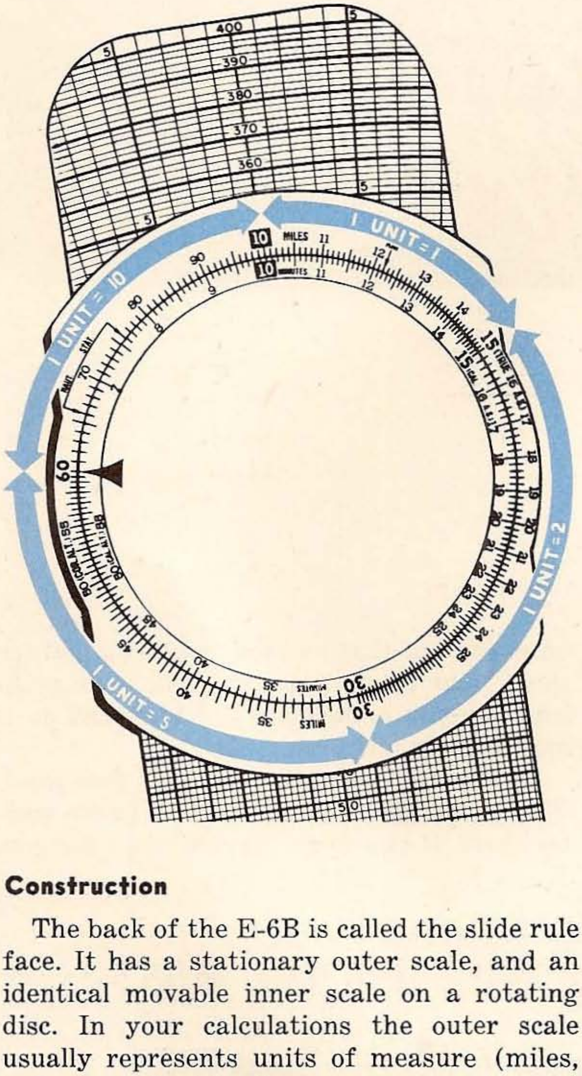
Computers are instruments for saving you time and trouble. As a bombardier, you will have to make many calculations involving mathematical figuring. Furthermore in the air you have to make them in a hurry. And in the air you're going to be busy! If you had the time, you could work out your problems on paper, but that method is difficult and too slow. Your computers can solve your problems for you **accurately**, and they can do it more **quickly** and more **easily.**

However, computers are not fool-proof. You've got to know them; you've got to **master** them, if you want them to work for you.

THE THREE COMPUTERS YOU WILL USE THE MOST . . .



SLIDE RULE AND AIRSPEED CALCULATIONS USING THE E-6B COMPUTER



Construction

The back of the E-6B is called the slide rule face. It has a stationary outer scale, and an identical movable inner scale on a rotating disc. In your calculations the outer scale usually represents units of measure (miles, gallons, etc.) while the inner represents units of time (hours and minutes). However, since these scales are standard logarithmic scales you can use them to solve any problem in multiplication or division.

On each of these scales, the numbering starts from an Index, labeled 10. If you begin at this Index and read **clockwise** around the circle, you will find the numbers increasing to 99. The next point on the scale is your Index 10 again, which is now equivalent to 100 (10×10).

If you continue reading in a clockwise direction, the point marked 11 on your scale now represents 110, the point marked 12 represents 120, etc. Thus, if you read around the circle once more, when you reach the Index again it will represent 1,000 (10×100). In other words, each time around the scale, the values **increase** in multiples of 10. Conversely, if you read the scale in a **counter-clockwise** direction, the values **decrease** in the same way. Thus, if your Index has a value of 1, the figure 90, read counter-clockwise, has a value of .9, 80 represents .8, etc.

Notice that there are two features common to all slide rule scales. First, the scales carry values from 10 to 100 only. Since the purpose of the scales is multiplication or division, this is no handicap; you can substitute the figure 20, for example, for 2 or 200 or .02 or any similar number, and you can adjust the decimal point in the answer accordingly. Likewise 55.5 can represent .555, 5,550, and all similar numbers. Consequently, you can use the available scales from 10 to 100 to represent any desired number, large or small.

The second feature of the slide rule scale is the way the space between the numbers is divided. The subdivisions are not the same way around the scale. Therefore, it is essential that you know and remember the values at any point of the scale. Usually when a bombardier says his computer gives him the wrong answer, it is because he has mis-read the value of the subdivisions.

Here is the way it works. From the Index 10 around to 15, each subdivision represents 1 unit. Thus, if you start clockwise from 100, (10 on the scale) the first point represents 101, the second 102, etc., up to and including 150.

From 150 (15 on the scale) to 300 (30), each subdivision represents 2 units. From 300 to 600, each subdivision represents 5 units; and from 600 to 1,000 (Index), each subdivision represents 10 units.

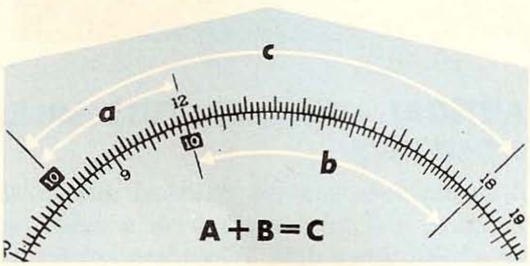
MULTIPLICATION AND DIVISION

The logarithmic scales on your E-6B Computer make it easy for you to multiply and divide. You can multiply numbers by adding their logarithmic distances and divide numbers by subtracting their logarithmic distances.

Examples—Multiplication

1. $12 \times 15 = 180$

Set the Index 10 of the inner scale under 12 on the outer scale, and opposite 15 on the inner scale read the answer on the outer scale (180). In so doing you add the logarithmic distance (**a**) of 12 to the logarithmic distance (**b**) of 15 to obtain a logarithmic distance (**c**) of 180. Thus $a + b = c$.



2. To calculate whole range in feet when you know the groundspeed in mph (182 mph) and the actual time of fall (23.7 sec.), and that a speed of 1 mph is equal to a speed of 1.47 ft. per sec., you have the equation:

$$WR = GS\ mph \times 1.47 \times ATF.$$

Therefore, $WR = 182 \times 1.47 \times 23.7$ ft.

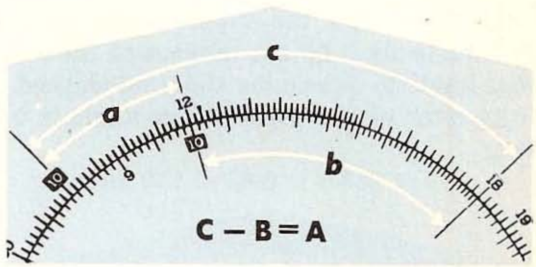
Here are two successive multiplications to perform. First you set the Index 10 on the inner scale under the 182 (same point as 18.2) on the outer scale; then find 1.47 (same as 14.7) on the inner scale, and read the product, 267 (same as 26.7) directly above on the outer scale. It is clear that this product is 267, not 2.67 or 26.7 or 2,670, because you are multiplying approximately 200 by 1.5, and should get a figure a little smaller than 300.

Next, multiply the intermediate product 267 by 23.7. Set the Index 10 of the inner scale under the 267, and then find 23.7 on the inner scale. Directly above 23.7 is your final answer on the outer scale, 6,340. Of course this is the scale point 63.4. But you know that you are multiplying a number close to 300 (267) by a number close to 20 (23.7), so the answer must be close to 6,000; hence it is 6,340.

Examples—Division

1. $\frac{180}{15} = 12$

Set 15 on the inner scale under 180 on the outer scale and over the Index 10 on the inner scale read the answer 12 on the outer scale. In so doing, you have subtracted the logarithmic distance (**b**) of 15 from the logarithmic distance (**c**) of 180 and obtained a logarithmic distance (**a**) of 12. Thus $c - b = a$.



2. In computing groundspeed in mph with the bombsight, you have the equation:

$$GS\ mph = \frac{DS \times BA}{7{,}773} \times \text{Tan WR}\angle$$

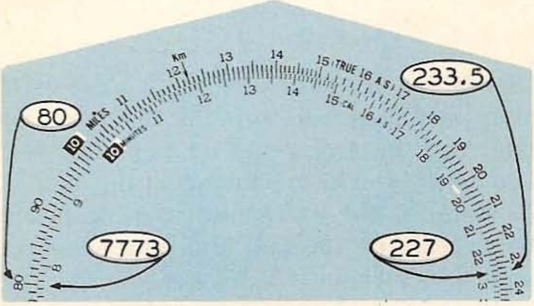
You will find that the bombing altitude and disc speed remain constant when bombing or calibrating instruments, whereas the tangent of the whole range angle will change with each change in groundspeed. In using this equation, you can substitute the constants of disc speed and bombing altitude. Then divide by 7,773 to find a constant which can be multiplied by the tangent of the whole range angle of any heading. Thus you can find the groundspeed on that heading.

The first part of this equation: $\frac{DS \times BA}{7{,}773}$ can be solved by one setting on the computer.

For a bombing altitude of 8,000 ft. the disc speed setting is 227 rpm. Therefore, set 7,773 on inner scale under 8,000 on the outer scale, and over 227 on the inner scale, read the intermediate product 233.5 on the outer scale.

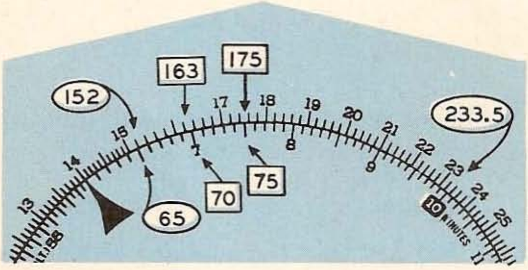
Note:

Over the index 10 on the inner scale you will find the quotient (division of 8,000 by 7,773) on the outer scale. Your next step would be to multiply this quotient by 227. This is done automatically, because you have already set the quotient on the outer scale over the index 10 on the inner scale.



After you find the intermediate product 233.5, multiply it by the tangent of the whole range angle to determine the groundspeed. If the tangent of the whole range angle is 0.65 then:

$$GS = 233.5 \times 0.65 = 152 \text{ mph.}$$



With this same setting on the computer, you can solve for the groundspeed on different headings by knowing the whole range angle, provided the bombing altitude and disc speed remain constant.

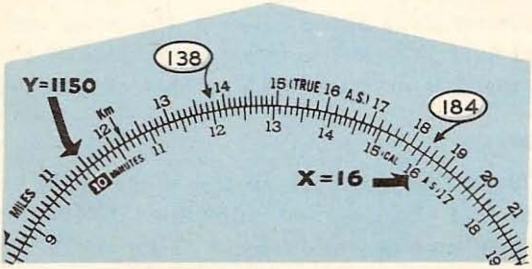
For Tan WR ∠ of 0.70,

$$GS = 233.5 \times 0.70 = 163 \text{ mph.}$$

For Tan WR ∠ of 0.75, GS = 175 mph.

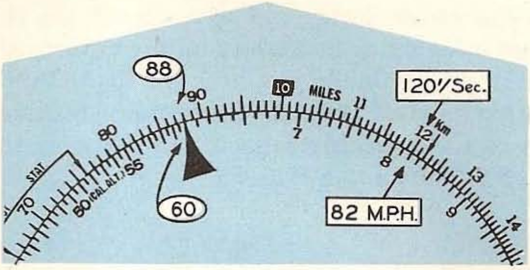
PROPORTIONS

The circular slide rule solves problems of proportion. Thus:



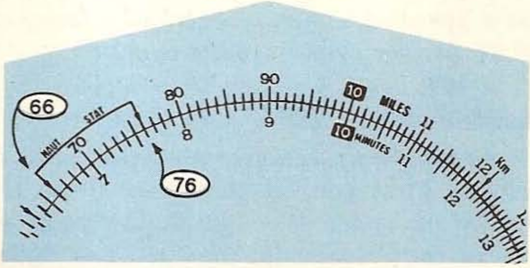
$$\frac{138}{12} = \frac{184}{X} = \frac{Y}{100}$$

Since 60 mph equals 88 ft/sec, you can convert mph to ft/sec by setting 60 on the inner scale under 88 on the outer scale or by setting the same proportion, 3,600 under 5,280. Then opposite any speed in mph on the inner scale you can read the same speed in ft/sec on the outer scale, and vice versa. For example, a speed of 120 ft/sec equals 82 mph.



NAUTICAL MILES, STATUTE MILES, KILOMETERS

You can interconvert nautical miles, statute miles, and kilometers with a single setting of the inner disc. When you set 66 nautical miles on the "NAUT" marker, the equivalent 76 statute miles and 122 kilometers appear under their respective markers.



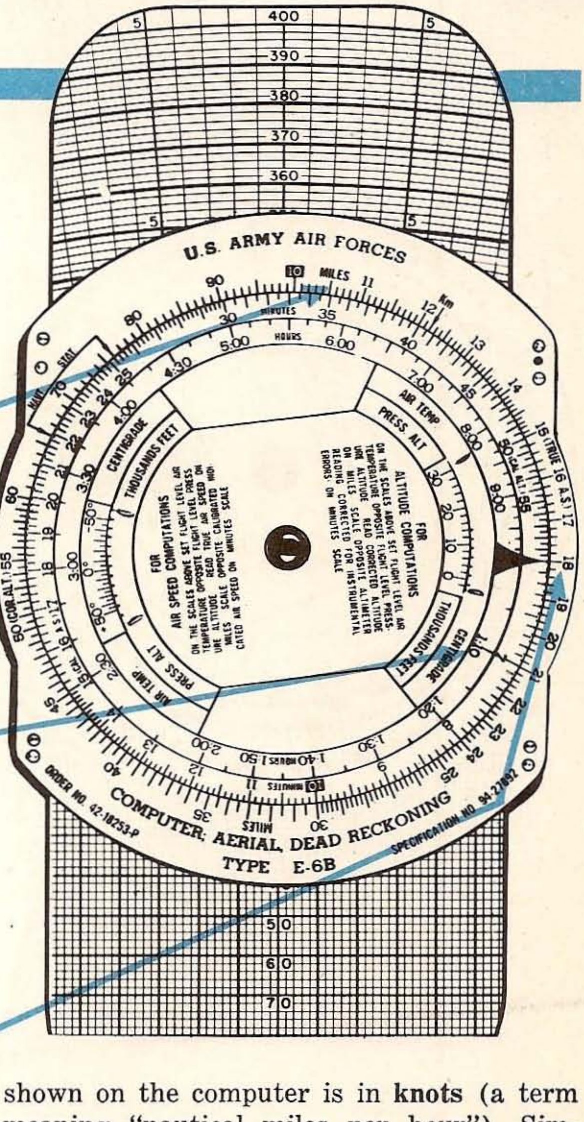
DISTANCE, TIME, AND SPEED

To convert minutes of time to hours, it is necessary to divide the number of minutes by 60, since there are 60 min. in 1 hr. Therefore, in any problems involving time, the solid black pointer found on the inner (time) scale at the number 60 must be used. This constitutes 1 hr. of time, or 60 min., and its multiples of 10: 600 min., 6,000 min., etc. The inner disc contains two scales, one calibrated in minutes and the other in hours and minutes.

There is a definite relationship between distance, time, and speed. Distance is the product when time is multiplied by speed. Speed or rate is the quotient when distance is divided by time. Time is the quotient of distance divided by speed.

Thus $\text{Rate} = \frac{\text{Distance}}{\text{Time}}$ Therefore in working problems involving these three factors, place **distance** on the outer scale opposite the **time** in hours or minutes on the inner scale. This automatically divides distance by time. Then read the **rate** per hour on the outer scale opposite the black pointer (the 60 min. or 1 hr. mark).

These positions are always the same regardless of which item (distance, time, or rate) is unknown. If you know two, and if you set them on the computer in their proper places, you can find the desired unknown figure at its correct place.



EXAMPLE 1

GIVEN: Groundspeed 180 knots. Time of flight 35 min.
FIND: Distance traveled.
SOLUTION: Set the black pointer opposite 180 (18) on the outer (miles) scale. Opposite 35 on the inner (minutes) scale, read on outer (miles) scale the distance traveled.
ANSWER: 105 nautical miles.

EXAMPLE 2

GIVEN: Groundspeed 180 knots. Distance to travel 210 nautical miles.
FIND: Time required to fly distance.
SOLUTION: Set black pointer to 180 (18) on outer scale. Opposite 210 on outer scale, read 70 (7) on inner scale, or 1 hr. 10 min. (1:10) directly below.
ANSWER: 1 hr. 10 min.

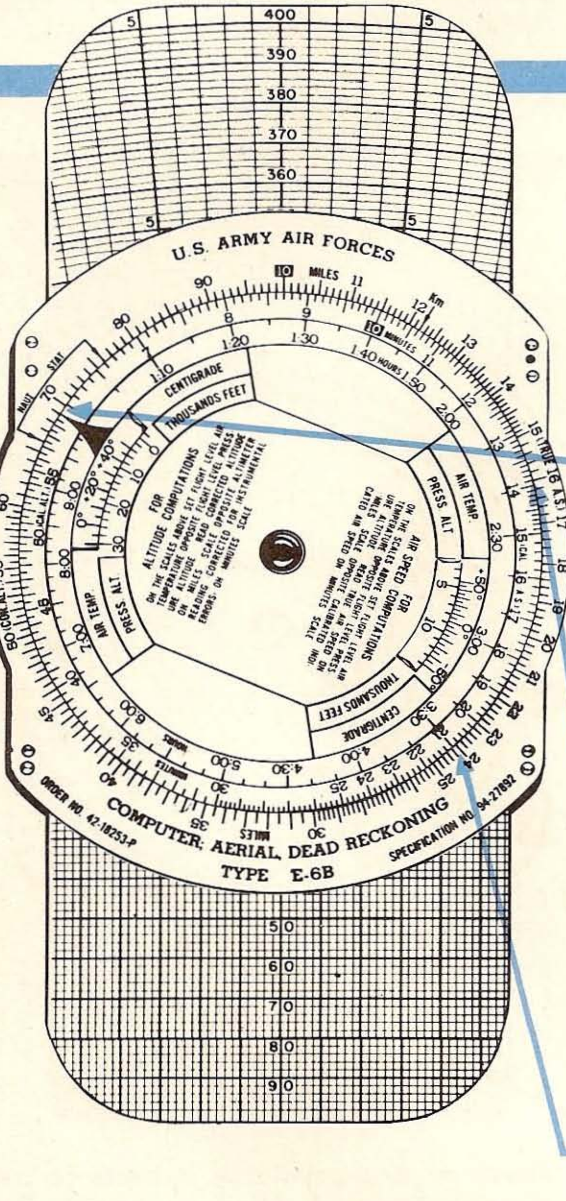
EXAMPLE 3

GIVEN: Distance traveled 240 nautical miles. Elapsed time 1 hr. 20 min.
FIND: Groundspeed.
SOLUTION: Set 1 hr. 20 min. (1:20) on inner scale opposite 240 (24) miles on outer scale. Opposite black pointer read groundspeed.
ANSWER: 180 knots.

NOTE: Always remember that your computer is dividing distance by time to give speed or rate. Therefore, if the distance is given in **nautical miles**, the groundspeed shown on the computer is in **knots** (a term meaning "nautical miles per hour"). Similarly, if the distance is given in **statute miles**, the groundspeed is in mph.

FUEL CONSUMPTION

Do this in the same manner as time, speed, distance. The only difference in the problem is that you substitute gallons of fuel for units of distance; therefore, find the rate of consumption at the black pointer.



EXAMPLE 1

GIVEN: Fuel consumed, 145 gal. Elapsed time, 2 hr. 6 min.
FIND: Rate of consumption.
SOLUTION: Opposite 145 on the outer scale, set 2 hr. 6 min. on the inner scale. Opposite the black pointer read the rate of fuel consumption.
ANSWER: 69 gals/hr.

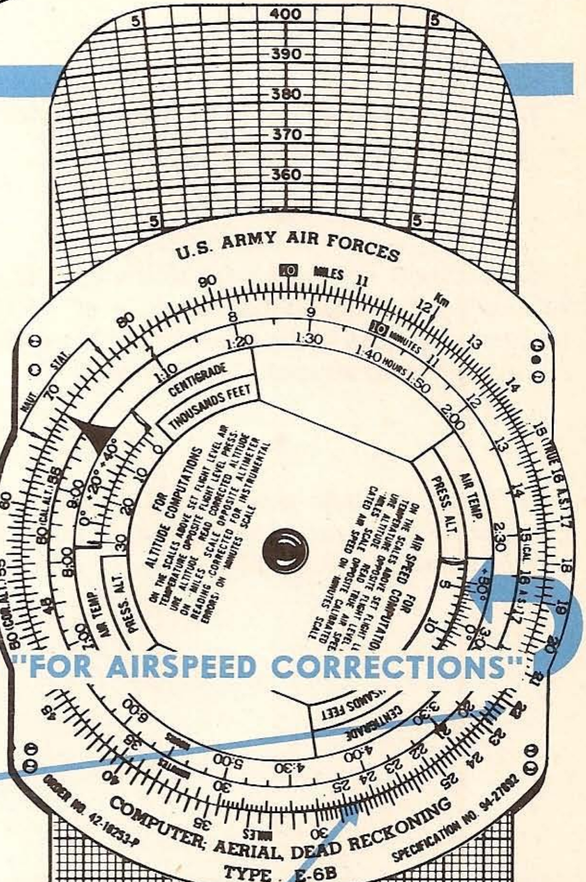
EXAMPLE 2

GIVEN: Fuel remaining, 160 gals. Rate of consumption 69 gals/hr.
FIND: Remaining flight time.
SOLUTION: Set black pointer to rate of consumption, 69 gals/hr. Opposite 160 on outer scale, read remaining time of flight on inner scale.
ANSWER: 2 hr. 19 min.

EXAMPLE 3

GIVEN: Rate of consumption, 69 gals/hr. Time needed for flight, 3 hr. 30 min.
FIND: Fuel needed for flight.
SOLUTION: Set black pointer to rate of consumption, 69 gals/hr. Opposite time of flight on inner scale, read gallons of fuel needed.
ANSWER: 241.5 gals.

INTERCONVERSION OF CALIBRATED AND TRUE AIRSPEED



EXAMPLE 1

GIVEN: Calibrated airspeed, 200 knots. Flight level pressure altitude, 10,000 ft. Flight level temperature, –12°C.

FIND: True airspeed.

SOLUTION: Adjust the rotating disc to bring the temperature, –12°C, opposite the figure 10 (10,000 ft.) on the pressure altitude scale which appears in the Airspeed Correction window.

BE SURE TO USE THE WINDOW MARKED "FOR AIRSPEED CORRECTIONS"

Opposite 200 (20) on the inner scale read the true airspeed on the outer scale.
ANSWER: 230 knots.

EXAMPLE 2

GIVEN: Flight level temperature, +10°C. Flight level pressure altitude, 8,000 ft. True airspeed, 280 mph.
FIND: Calibrated airspeed.
SOLUTION: Set flight level temperature +10°C. opposite flight level pressure altitude 8,000 ft. Opposite 280 mph true airspeed on the outer scale, read calibrated airspeed on the inner scale.
ANSWER: 244 mph.

Exercises

1. At a groundspeed of 158 mph, how far will you travel in 1 hr. and 26 min.?

•

2. How many kilometers and statute miles are equivalent to 355 nautical miles?

•

3. If an airplane flies 1,350 miles in 7 hrs. 20 min., what is its average groundspeed?

•

4. At flight level pressure altitude of 21,-900 and a flight level temperature of −8°C (corrected), what is the true airspeed in mph if the calibrated airspeed is 131 mph?

•

5. If an airplane consumes 153 gals. of gasoline in 2 hrs. and 18 min., what is its rate of consumption per hour?

6. If you travel a distance of 308 miles in 2 hrs. and 13 min., what is your groundspeed?

•

7. How many feet per second is the equivalent of 168 mph?

•

8. A fully loaded airplane holds 435 gals. of gasoline. If it uses fuel at the rate of 84 gals/hr, how long can it remain in the air?

•

9. At a groundspeed of 210 mph, how long will it take to travel 895 miles?

•

10. Suppose you are flying at a bombing altitude of 4,000 ft. and the disc speed is 326. If the tangent of the whole range angle is .94, what is the groundspeed in mph? If Tan of whole range angle is 1.07 what is the groundspeed?

ANSWERS

1. 226 miles.
2. 408 statute miles.
   658 kilometers.
3. 184 mph.
4. 192½ mph.
5. 66½ gals/hr.
6. 139 mph.
7. 246.5 ft/sec.
8. 5 hrs. 12 mins.
9. 4 hrs. 16 mins.
10. 158 mph.
    180 mph.

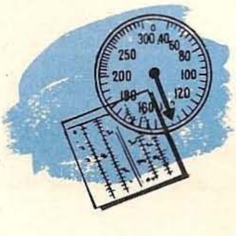
VECTOR SOLUTIONS

Definitions

Before you try to solve vector problems on your computer, you need to understand a few terms that are constantly used. The most essential terms are:

INDICATED AIRSPEED IAS

The reading of the airspeed indicator in mph.

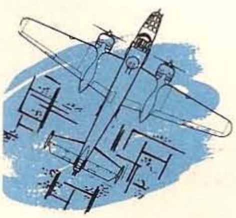


CALIBRATED AIRSPEED CAS

The reading of the airspeed indicator, corrected for instrumental and installation error. In bombing, "miles per hour" is generally used; for navigation, "knots." For the latter purpose, indicated airspeed is calibrated and converted to knots in one operation by reading the appropriate column on the airspeed meter calibration card.

TRUE AIRSPEED TAS

The true speed of an aircraft relative to the air. Airspeed is always true airspeed unless otherwise designated. Airspeed is obtained by correcting the calibrated airspeed for density, using temperature and pressure altitude corrections.

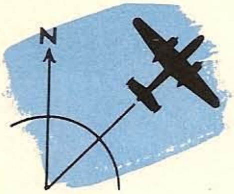


GROUNDSPEED GS

Actual speed of aircraft relative to the earth's surface.

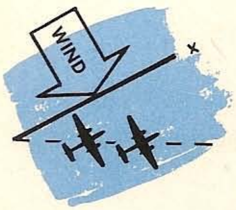
TRUE COURSE TC

The direction of flight over the surface of the earth, expressed as an angle with respect to true north. Course is always true course unless otherwise designated. It is the course laid out on the chart or map. All courses are measured clockwise from true north through 360°. True course made good may be called "track."



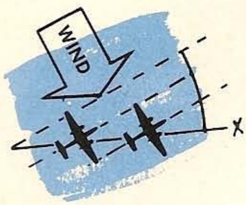
TRUE HEADING TH

The direction of the longitudinal axis of the aircraft, expressed as an angle with respect to true north. In other words, it is the true course with the drift correction applied. Heading is always true heading unless otherwise designated.



DRIFT Dr.

The angle between the true heading and the true course. Named right or left according to the direction an aircraft is drifting.

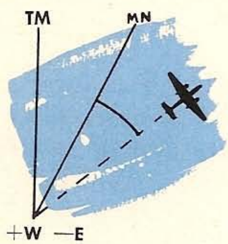


DRIFT CORRECTION Dr. Corr.

The angle added to or subtracted from an aircraft's true course to obtain true heading. When you have right drift, subtract the angle from the true course to obtain the true heading (Minus Corr.); when you have left drift, add the angle (Plus Corr.).

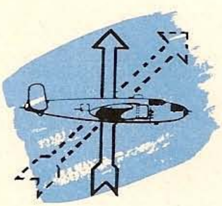
VARIATION Var.

The angle between a line to true north and a line passing through a freely suspended compass needle influenced solely by the earth's magnetism. It is the angle between lines to true north and magnetic north. It is named east or west according to the direction of the compass needle from true north. Variation changes with time and place.



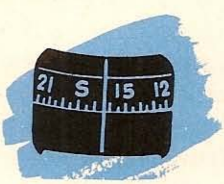
MAGNETIC HEADING MH

True Heading with variation applied. The direction of the longitudinal axis of the aircraft, expressed as an angle with respect to magnetic north. If the variation is **west** ADD **variation** to true heading to obtain magnetic heading. If variation is **east** SUBTRACT.



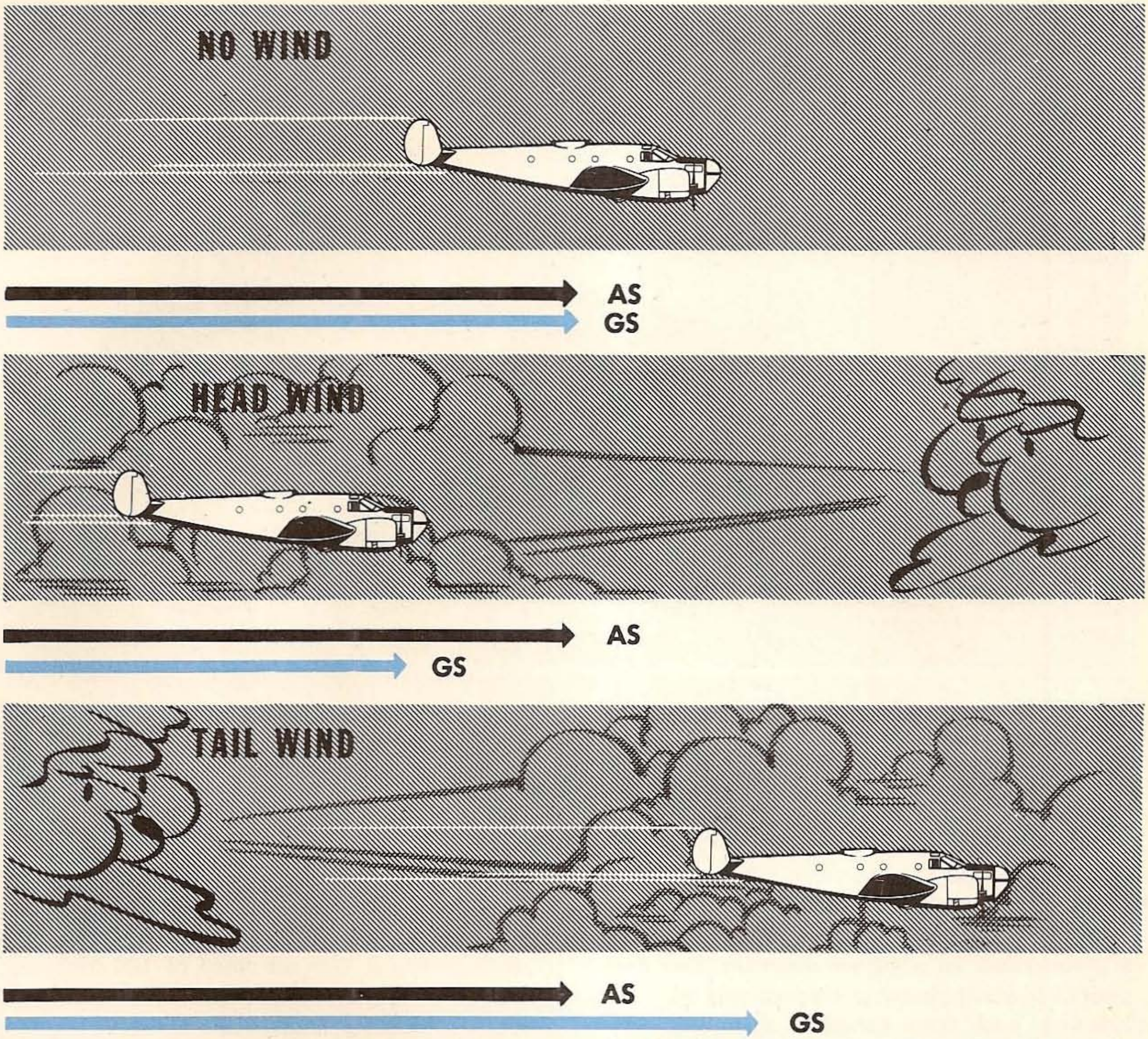
DEVIATION Dev.

The angle between a line to magnetic north and a line passing through a compass needle. Deviation is caused by magnetic influences in an aircraft. It is named east or west according to the direction in which the needle is deflected from magnetic north.



COMPASS HEADING CH

Magnetic heading with deviation applied. If the deviation is **west,** ADD deviation to magnetic heading to obtain compass heading. If deviation is **east** SUBTRACT.



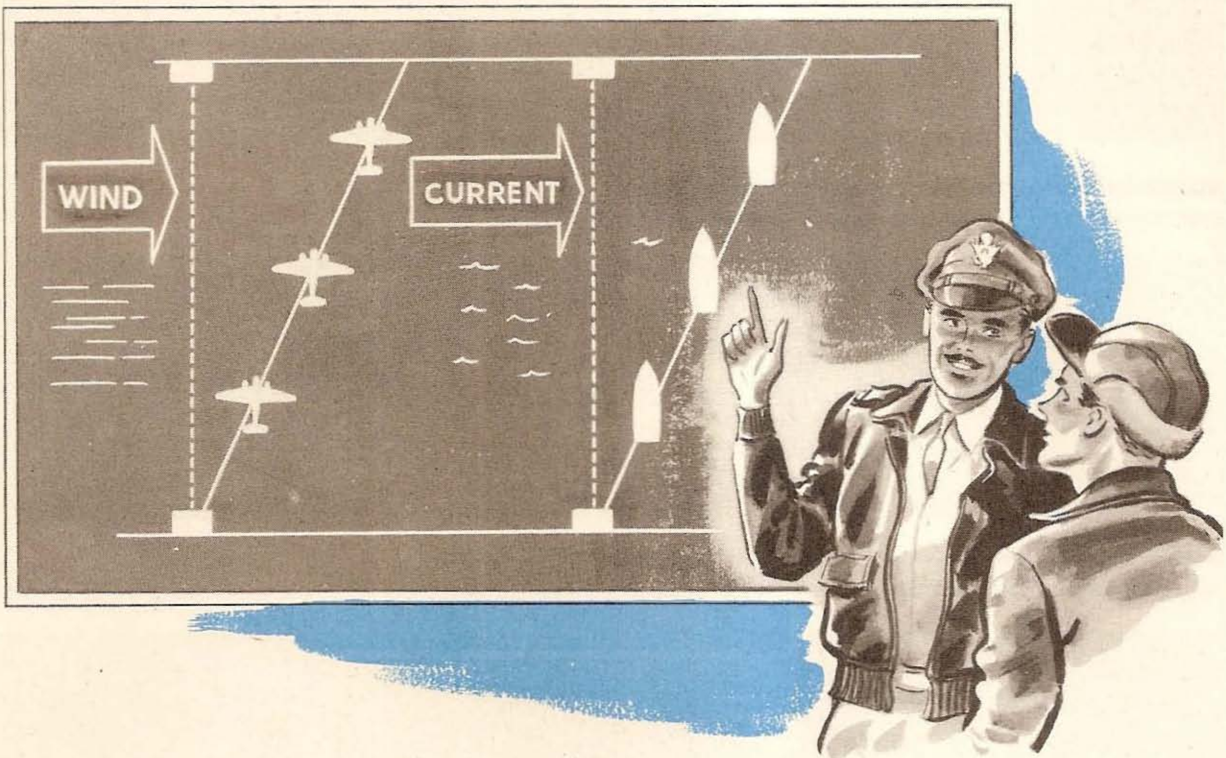
WIND

When there is no wind, an airplane which flies a true airspeed of 150 mph on a true heading of 90° will actually travel 150 mph over the ground in an easterly direction. That is, true airspeed and groundspeed are equal, and true heading and true course coincide. But wind changes the situation. The airplane can still fly 150 mph through the air on an easterly heading; but if the air moves while the airplane flies through it, it affects both the airplane's groundspeed and true course.

Here's a simple example. Suppose an airplane flying east at a true airspeed of 150 mph encounters a 20 mph wind from the east. Clearly, the moving air mass would carry the airplane 20 miles west while it flew 150 miles east through the air; the result would be a net groundspeed of 130 mph in an easterly direction. If the 20 mph wind blew in the same direction as the heading, the airplane would fly 150 miles east through an air mass which would itself move 20 miles east during the same hour. Thus the airplane would actually move 170 mph over the ground.

When the wind blows at an angle to the heading, the airplane is subject to forces moving it in two directions: (1) in the direction of its heading at true airspeed, and (2) in the direction of air movement at wind speed. However, the airplane actually moves over the ground in a single direction and at a groundspeed which is a **resultant** or combination of the flight and wind movements.

VECTOR DIAGRAMS



A vector is a straight line which proceeds from a starting point in a given direction, and whose length shows **distance traveled in a given time.** In a vector diagram, two **component** vectors showing respectively (1) **true** heading and true airspeed and (2) wind direction and speed will determine the position and length of a **resultant** vector. The **resultant** vector shows the true course and groundspeed.

To illustrate the principle, assume that you have a toy motorboat which can cross a 10-foot stream in one minute, and that the stream also flows 10 ft/min. If the boat went directly across the stream, it would reach the opposite bank in just one minute. During that minute, however, the mass of **water** in which the boat moves carries the boat 10 ft. downstream; so the boat reaches the opposite bank 10 ft. downstream from its point of departure. As it crosses the stream its bow is always **headed** for the opposite bank, but its **course** forms a 45° diagonal (a resultant vector) across the stream.

You have more practical use of vectors when you solve for the **heading** which will give you a desired course. Assume that your airplane has a true airspeed of 100 mph and that you want to fly due east when a 20 mph wind is blowing from 315°. Clearly, if your airplane heads directly east, the air movement to the southeast will carry you south of your course. Therefore, your airplane must be turned "into the wind"—that is, toward the source of the wind—sufficiently to counteract the southward drift caused by the wind. To find your desired heading, you begin by assuming that your airplane must always be on its course (line AX). Then chart the effect of an hour's wind movement (AB) from the starting point A to point B; from point B, swing an arc using a radius of an hour's true airspeed, to intersect the desired true course line. Draw a line through the point of intersection (point C) from point B. The direction of line BC represents the **true heading** which must be flown in order to keep the airplane on the desired 90° true course.

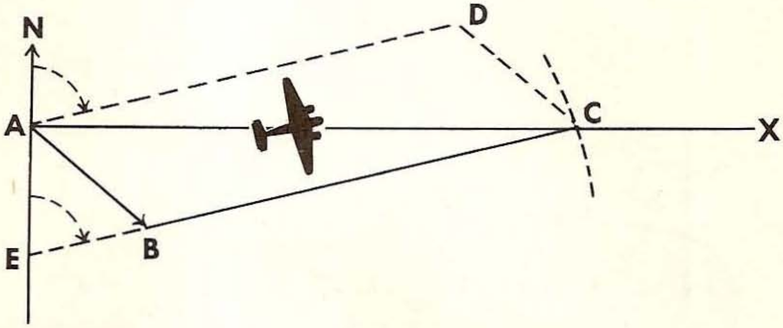
TO FIND HEADING AND GROUNDSPEED

GIVEN:

Desired true course 90°
True airspeed 100 mph
Wind from 315° at 20 mph

REQUIRED:

True heading
Groundspeed



NOTE:

In all vector problems, first notice the direction of your course or heading, and lay your problem out accordingly. The top of the paper is north. In this problem you are going east; therefore, your diagram will begin on the left side of the paper.

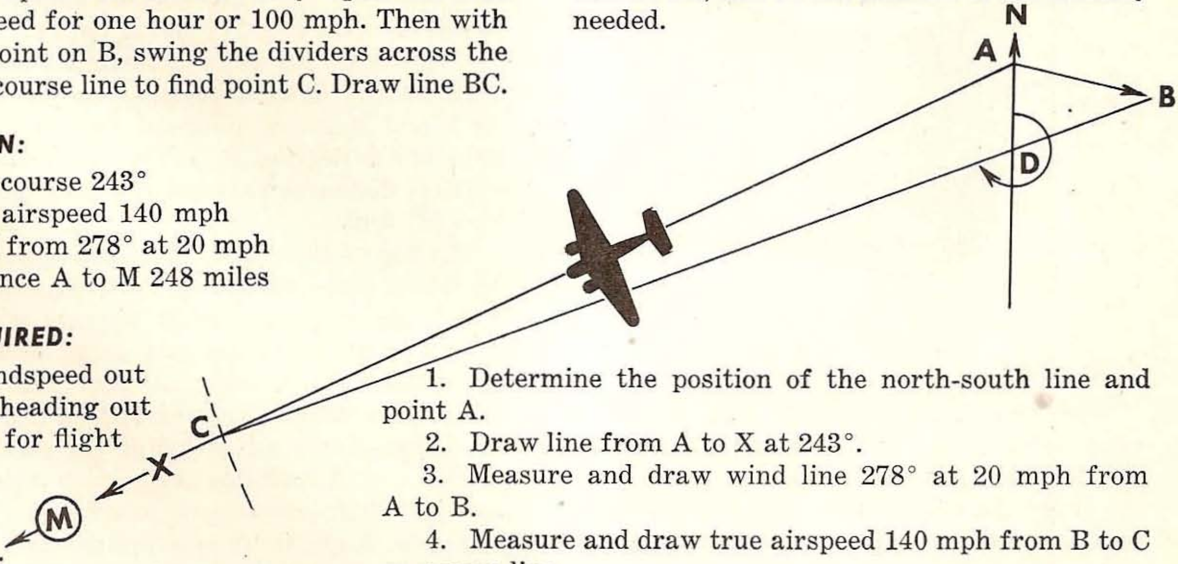
1. First, lay out a north-south line on the left side of the paper.
2. From A draw the true course line 90° as AX.
3. From A draw the wind line AB from 315° at 20 mph.
4. Make the distance AB equal to 20 miles or one hour's wind movement, on the scale you wish to use.
5. Spread dividers so they equal the true airspeed for one hour or 100 mph. Then with one point on B, swing the dividers across the true course line to find point C. Draw line BC.
6. The required true heading is the direction of the line BC.
7. You may make triangle ADC so that ABCD is a parallelogram. (Now the line AD also shows the required true heading.)
8. The required groundspeed is shown by the length of line AC.
9. It usually is not necessary to complete the parallelogram, as the required true heading and groundspeed may be determined from the triangle ABC. Note that the angle NAD, which is the true heading angle, is the same as the angle NEC (CB continued through B to E). The true heading may therefore be determined by finding the direction of BC, and so the side AD is not actually needed.

GIVEN:

True course 243°
True airspeed 140 mph
Wind from 278° at 20 mph
Distance A to M 248 miles

REQUIRED:

Groundspeed out
True heading out
Time for flight

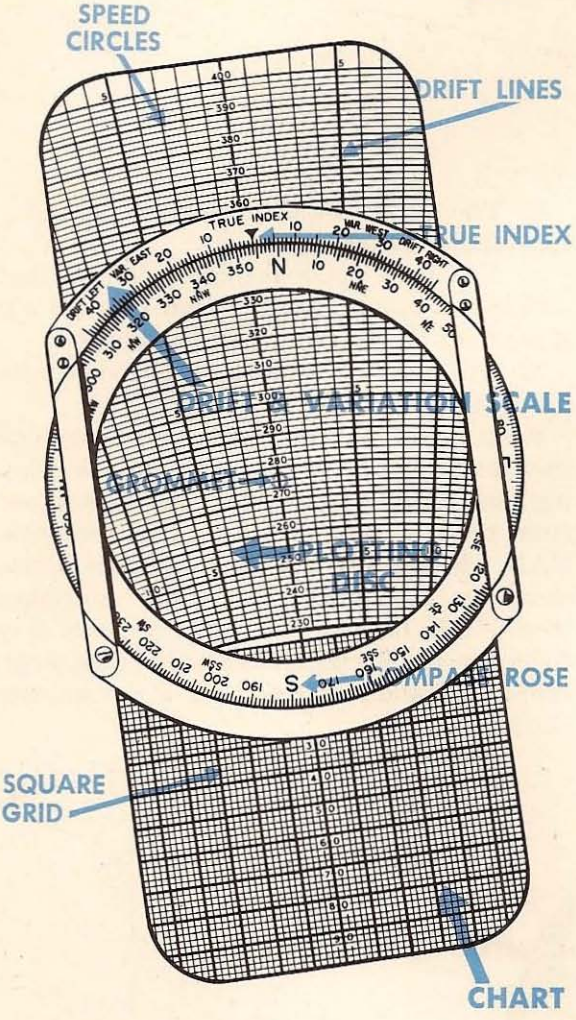


1. Determine the position of the north-south line and point A.
2. Draw line from A to X at 243°.
3. Measure and draw wind line 278° at 20 mph from A to B.
4. Measure and draw true airspeed 140 mph from B to C on course line.
5. Measure line AC, groundspeed.
6. Measure angle NDC and subtract it from 360°, true heading.
7. Divide distance AM (248) by groundspeed, time for flight.

NOTE.

The exercises at the end of the next chapter (Vector solutions using the E-6B computer) are all suitable for solution by vector triangles.

VECTOR SOLUTIONS ON THE *E·6B Computer*



GENERAL

With the E-6B computer you can solve wind vectors and similar problems without plotting the complete triangles. By moving the chart and the plotting disc, and making a few pencil marks on the face of the computer, you can solve any wind problem. You do not need to work out in your mind such things as variation, drift angles, wind angles, or groundspeed factors. You can read all the data and the answers right on the scales of the computer.

Description

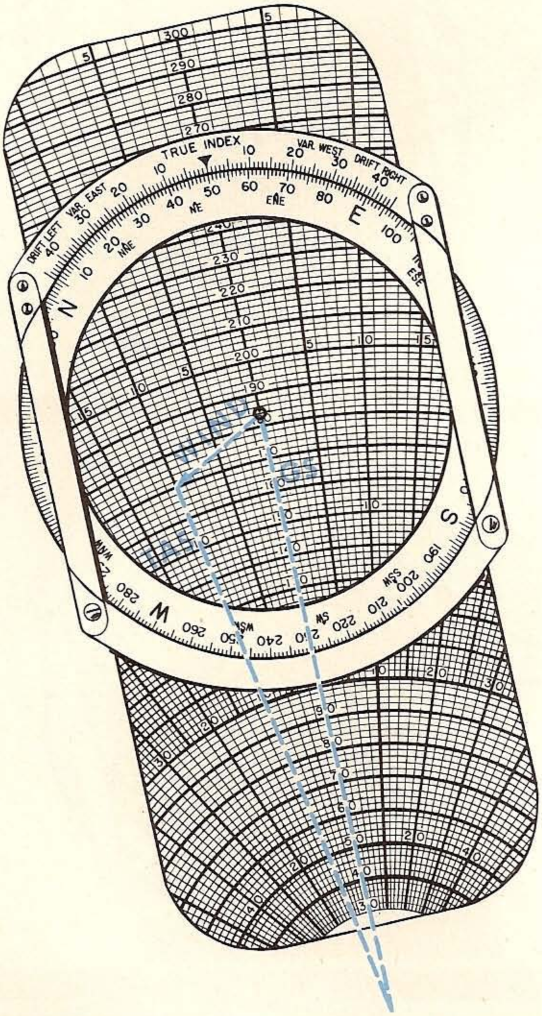
To solve vector problems, use the front side of the computer. This side consists of a transparent **plotting disc,** a sliding **chart,** and a **drift & variation scale.**

The outer edge of the plotting disc is a **compass rose** graduated in degrees and at the center is a small circle called the **grommet.** The plotting disc can be rotated then 360°.

Radiating **drift lines,** concentric **speed circles,** and a **square grid** are printed on the chart. The chart sets in the metal frame and can be so adjusted that any desired part of it can be set under the plotting disc. The concentric speed circles are graduated in units of speed. The distance between all light speed circles is two (2) units and the distance between the dark speed circles is ten (10) units. For speeds of 100 units or more the distance between the light drift lines is one degree (1°) and distance between the dark drift lines is five degrees (5°). The horizontal and vertical distances between the grid lines are two (2) units.

The top of the metal frame has a drift and variation scale matching the compass rose. This scale is graduated in degrees starting with zero at the center and going to 45° on each side. The marker at zero degrees is called **True Index**. West **variations** and right **drift corrections** are found on the right side of the drift & variation scale; east variations and left drift corrections are found on the left side. Right drift is a minus correction; left drift is a plus correction. It will help you to keep this straight if you scratch a minus sign (–) on the right side and a plus sign (+) on the left side. Then you can always read proper drift correction from the computer.

The Vector Triangle



Using the E-6B computer you solve the vector triangle exactly as you would if plotting it on graph paper. Each of the three sides of the triangle is called a vector and represents a direction and speed.

The three vectors are:

DIRECTION	SPEED
Wind Direction	Wind Speed
True Heading	True Airspeed
True Course	Groundspeed

If you know any two of the three directions and any two of the three speeds you may solve for the other direction and speed on your computer. But remember in the vector triangle:

Wind Direction and Wind Speed **always go** together:

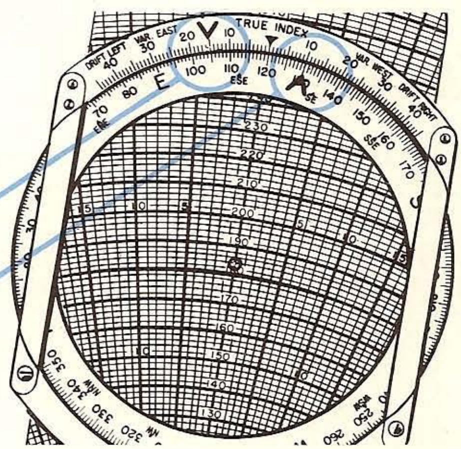
True Heading and True Airspeed **always** go together; and

True Course and Groundspeed **always go** together.

Mark:

MAGNETIC INDEX on the drift & variation scale at the local variation, with a V.

TRUE COURSE on the compass rose with a Λ.

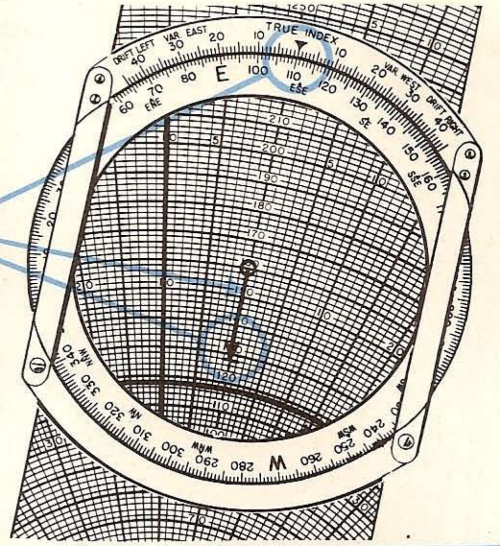


Plot:

WIND ARROW on the plotting disc by setting the wind direction at the True Index and tracing the measurement of the wind speed from the grommet down the centerline of the chart, then mark end with a short crosswise line and/or point.

DRIFT on the plotting disc by tracing along the appropriate radiating drift line.

GROUNDSPEED on the plotting disc by tracing along arc of the appropriate groundspeed circle.



Always Set or Find:

MAGNETIC HEADING at magnetic index.

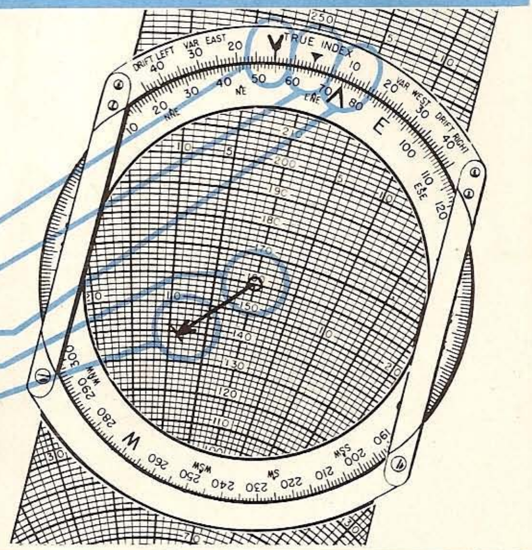
TRUE HEADING at True Index.

TRUE COURSE on compass rose at the drift correction on drift & variation scale.

TRUE AIRSPEED under grommet.

GROUNDSPEED at point of wind arrow.

WIND DIRECTION at True Index. (This is the direction from which wind is blowing.)

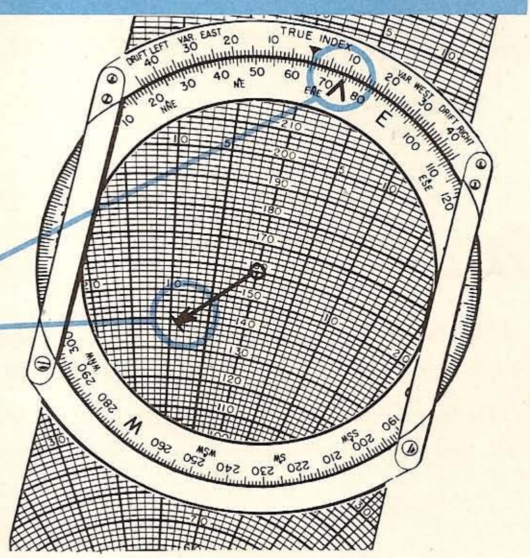


Always Find:

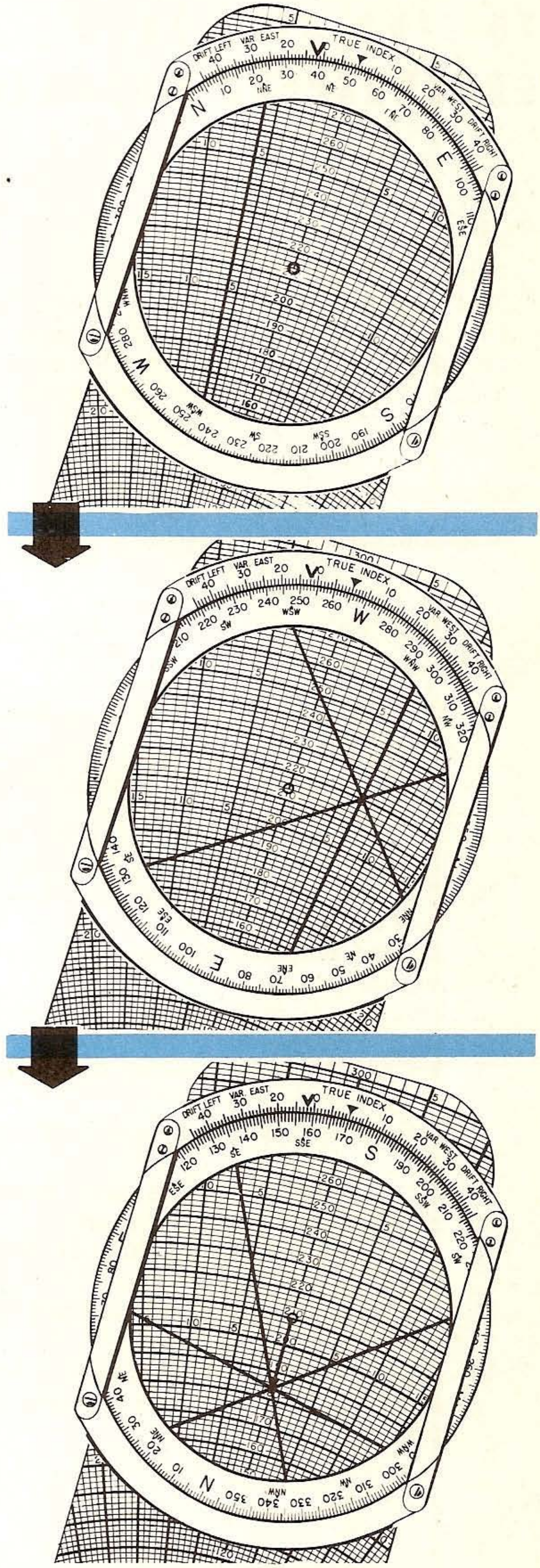
DRIFT CORRECTION on drift & variation scale opposite true course.

DRIFT at point of wind arrow.

WIND SPEED by measuring from grommet down centerline of chart to point of wind arrow.



TO FIND WIND FROM DRIFT MEASUREMENTS



GIVEN:

Variation 12°E
True Airspeed 214 mph
1st Magnetic Heading 39° : Drift 6°L
2nd Magnetic Heading 308° : Drift 3°R
3rd Magnetic Heading 253° : Drift 7°R

FIND:

Wind Direction
Wind Speed

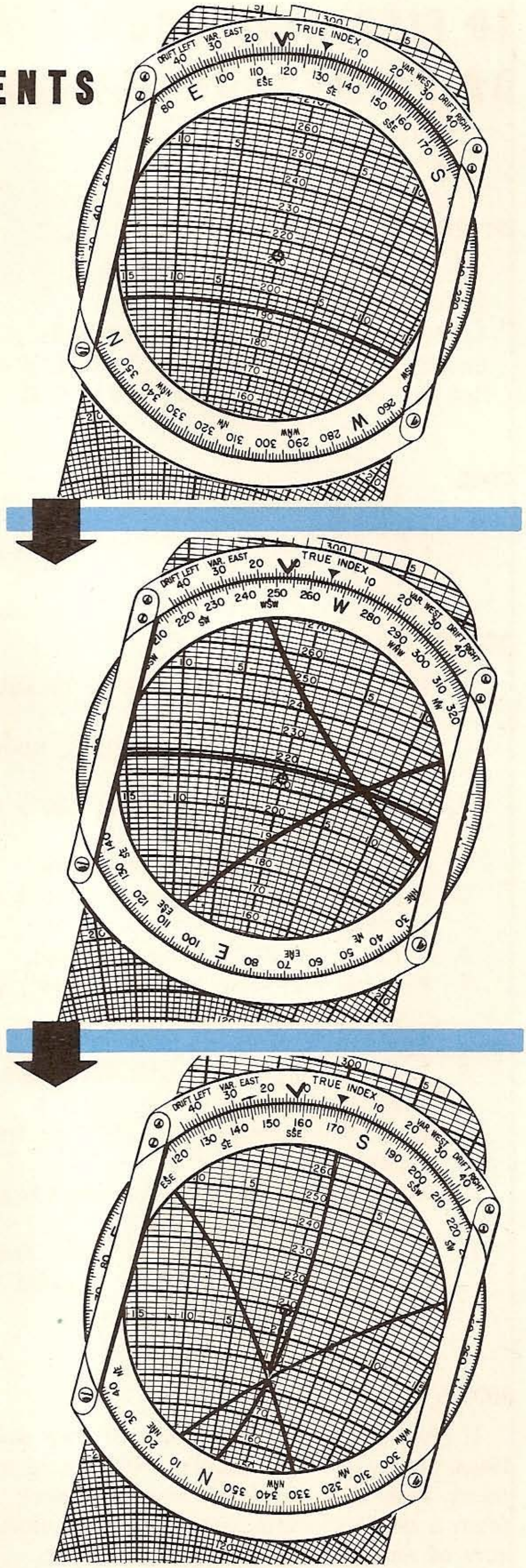
SOLUTION:

1. Mark magnetic index (12°E) on drift & variation scale.
2. Set true airspeed (214 mph) under grommet.
3. Set 1st magnetic heading (39°) at magnetic index.
4. Trace drift (6°L) along drift line.
5. Set 2nd magnetic heading (308°) at magnetic index.
6. Trace drift (3°R) along drift line.
7. Set 3rd magnetic heading (253°) at magnetic index.
8. Trace drift (7°R) along drift line.
9. Set intersection of drift lines below grommet on centerline of chart.
10. Find wind direction **(170°)** at true index.
11. Draw wind arrow from grommet to intersection of drift lines.
12. Measure wind speed **(26 mph)** from grommet down centerline to point of wind arrow of chart.

NOTE:

If you plot the intersection of **two drift lines,** you get a fairly accurate wind measurement. But if **three drift lines** intersect, or form a small triangle, you can be reasonably sure of an accurate wind measurement.

TO FIND WIND FROM GROUNDSPEED MEASUREMENTS



GIVEN:

Variation 12°E
True Airspeed 214 mph
1st Magnetic Heading 118° : GS 194 mph
2nd Magnetic Heading 210° : GS 199 mph
3rd Magnetic Heading 253° : GS 218 mph

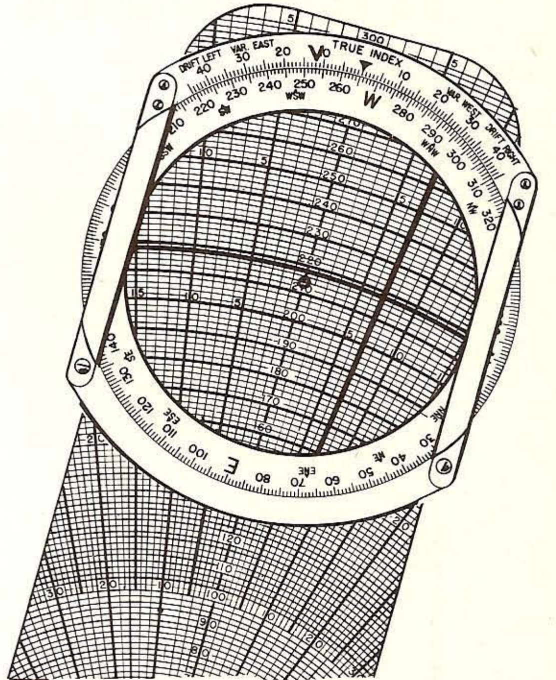
FIND:

Wind Direction
Wind Speed

SOLUTION:

1. Mark magnetic index (12°E) on drift & variation scale.
2. Set true airspeed (214 mph) under grommet.
3. Set 1st magnetic heading (118°) at magnetic index.
4. Trace arc of (194 mph) along GS circle.
5. Set 2nd magnetic heading (210°) at magnetic index.
6. Trace arc of (199 mph) along GS circle.
7. Set 3rd magnetic heading (253°) at magnetic index.
8. Trace arc of (218 mph) along GS circle.
9. Set intersection of GS arcs below grommet on centerline of chart.
10. Find wind direction **(170°)** at true index.
11. Draw wind arrow from grommet to intersection of GS arcs.
12. Measure wind speed **(26 mph)** from grommet down centerline of chart to point of wind arrow.

TO FIND WIND FROM DRIFT AND GROUNDSPEED MEASUREMENTS



GIVEN:

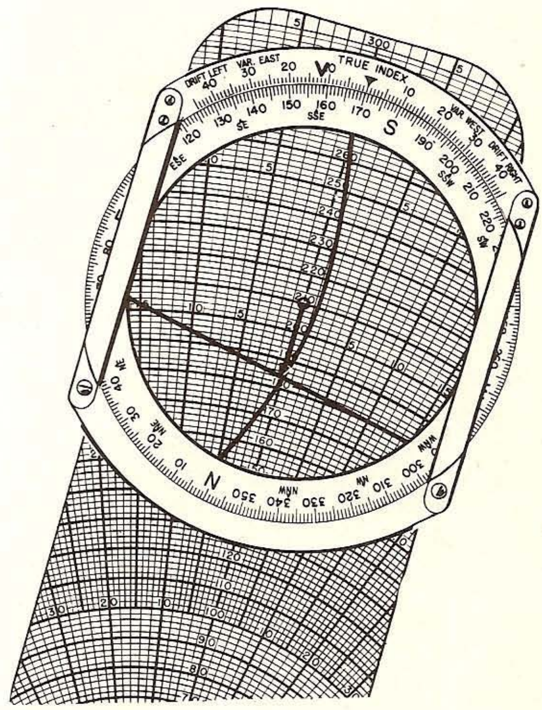
Variation 12°E
True Airspeed 214 mph
Magnetic Heading 253°
Drift 7°R
Groundspeed 218 mph

FIND:

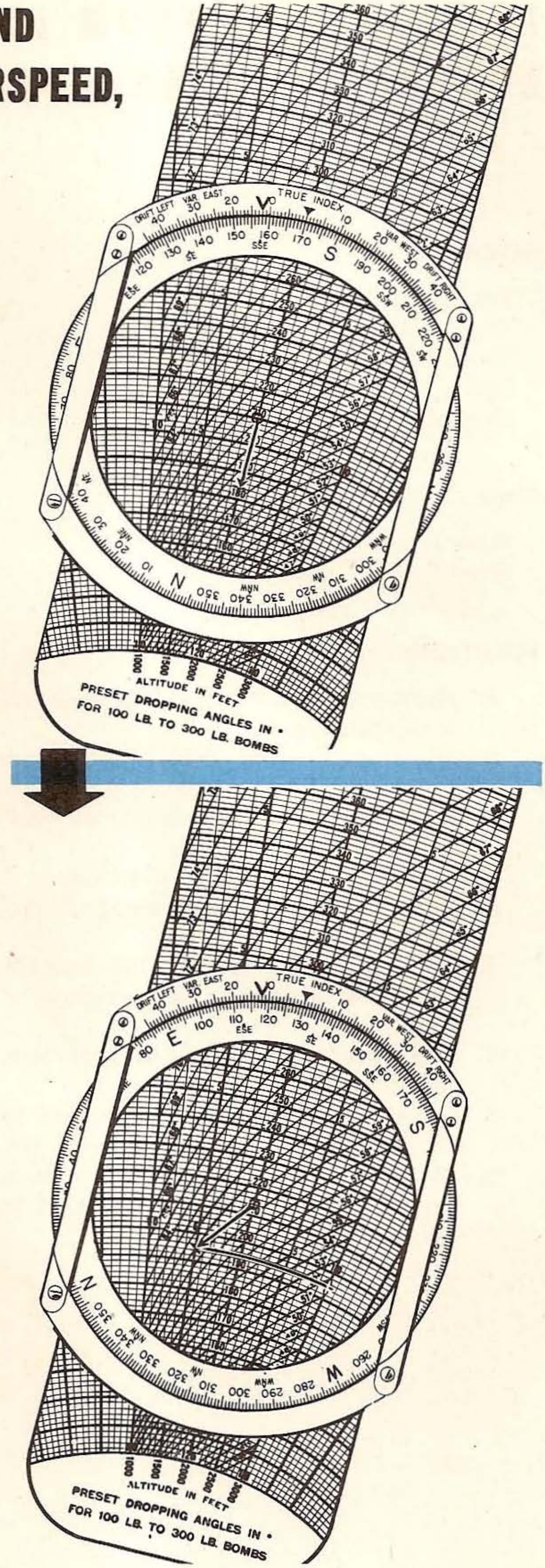
Wind Direction
Wind Speed

SOLUTION:

1. Mark magnetic index (12°E) on drift & variation scale.
2. Set true airspeed (214 mph) under grommet.
3. Set magnetic heading (253°) at magnetic index.
4. Trace drift (7°R) along drift line.
5. Trace arc of (218 mph) along GS circle.
6. Set intersection of drift line and GS arc below grommet on centerline of chart.
7. Find wind direction **(170°)** at true index.
8. Draw wind arrow from grommet to intersection of drift line and GS arc.
9. Measure wind speed **(26 mph)** from grommet down centerline of chart to point of wind arrow.



TO FIND DRIFT, GROUNDSPEED AND DROPPING ANGLE FOR GIVEN AIRSPEED, HEADING, WIND AND ALTITUDE



GIVEN:

Variation 12°E
True Airspeed 214 mph
Magnetic Heading 118°
Wind from 170° at 26 mph
Bombing Altitude 3,000 ft.

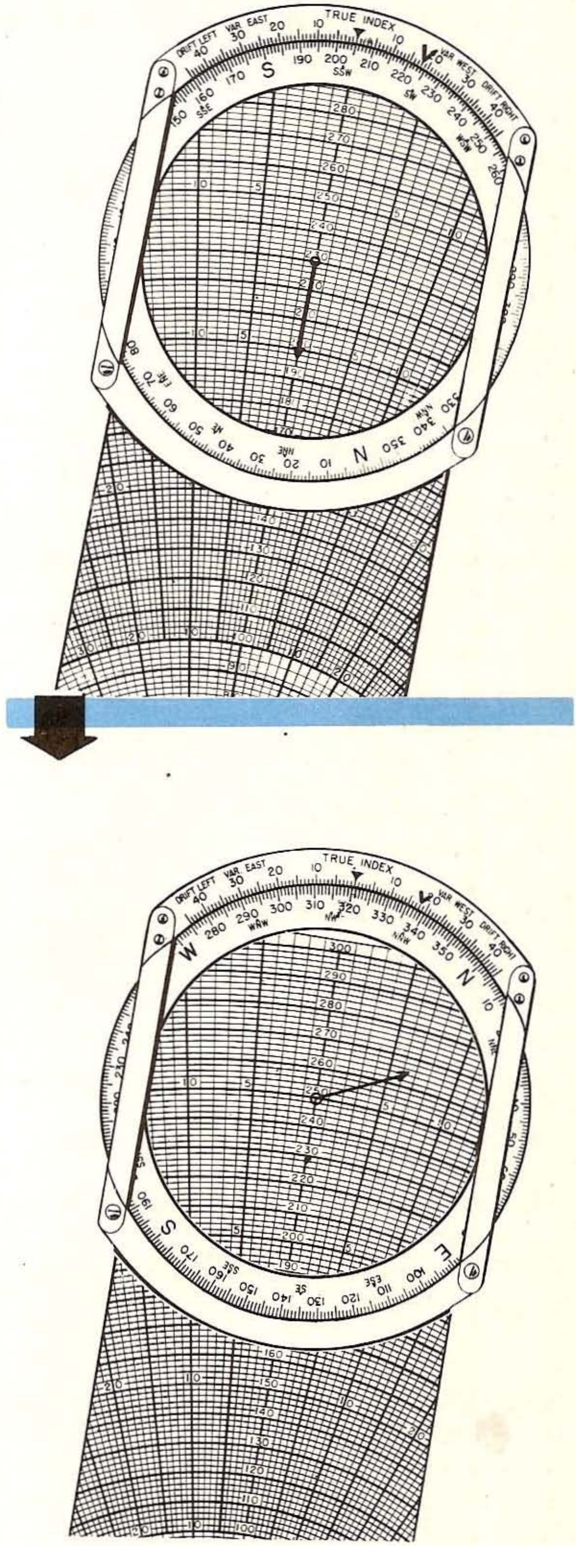
FIND:

Drift
Groundspeed
Dropping angle

SOLUTION:

1. Mark magnetic index (12°E) on drift & variation scale.
2. Use dropping angle chart for 100 lb. bomb at 3,000 ft. BA.
3. Set wind direction (170°) at true index.
4. Trace measurement of wind speed (26 mph) from grommet down centerline of chart and mark.
5. Set true airspeed (214 mph) under grommet.
6. Set magnetic heading (118°) at magnetic index.
7. Find drift **(5°L)** at point of wind arrow.
8. Find GS **(195 mph)** at point of wind arrow.
9. Find dropping angle **(51.7°)** at intersection of 195 mph GS circle and drift line marked "3,000 ft. bombing altitude."

TO FIND GROUNDSPEED, DRIFT, AND COURSE FOR A GIVEN AIRSPEED, HEADING AND WIND



GIVEN:

Variation 18°W
True Airspeed 249 mph
Magnetic Heading 338°
Wind from 205° at 33 mph

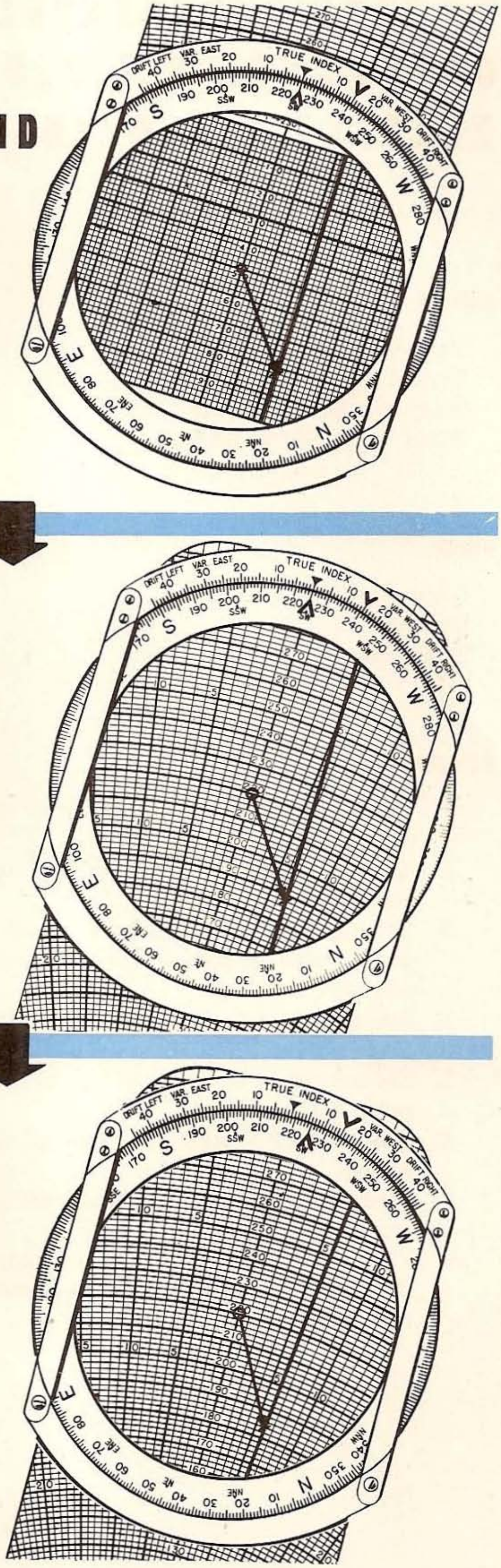
FIND:

Groundspeed
Drift
True Course

SOLUTION:

1. Mark magnetic index (18°W) on drift & variation scale.
2. Set wind direction (205°) at true index.
3. Trace measurement of wind speed (33 mph) from grommet down centerline of chart and mark.
4. Set true airspeed (249 mph) under grommet.
5. Set magnetic heading (338°) at magnetic index.
6. Find GS **(265 mph)** at point of wind arrow.
7. Find drift **(6½°R)** at point of wind arrow.
8. Find true course **(326½°)** on compass rose opposite 6½°R on drift & variation scale.

TO FIND HEADING AND GROUNDSPEED FOR A GIVEN COURSE, AIRSPEED AND WIND



GIVEN:

Variation 15° W
True Airspeed 220 mph
True Course 225°
Wind from 190° at 40 mph

FIND:

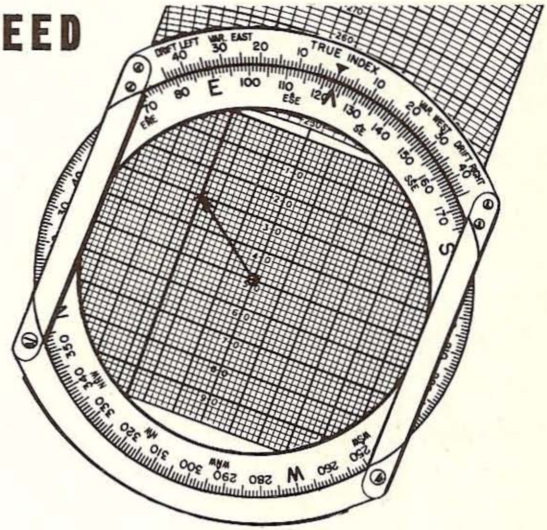
Groundspeed
Magnetic Heading

SOLUTION:

1. Mark magnetic index (15°W) on drift & variation scale.
2. Mark true course (225°) on compass rose.
3. Set wind direction (190°) at true index.
4. Trace measurement of wind speed (40 mph) from grommet down centerline of chart and mark.
5. Turn chart over and place square grid lines under plotting disc.
6. Set true course (225°) at true index.
7. Trace a line through point of wind arrow along a vertical grid line. (This is a **line of course.**)
8. Turn chart over.
9. Set true airspeed (220 mph) under grommet.
10. Rotate plotting disc until "line of course" is along a drift line.
11. Find GS (**184 mph**) at point of wind arrow.
12. Find magnetic heading (234°) at magnetic index.

Note: You will find that the true course (225°) is at 6° right drift on drift & variation scale when the point of the wind arrow is at 6° right drift on drift lines if this problem is properly solved.

TO FIND HEADING AND AIRSPEED FOR A GIVEN COURSE, GROUNDSPEED AND WIND

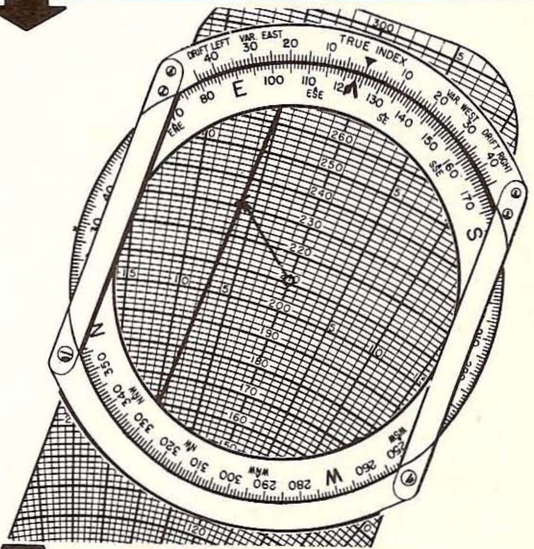


GIVEN:

Wind, from 250° at 32 mph
Groundspeed 232 mph
True Course 123°

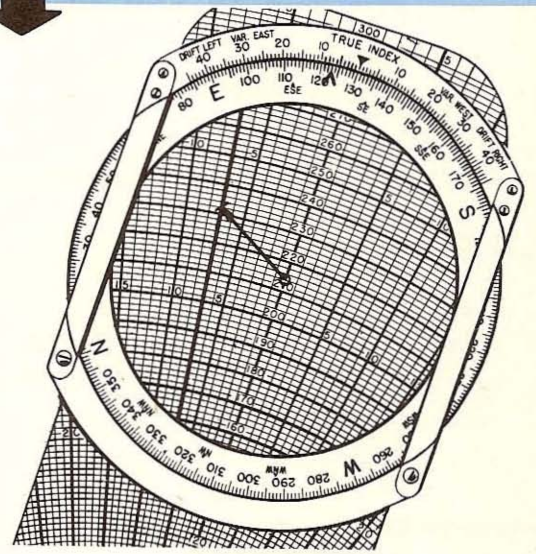
FIND:

True Heading
True Airspeed



SOLUTION:

1. Set wind direction (250°) at true index.
2. Trace measurement of wind speed (32 mph) from grommet down centerline of chart and mark.
3. Turn chart over and place square grid lines under plotting disc.
4. Mark true course (123°) on compass rose.
5. Set true course (123°) at true index.
6. Trace a (line of course) through point of wind arrow along a vertical grid line.
7. Turn chart over.
8. Set point of wind arrow at arc of (232 mph) on GS circle.
9. Rotate plotting disc, keeping point of wind arrow at arc of (232 mph) on GS circle until "line of course" is along a drift line.
10. Find true heading **(130°)** at true index.
11. Find true airspeed **(214 mph)** under grommet.



Exercises

1. **GIVEN:** True Airspeed 148 mph
   1st True Heading 335° : Drift 3°R
   2nd True Heading 50° : Drift 8°R

   FIND: Wind Direction
   Wind Speed

2. **GIVEN:** Variation 7°W
   True Airspeed 153 mph
   Magnetic Heading 326°
   Groundspeed 161 mph
   Drift 6°L

   FIND: Wind Direction
   Wind Speed

3. **GIVEN:** True Airspeed 136 mph
   1st True Heading 350° : Drift 3°R
   2nd True Heading 50° : Drift 1°L

   FIND: Wind Direction
   Wind Speed
   GS on 1st True Heading
   GS on 2nd True Heading

4. **GIVEN:** Variation 15°E
   True Airspeed 162 mph
   Magnetic Heading 16°
   Wind from 265° at 18 mph

   FIND: True Course
   Groundspeed

5. **GIVEN:** True Airspeed 150 mph
   True Heading 210°
   True Course 216°
   Groundspeed 172 mph

   FIND: Drift
   Wind Direction
   Wind Speed

6. **GIVEN:** True Heading 275°
   Groundspeed 154 mph
   Wind from 310° at 24 mph

   FIND: True Course
   True Airspeed

7. **GIVEN:** Variation 4°W
   True Airspeed 185 mph
   True Course 92°
   Wind from 130° at 32 mph

   FIND: Magnetic Heading
   Groundspeed

8. **GIVEN:** True Course 115°
   Groundspeed 173 mph
   Wind from 20° at 25 mph

   FIND: True Airspeed
   True Heading

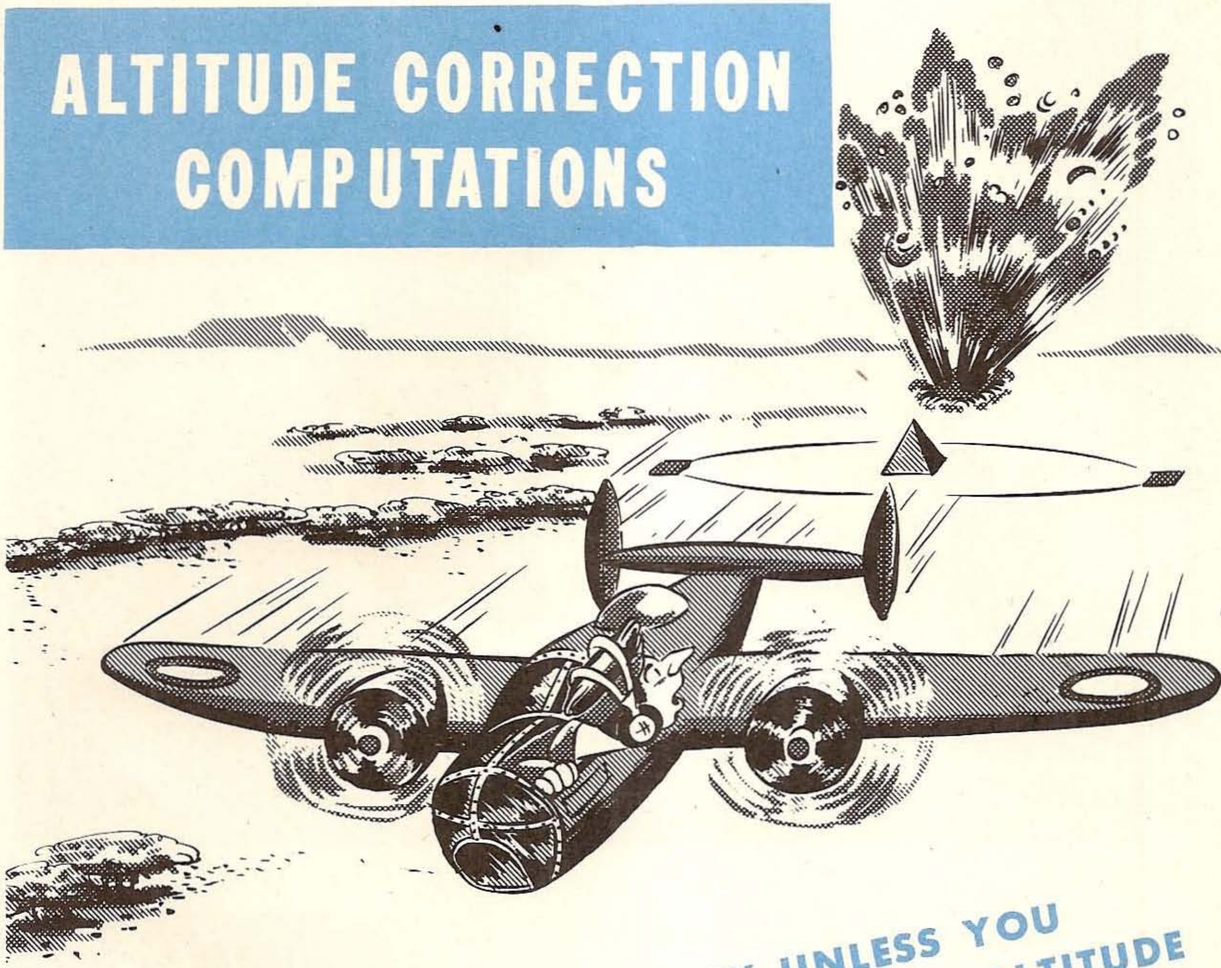
9. **GIVEN:** Variation 9°E
   True Airspeed 163 mph
   Magnetic Heading 175°
   True Course 183°
   Groundspeed 178 mph

   FIND: Wind Direction
   Wind Speed

ANSWERS:

1. 317°
   21 mph
2. 72°
   18 mph
3. 213°
   10 mph
   1st—144 mph
   2nd—146 mph
4. 36°
   173 mph
5. Drift 6°R
   70°
   27 mph
6. 270°
   173 mph
7. 102°
   159 mph
8. 173 mph
   107°
9. 353°
   16 mph

ALTITUDE CORRECTION COMPUTATIONS



YOU CAN'T BOMB ACCURATELY UNLESS YOU KNOW YOUR EXACT BOMBING ALTITUDE

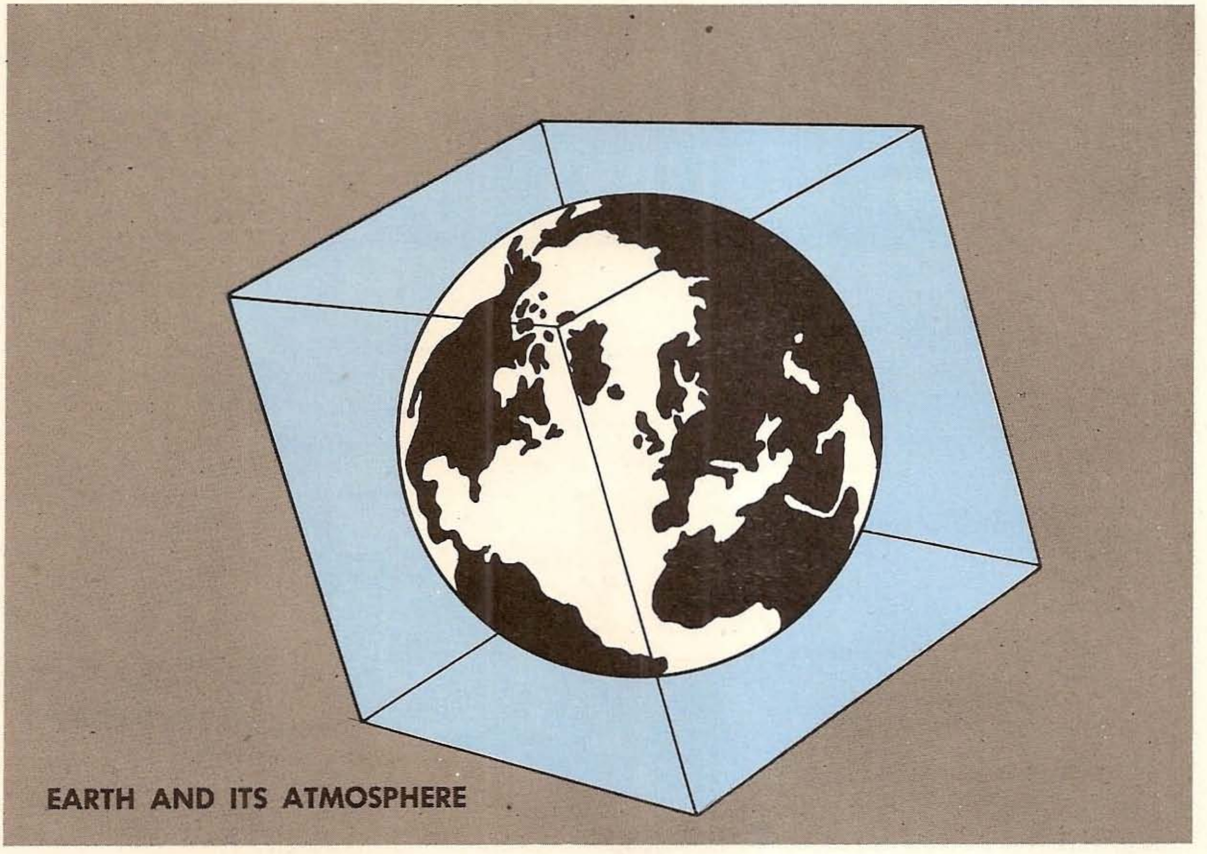
In order to bomb with precision, one thing you MUST know is how to find the exact height of your airplane above the target. This is called the Bombing Altitude (BA). It is comparatively easy to find, if you know how to use an altimeter, the free air temperature gage and your C-2, AN, or E-6B computer.

You can memorize the procedures — **but that isn't enough.** To make accurate altitude correction computations, you must **know** WHAT you are doing, and **understand** HOW and WHY you are doing it. First you must understand certain facts about the air in which you fly.

The Atmosphere

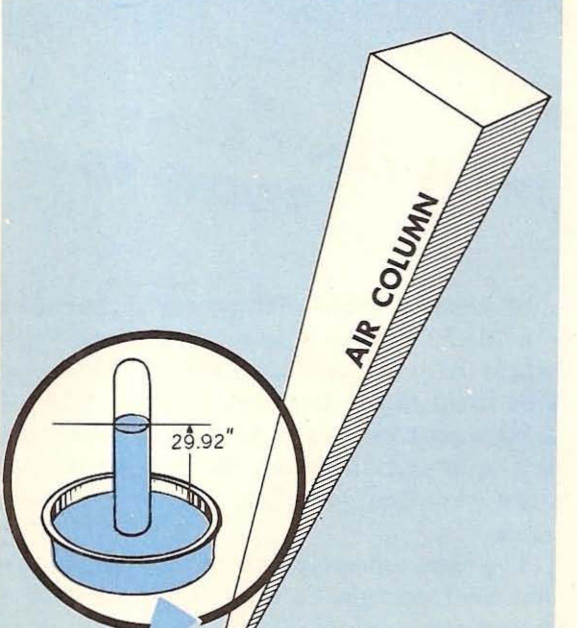
The atmosphere is an ocean of air surrounding the earth. The air has density or weight, just as water has, and this weight produces pressure. The pressure is heaviest at the bottom of the "ocean" of air, that is, at the surface of the earth, just as the pressure of water is greatest at the bottom of the ocean. As you go up, the pressure of the air decreases. The temperature of the air also decreases with altitude. You use these factors, pressure and temperature, in making altitude correction computations.

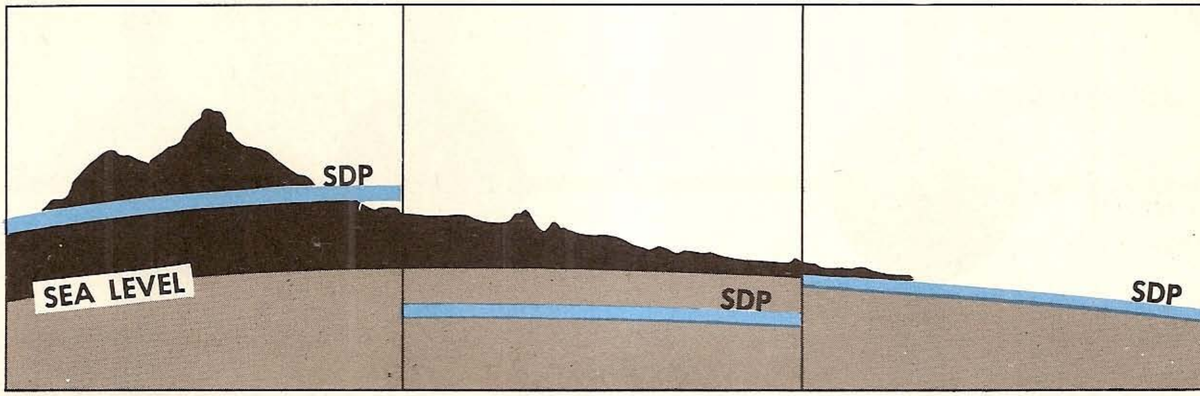
You can measure the pressure of the atmosphere at different altitudes with a tube



of mercury sealed at the top and inverted in a cup of mercury. An aneroid barometer works on the same principle. At sea level, under U. S. Standard atmospheric conditions, the weight of a column of air pushes a column of mercury up in the tube to a height of 29.92 inches, when the temperature is 15° C and there is a temperature decrease of 2°C for each 1,000 ft. increase in altitude (standard lapse rate).

When you take a barometer up into the atmosphere, the column of mercury falls approximately 1 inch for every 1,000 ft. increase in altitude. Thus, when a barometer registers 28.92, it is theoretically 1,000 ft. above the place where the barometric pressure is 29.92. If the barometric pressure at sea level were always 29.92, the problems would be simple. But barometric pressures change with weather, temperature, and season. Therefore, all that a barometer can indicate to you about altitude, is the pressure measurement in feet above a certain pressure level.



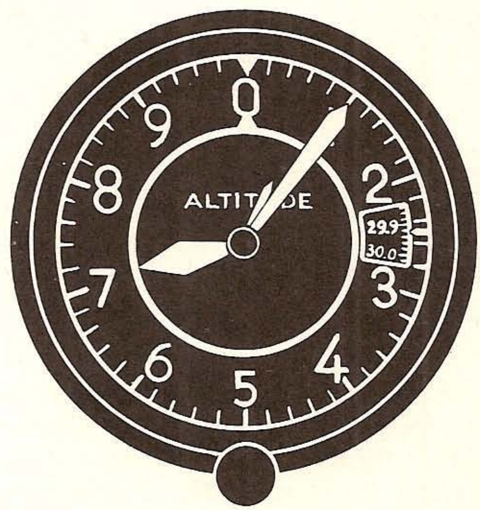


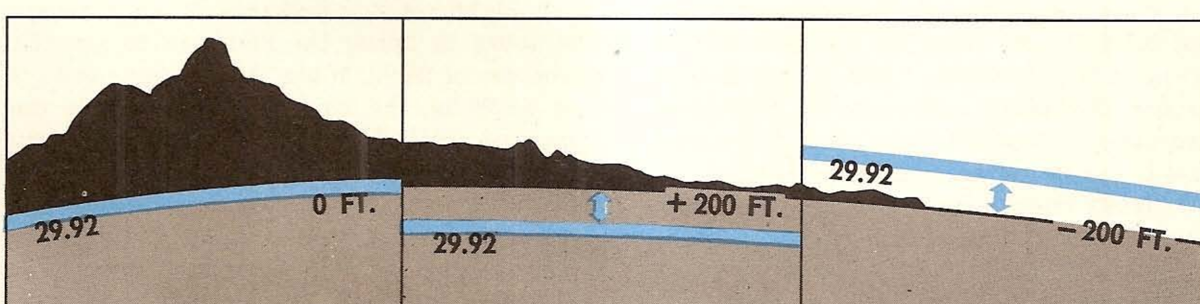
In order to use pressure for computing your altitude, you must have some level from which to measure. For convenience, the so-called **standard datum plane** (SDP) is used. This plane is the level where barometric pressure is exactly 29.92. Sometimes this level is above sea level; sometimes it is below.

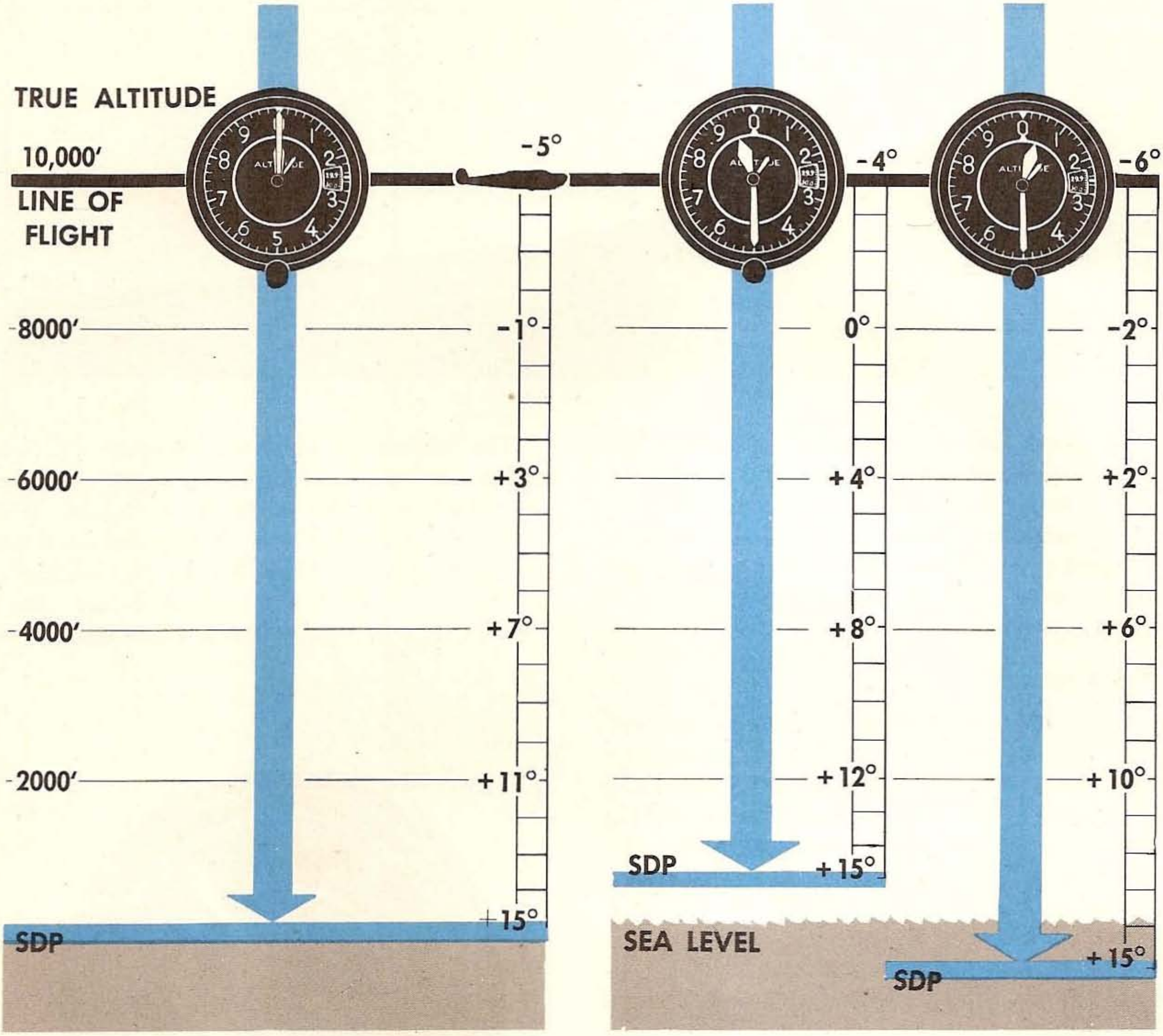
The difference between pressure altitude (PA) and surveyed elevation above sea level is called pressure altitude variation (PA Var.). It is the distance in feet between sea level and the standard datum plane (SDP). Remember that the standard datum plane (SDP) may be above or below sea level.

The Altimeter

Your altimeter that you use in the present training and tactical bombing airplane is an aneroid barometer. It measures pressure and interprets it in terms of feet above a certain pressure level. It has a window in the dial through which you can read a scale calibrated in inches of mercury. When you set a given barometric pressure on this scale, the hands on the dial of the altimeter will indicate the pressure measurement, in feet, that the airplane is **above the level** where that **barometric pressure exists.** Thus if you set on the pressure scale the pressure of the standard datum plane, 29.92, the hands will indicate your pressure measurement in feet above the standard datum plane (SDP). This is your pressure altitude (PA), provided, of course, your altimeter is properly calibrated.





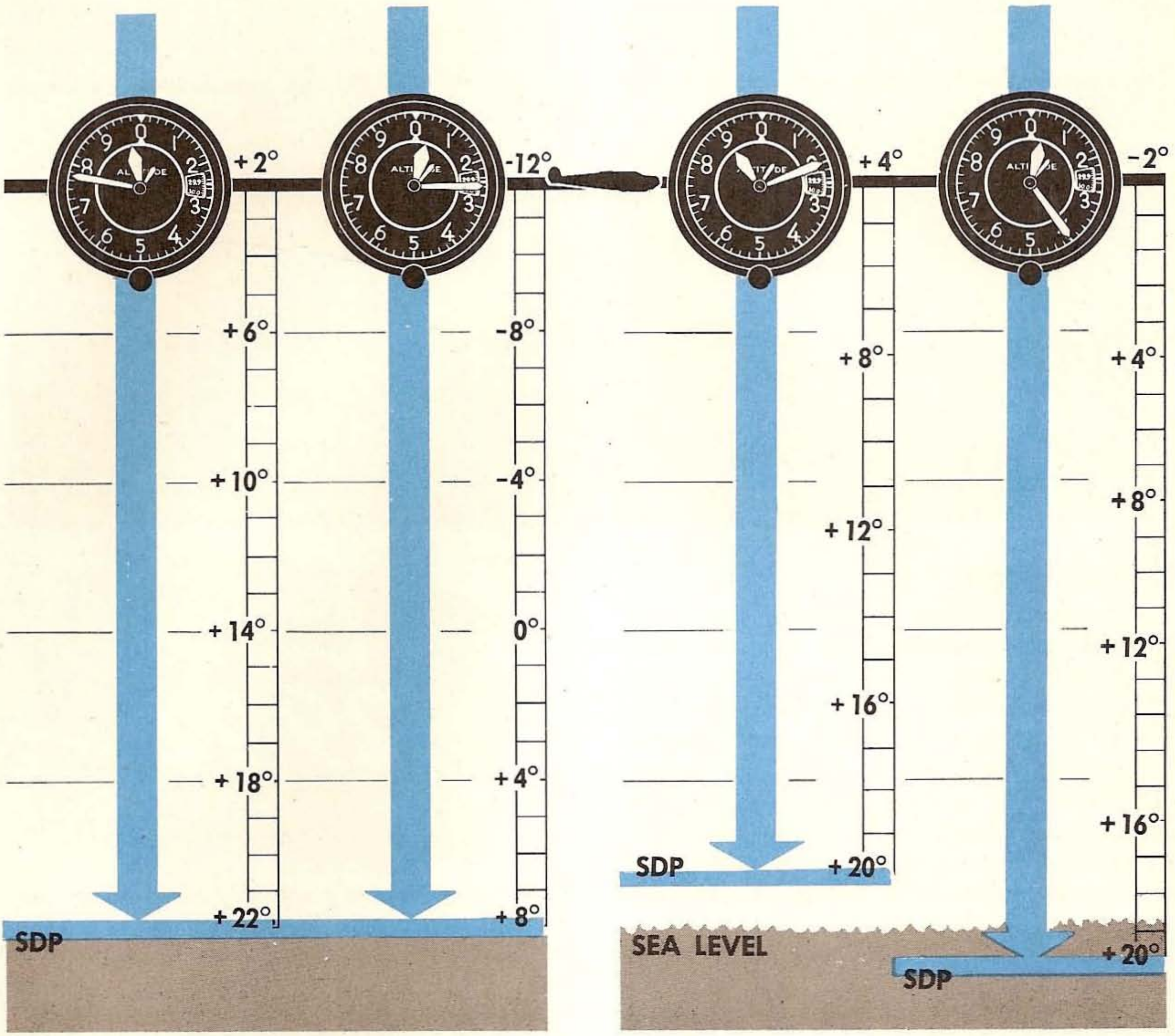


Under standard atmospheric conditions (which rarely exist), your altimeter indicates a pressure altitude which is the true altitude (TA) above sea level. Standard atmospheric conditions exist only when the standard datum plane (barometric pressure 29.92) is at sea level, when the air temperature at sea level is 15°C, and when the air temperature decreases 2°C for each 1,000 ft. increase in altitude. Standard atmospheric conditions comprise a convenient "yardstick." In actual practice, you'll never encounter them.

With any change from standard conditions, the altimeter indicates a pressure altitude that has a definite relationship to the true altitude above sea level. If you know this relationship, you know why you must correct pressure altitude to find true altitude.

The barometric pressure is changing continually, and it varies from one location to another on the surface of the earth and at sea level. These changes are usually gradual and the barometric pressure at sea level can be above or below the standard barometric pressure of 29.92. When the pressure scale is set at 29.92, the altimeter will indicate the pressure altitude above the level where the barometric pressure of 29.92 exists.

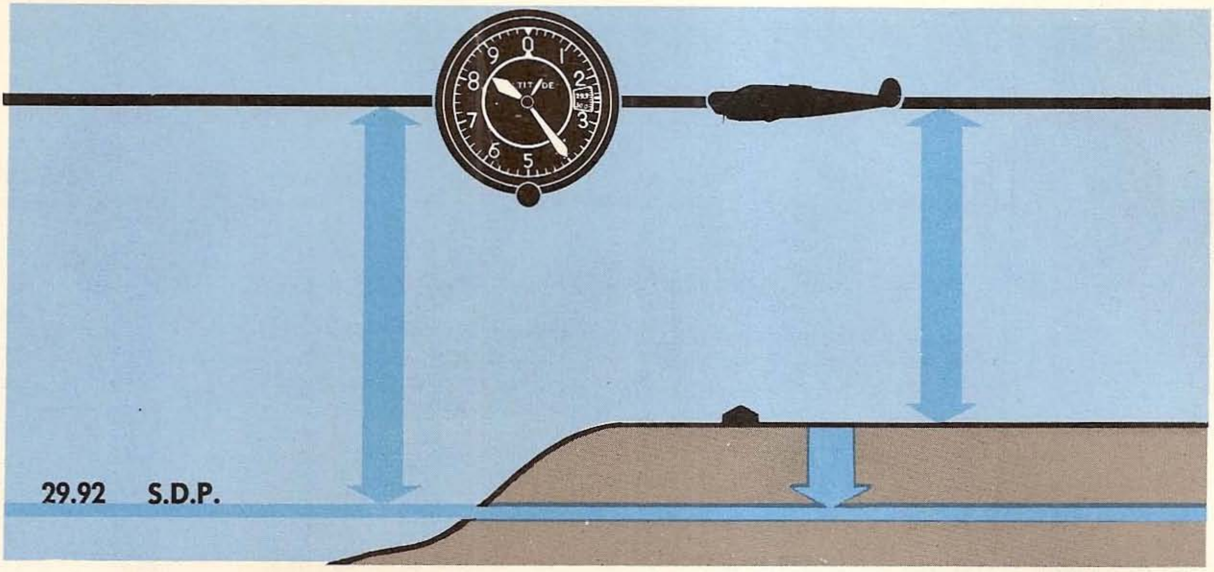
It is necessary to know the difference between sea level and the standard datum plane (the pressure altitude variation) in order to find the correct sea level pressure altitude.



The numerical value of sea level pressure altitude is equal to the pressure altitude variation. (SLPA = Zero + PA Var.)

The temperature of the atmosphere is fully as changeable as the barometric pressure. It varies greatly from one locality to another and at different levels above sea level. You remember, of course, how air expands as it grows warmer, making it less dense. Therefore, the indication of the altimeter at different levels in the atmosphere will be increased. The indication of the altimeter will be decreased when the air is colder and more compressed. You must correct for this increase or decrease in the indication of the altimeter. Thus you must know the correct temperature of the air column in order to correct the altimeter's indication the proper amount to get a true measurement of the air column.

The barometric pressure and temperature of the atmosphere will always vary from standard conditions. The altimeter will indicate the pressure altitude above the standard datum plane. This pressure altitude can be corrected for temperature to find the true distance above the standard datum plane. To find the true altitude above sea level, you must get the pressure altitude above sea level, which is the pressure altitude plus pressure altitude variation. Then the pressure altitude above sea level can be corrected for temperature to find the true altitude.



Bombing Altitude

In order to bomb accurately, you must know the true altitude of the airplane above the target (bombing altitude—BA). You can't measure this directly with the altimeter. What you can find is the **Pressure Altitude** of the airplane **Above** the **Target** (PA above T). In other words, you can find the pressure measurement of the column of air between the airplane and the target. You get this by subtracting the target pressure altitude (TPA) from the flight level pressure altitude (FLPA). Then, if you correct this pressure altitude above target (PA Above T) for temperature and density, using the existing pressure and temperature of the air column, the result will be the bombing altitude (BA)—the actual height between the airplane and the target.

FLPA – TPA = PA Above T

PA Above T (corrected for temperature) equals BA.

It is easy to find the flight level pressure altitude (FLPA) of the airplane. Set the pressure scale at 29.92. The altimeter will then show the flight level pressure altitude (FLPA).

NOTE:

All instruments require regular and frequent calibrations. You should check the calibration of your altimeter and temperature gage very often to get proper pressure altitude (PA) and temperature readings for

ALWAYS SET PRESSURE SCALE AT 29.92 BEFORE TAKE-OFF

computing bombing altitude (BA). You can check the altimeter calibration by using the runway barometric pressure (corrected to sea level conditions) (RBP corr.); this is called the altimeter setting, and can be obtained from the metro station. When the altimeter setting is set on the pressure scale, the altimeter will read the elevation of the runway on which the airplane is sitting if the altimeter is in proper calibration. If it does not read runway elevation (R Elev.), have your altimeter inspected by the instrument specialist. Remember only recent metro information is useful in calibration.

As a bombardier you will have no need for altimeter setting except for checking the calibration of your altimeter.

The basic problem in all altitude correction computations is finding the target pressure altitude (TPA), and the target temperature (T Temp.). To make accurate altitude correction computations, you must know these conditions. Make every effort to get this information from the best available source.

HOW TO FIND TARGET PRESSURE ALTITUDE

When You Can Assume Target Atmospheric Conditions Are Comparable to Conditions At Take-Off Position

Usually when the target is not far from the take-off position, you can assume that the atmospheric conditions at the two points are approximately the same. Thus you can compute the target pressure altitude (TPA) and the target temperature (T Temp.) from the conditions that exist on your runway. The best method you can use to find your target pressure altitude (TPA) is:

RPA – R Elev. = PA Var.
T Elev. + PA Var. = TPA

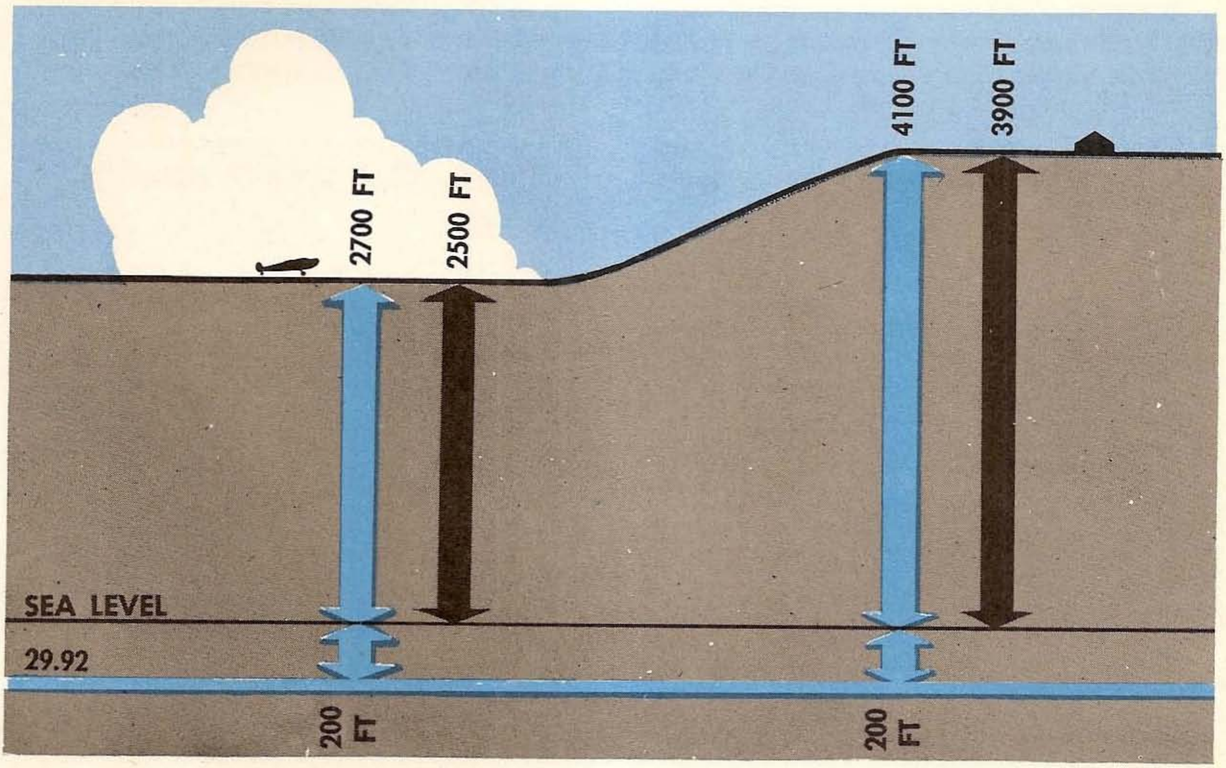
Before starting on a bombing mission, you know the surveyed elevation of the target and the runway where you take off. To find the runway pressure altitude (RPA), remember that you always set 29.92 on the pressure scale before any take-off. When you do this, the hands on the altimeter will indicate the runway pressure altitude (RPA). (Note—always tap the altimeter firmly to free hands from any friction that might cause them to give an incorrect reading.)

Find pressure altitude variation (PA Var.) by subtracting runway elevation (R Elev.) from runway pressure altitude (RPA).

Add pressure altitude variation (PA Var.) to target elevation (T Elev.) to find target pressure altitude (TPA).

Suppose the runway pressure altitude (RPA) is 2,700 ft. You are going to bomb a target whose surveyed elevation is 3,900 ft., and the elevation of your runway is 2,500 ft. above sea level.

PA Var. = 2,700 – 2,500 = (+200 ft.)
TPA = 3,900 + 200 = 4,100 ft.



When You Know Target Atmospheric Conditions

Frequently, the atmospheric conditions at the target can be predicted by your metro station. The metro station can and should give you the target pressure altitude (TPA). But if they give you, instead, the target barometric pressure (corrected to sea level conditions) (TBP corr.), you must be able to find the target pressure altitude (TPA) by the use of the following equation:

1,000 (29.92 – TBP Corr.) = PA Var.
T Elev. + PA Var. = TPA

If the target barometric pressure (corrected to sea level conditions) (TBP corr.) is **greater** than 29.92, the pressure altitude variation (PA Var.) is a **negative** value and the target pressure altitude (TPA) will be **less** than the target elevation (T Elev.).

When BP Increases PA Decreases

Suppose the target barometric pressure (corrected to sea level conditions) (TBP corr.) is 30.22 and the target elevation (T Elev.) is 2,200 ft. above sea level. The difference between 29.92 and 30.22 is (–0.3 in.). Since 1 in. of mercury equals 1,000 ft. of altitude, (–0.3 in.) equals (–300 ft.).

This means that the standard datum plane (where the altimeter would indicate zero PA) is 300 ft. **higher** than sea level. If the altimeter were at sea level it would indicate (–300 ft.) pressure altitude (PA). Therefore, **ADD** (–300 ft.) to 2,200 ft. to get 1,900 ft., the target pressure altitude (TPA).

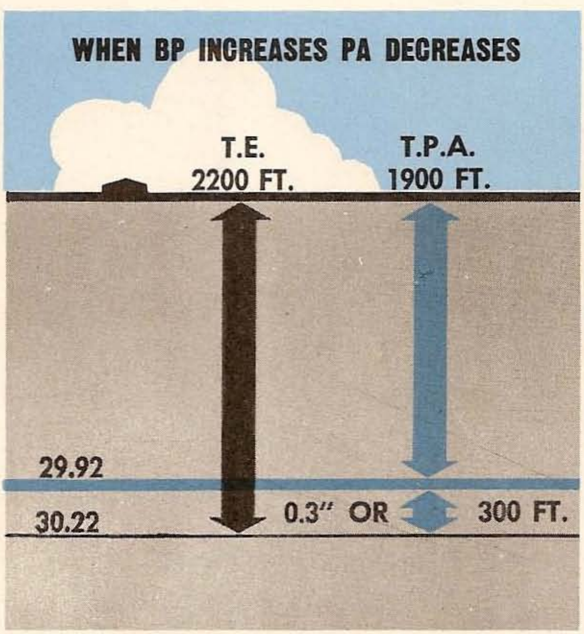
(29.92 – 30.22) 1,000 = PA Var.
(–0.3) 1,000 = (–300) = PA Var.
2,200 + (–300) = TPA
2,200 – 300 = 1,900 ft. = TPA

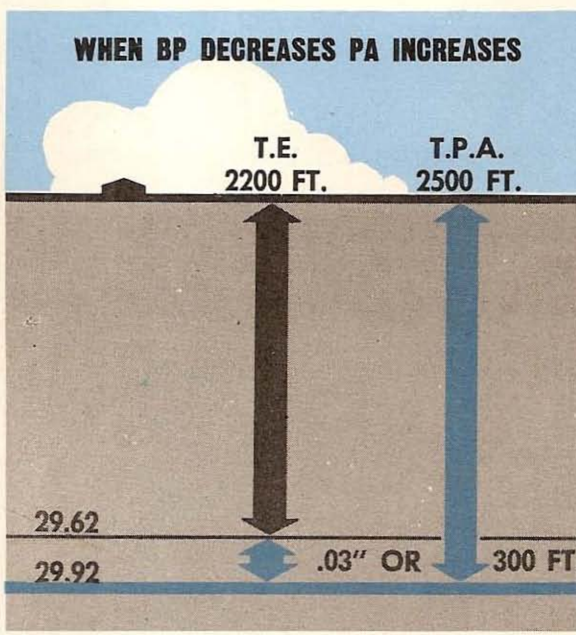
If the target barometric pressure (corrected to sea level conditions) (TBP corr.) is smaller than 29.92, the pressure altitude variation (PA Var.) is a **positive** value and the target pressure altitude (TPA) will be **more** than the target elevation (T Elev.).

When BP Decreases PA Increases

Suppose that on another occasion the barometric pressure (corrected to sea level conditions) (BP corr.) of this same target area is 29.62. The difference between 29.92 and 29.62 is (+0.3 in.). This means that the standard datum plane is 300 ft. **lower** than sea level. If the altimeter were at sea level it would indicate (+300 ft.) pressure altitude (PA). Therefore, **ADD** (+300 ft.) to 2,200 ft. to get 2,500 ft., the target pressure altitude (TPA).

(29.92 – 29.62) 1,000 = PA Var.
(+0.3) 1,000 = (+300) = PA Var.
2,200 + (+300) = TPA
2,200 + 300 = 2,500 ft. = TPA





When You Know Nothing About Atmospheric Conditions at Target

Sometimes in combat the metro station cannot predict the atmospheric conditions at the target, and the target is so far from your take-off position that you must assume target conditions are different from your runway conditions. In such a situation, you must assume that the target pressure altitude (TPA) is the same as the surveyed elevation of the target. This is not very accurate, but it is the best you can do with the information you have.

CORRECTION FOR DENSITY AND TEMPERATURE OF AIR COLUMN

When the pressure scale is set at 29.92, the indication on your altimeter, corrected for instrumental and installation errors, is the flight level pressure altitude (FLPA).

Once you have determined the target pressure altitude (TPA) you can find the pressure altitude above the target (PA Above T)

PA Above T = FLPA – TPA.

You now have the pressure measurements of the column of air. You must correct this pressure measurement for temperature and density of the air column to find your bombing altitude (BA). This is where you use your computers. With the correct data properly set in, the C-2, AN, or the E-6B will automatically make this correction for you.

PA Above T (Corrected for Temperature) equals BA.

Temperature

Temperature, like pressure, decreases with altitude. As you go up through the atmosphere, the air grows increasingly colder. When you reach the stratosphere, however, you find that the temperature stays close to –55°C. The temperature of a given altitude does not remain constant; it changes from day to day; furthermore, the rate of decrease in temperature as you go up into the atmosphere is not constant.

In taking your readings, you must remember that your thermometer is rushing through the air at the speed of the airplane. This rapidly moving air, by producing adiabatic compression and friction, causes a higher temperature indication than the actual air temperature. Therefore you must correct each indication by **subtracting** an airspeed correction. This correction can be found by the following equation:

$$\text{Correction} = -.00008 \times \text{TAS}^2$$

The following table shows the proper corrections for different true airspeeds, which are computed by using this formula:

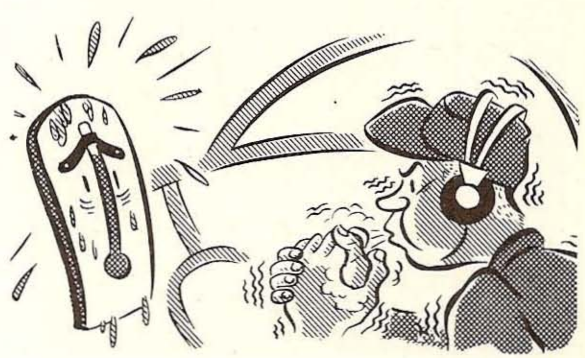
Airspeed Corrections for Thermometers

True Airspeed MPH	Correction Degrees Centigrade	True Airspeed MPH	Correction Degrees Centigrade
80	—0.5	300	— 7.2
100	—0.8	320	— 8.2
120	—1.1	340	— 9.2
140	—1.6	360	—10.4
160	—2.0	380	—11.6
180	—2.6	400	—12.8
200	—3.2	420	—14.1
220	—3.9	440	—15.5
240	—4.6	460	—16.9
260	—5.4	480	—18.4
280	—6.3	500	—20.

NOTE:

The average true airspeed of the AT-11 is 160 mph. The correction for this speed is –2°. Therefore in your training your usual airspeed correction for temperature is –2°.

What you are concerned with is the temperature of the air column between the airplane and the target. Since the temperatures will vary at different points in that column, you use the **average** of these various temperatures for your computations. This is called the **mean temperature.** Theoretically, it is the temperature at a point halfway between the airplane and the target.



HOW TO FIND MEAN TEMPERATURE

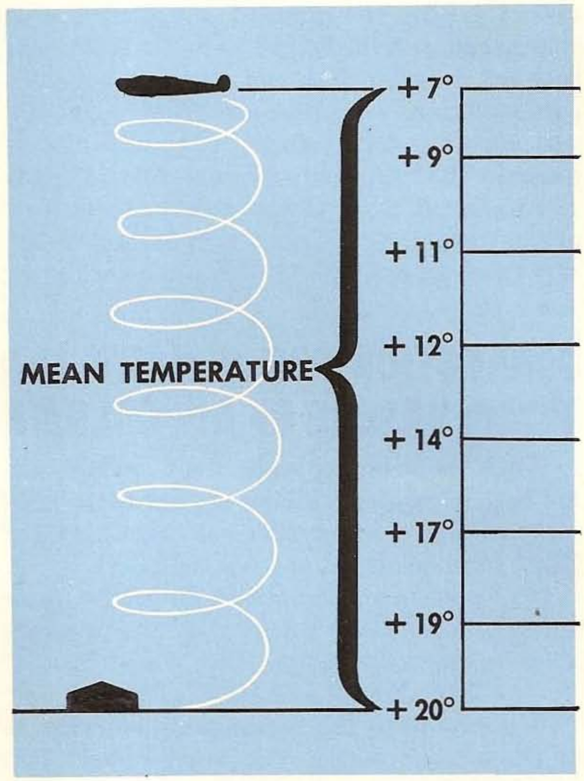
When You Can Assume Target Atmospheric Conditions Are Comparable to Conditions At Take-Off Position

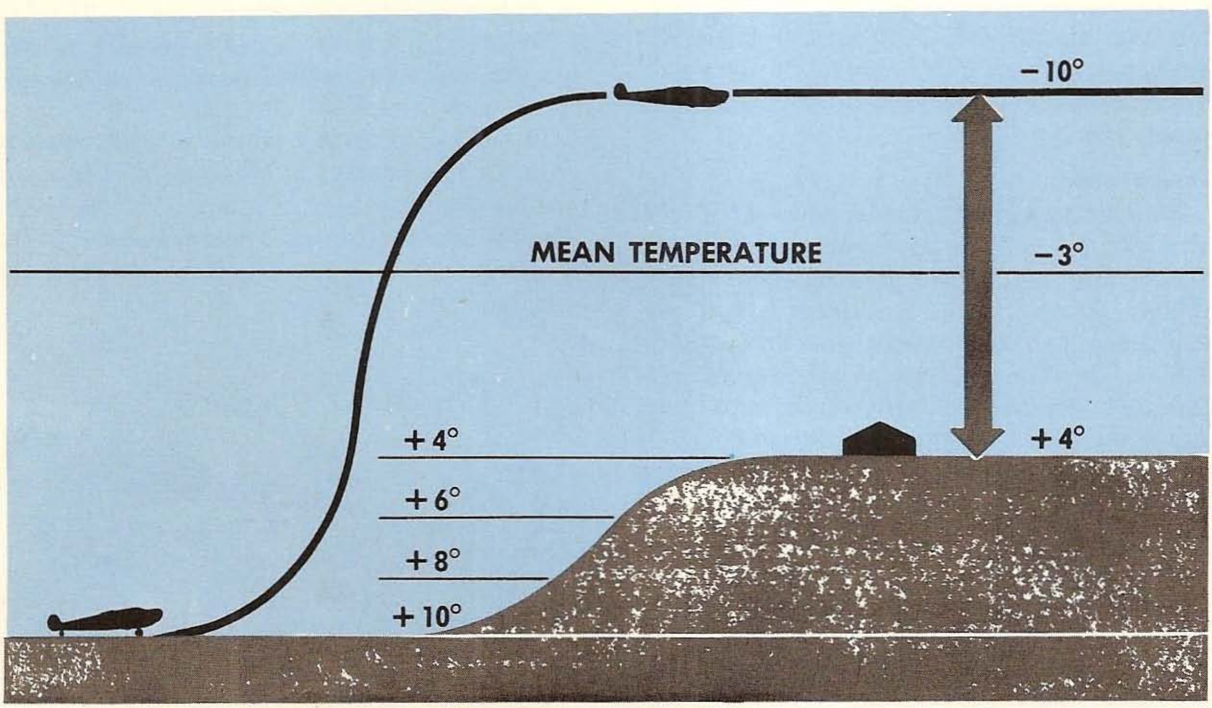
Sometimes your target is near enough to your take-off position that you can assume the atmospheric conditions at the two places are similar. In this case, you can compute the target temperature and the temperature at any place in the column of air between target and flight level.

You can assume that the temperature changes 2° for every 1,000 ft. difference in elevation between the target and runway. This temperature change is known as the standard lapse rate. If the target is **higher** than the runway, the target temperature will be 2° **lower** for each 1,000 ft. difference in elevation. If the target is **lower** than the runway, the target temperature will be 2° higher for each 1,000 ft. difference in elevation.

You can find the mean temperature of the air column by adding target temperature (T Temp.) to flight level temperature (FL Temp.) and dividing them by 2.

$$\frac{\text{FL Temp.} + \text{T Temp.}}{2} = \text{Mean Temp.}$$





Rather than taking two temperatures to find the mean, it is more accurate to take temperature readings for each 1,000 ft. between take-off position and flight level. By using these temperatures you can find target temperature and temperature for each 1,000 ft. above the target up to flight level. To find the mean of these temperatures of the air column, add all temperature readings and divide their sum by the number of readings taken.

$$\frac{\text{Total of Temp. Readings}}{\text{Number of Temp. Readings}} = \text{Mean Temp.}$$

When You Know Target Atmospheric Conditions

When the metro station can give you the target temperature (T Temp.) it is easy to get a fairly accurate mean temperature. Take the target temperature (T Temp.), add the flight level temperature (FL Temp.), and divide by 2. For example:

$$\frac{\text{T Temp.} + \text{FL Temp.}}{2} = \text{Mean Temp.}$$

$$\frac{(+18^\circ) + (-6^\circ)}{2} = \frac{(+12^\circ)}{2} = (+6^\circ\text{C})$$

When You Know Nothing About Atmospheric Conditions at Target

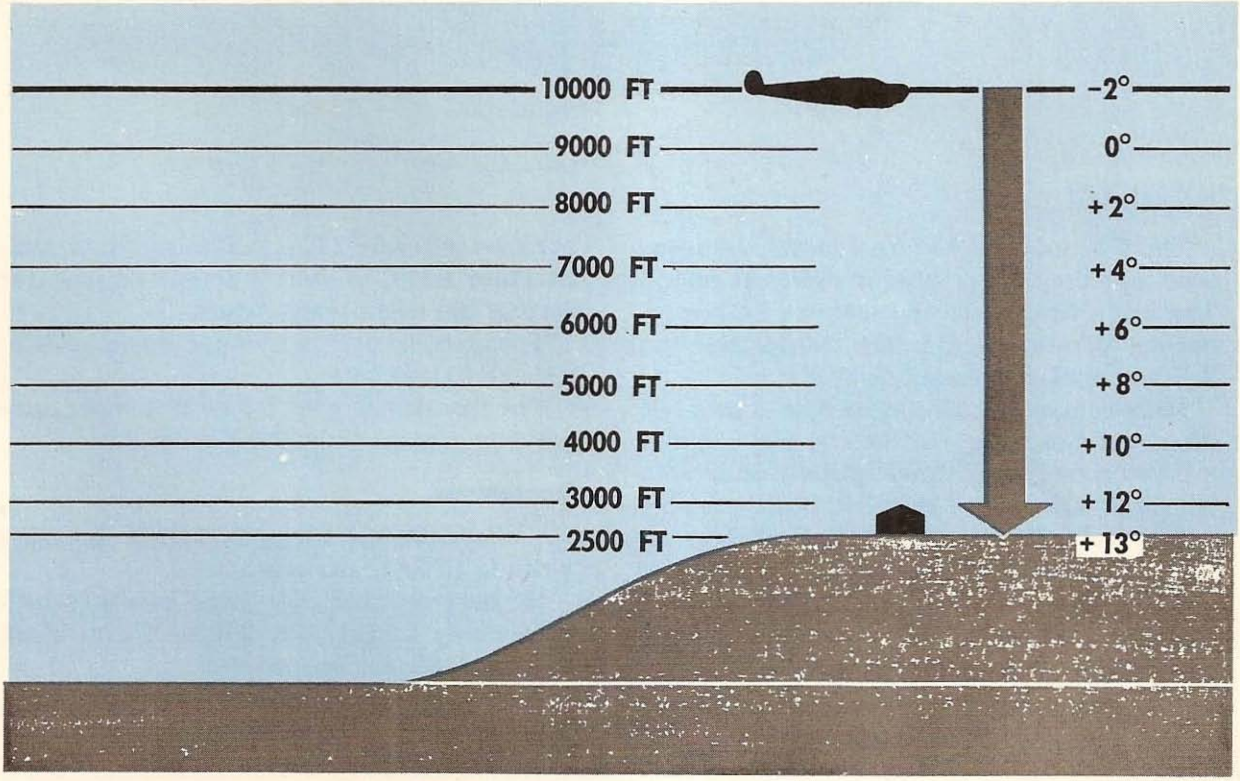
If the metro station cannot predict the target conditions, you can use the standard lapse rate (or the seasonal lapse rate for your particular locality) to compute the temperature at the target. Take the corrected flight level temperature, and **increase** it 2° for each 1,000 ft. down to target elevation. If the corrected temperature is –2° at a flight level of 10,000 ft., and the target elevation is 2,500 ft., then the target temperature is +13°.

$$\text{FL Temp.} + \left\{\frac{\text{FLPA} - \text{TPA}}{1{,}000} \times 2\right\} = \text{T Temp.}$$

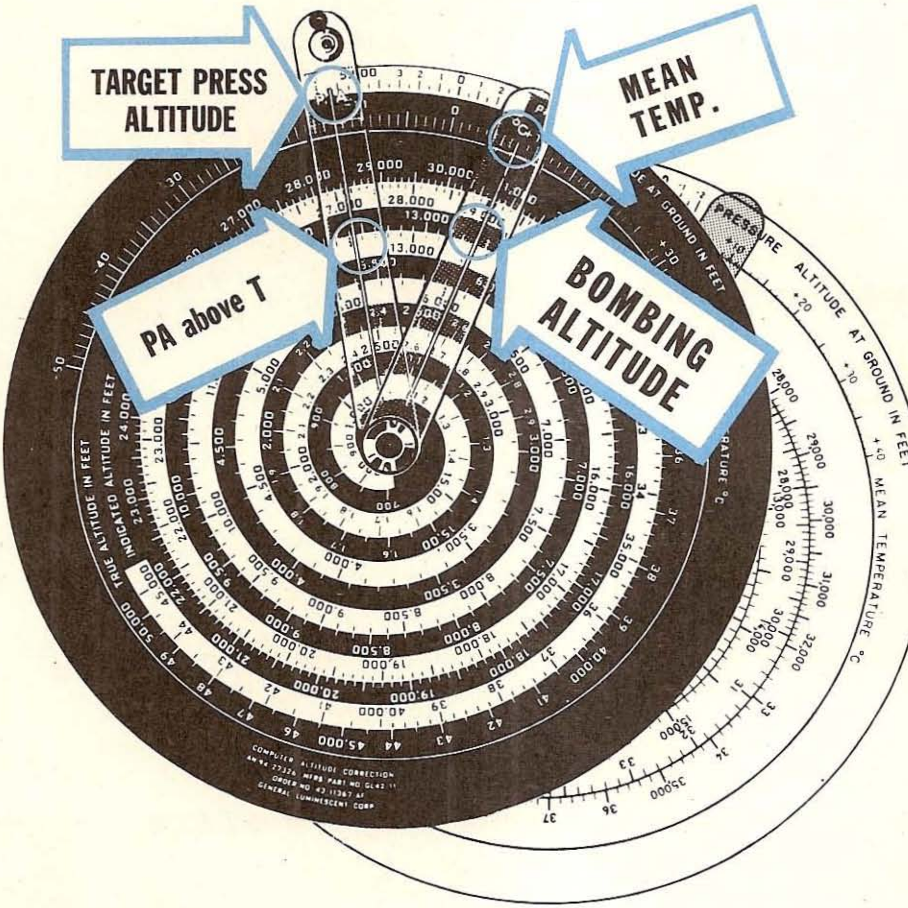
$$-2^\circ + \left\{\frac{10{,}000 - 2{,}500}{1{,}000} \times 2\right\} = +13^\circ\text{C}$$

With target temperature determined, find your mean temperature in the usual way.

$$\frac{(+13^\circ) + (-2^\circ)}{2} = \frac{(+11^\circ)}{2} = +5\tfrac{1}{2}^\circ\text{C}$$



HOW TO USE *C-2* AND *AN* COMPUTERS TO FIND BOMBING ALTITUDE (BA)



Description

The C-2 and the AN are exactly alike, except that they are printed in different colors. The black figures are the same on both computers. Where the C-2 has red figures, the AN has light fluorescent figures.

Both computers consist of two concentric discs and two arms. On the small inside disc are two spiral logarithmic altitude scales. On the outer side of the spiral is the (true altitude) scale with light (or red) figures on which is found **bombing altitude** (BA). On the inner side of the spiral is the (indicated altitude) scale with black figures for setting **pressure altitude above target** (PA Above T).

The large outside disc has a pressure altitude scale, in black figures, for setting **target pressure altitude** (TPA). It also has a temperature scale, in light (or red) figures, for setting the **mean temperature.**

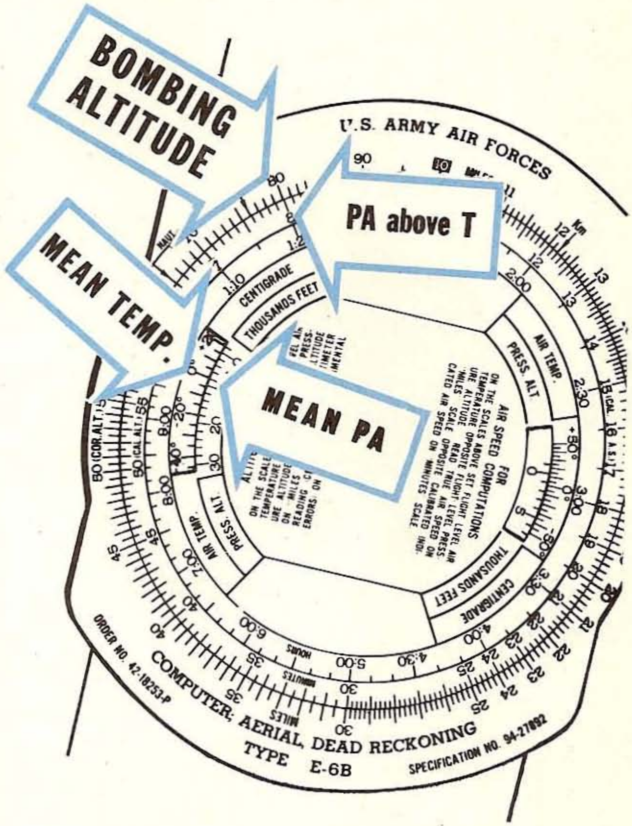
The clamped arm is used for Pressure Altitude (PA) settings.

The free arm is used for mean temperature and bombing altitude (BA) setting.

Operations

1. Set clamped arm at target pressure altitude (TPA), and lock.
2. Rotate small disc until pressure altitude above target (PA Above T), in black figures, is under clamped arm.
3. Set free arm at mean temperature.
4. Find bombing altitude (BA), in light (or red) figures, under free arm.

HOW TO USE THE *E-6B* COMPUTER TO FIND BOMBING ALTITUDE (BA)



Description

To find bombing altitude (BA) from the E-6B you use the circular slide rule and the window marked "For Altitude Computations."

The window marked "For Altitude Corrections" consists of two scales. Air temperature in the window is set opposite pressure altitude under the window. On the outer scale of the slide rule is found true altitude (Cor. Alt.), opposite pressure altitude (Cal. Alt.) on the inner scale.

Operations

You have your choice of two possible ways, depending on whether or not you know the atmospheric conditions at the target. The most accurate method is the one used when the atmospheric conditions at the target are known. If you use the computer properly, taking care in the setting and reading of your numbers, you will get accurate results.

When You Know Target Pressure Altitude and Temperature

1. Compute mean pressure altitude (MPA). This is the pressure altitude which exists half way between the target pressure altitude (TPA) and the flight level pressure altitude (FLPA). You find it the same way you found mean temperature. Add target pressure altitude (TPA) to flight level pressure altitude (FLPA) and divide by 2.

Note: To use your computer, you must set in the proper temperature for a given altitude. You will use mean temperature because it is the most accurate reading you can get. Therefore, you must use mean pressure altitude (MPA), the pressure altitude where mean temperature exists.

2. Set mean pressure altitude (MPA) opposite mean temperature in the correction window.

3. Find bombing altitude (BA) on the outer scale opposite pressure altitude above target (PA Above T) on the inner scale.

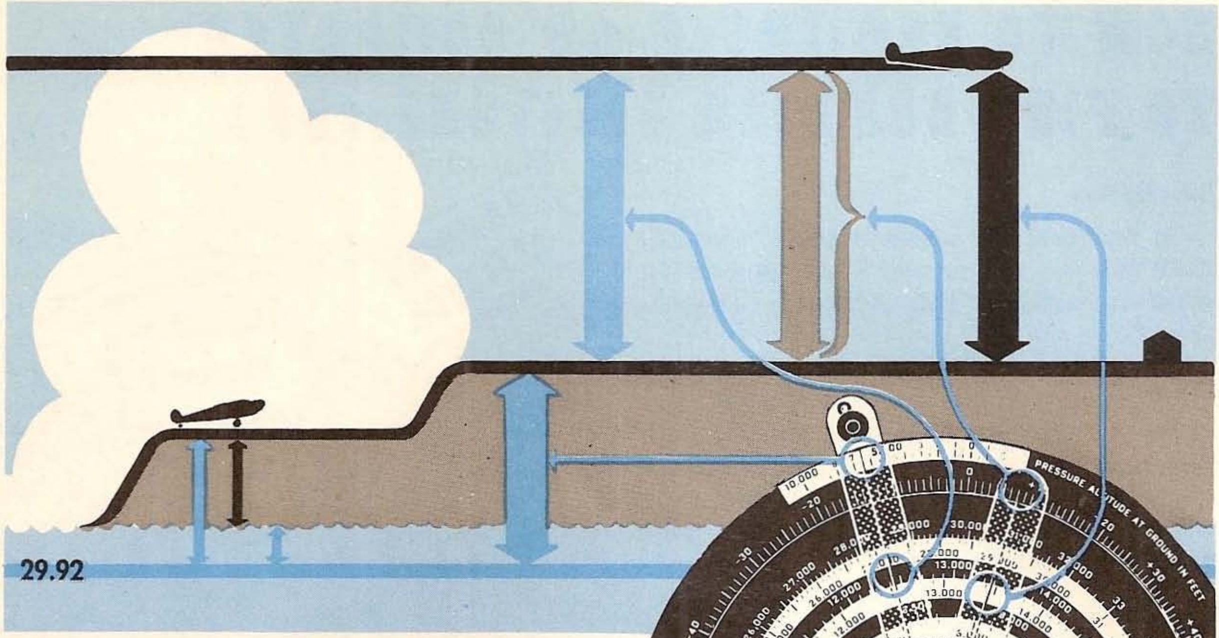
When You Don't Know Target Pressure Altitude and Temperature

1. Set flight level pressure altitude (FLPA) opposite corrected flight level temperature (FL Temp.) in the correction window.

2. Find true altitude above sea level on the outer scale opposite flight level pressure altitude (FLPA) on the inner scale.

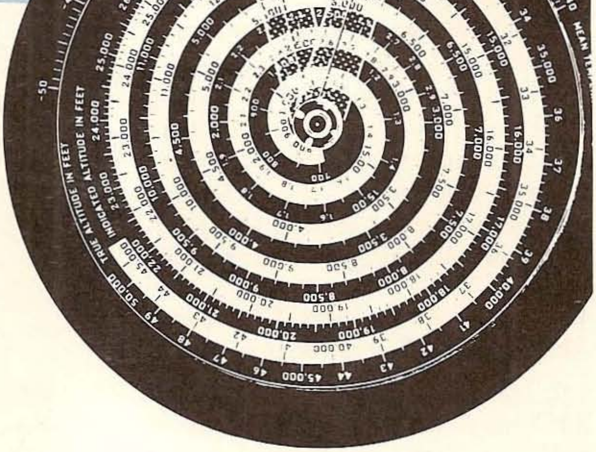
3. Find bombing altitude (BA) by subtracting target elevation from true altitude above sea level.

Note: This method is the least accurate because the altitude found is actually the altitude above the standard datum plane instead of above sea level, and the temperature changes between flight level and target are not considered. This method assumes that pressure variation is zero and that temperature variation of the air column has a standard lapse rate of approximately 2°C per 1,000 ft.



Example No. 1-A

USING C-2 OR *AN* COMPUTER



GIVEN:

Flight level pressure altitude (FLPA) 19,000 ft.

Target elevation (T Elev.) 6,140 ft.

Runway pressure altitude (RPA) 5,600 ft.

Runway elevation (R Elev.) 5,280 ft.

The following temperature readings at the pressure altitudes indicated:

Pressure Altitude	Temperature Readings (Corrected)	Pressure Altitude	Temperature Readings (Corrected)
6,460	+22°C	13,000	+6°C
7,000	+20°C	14,000	+4°C
8,000	+18°C	15,000	+2°C
9,000	+15°C	16,000	0°C
10,000	+13°C	17,000	—2°C
11,000	+10°C	18,000	—4°C
12,000	+ 8°C	19,000	—6°C

FIND:

Bombing altitude (BA).

SOLUTION:

A. Find pressure altitude variation:
RPA – R Elev. = PA Var.
5,600 – 5,280 = (+320 ft.)

B. Find target pressure altitude:
T Elev. + PA Var. = TPA
6,140 + (+320) = 6,460 ft.

C. Find pressure altitude above target:
FLPA – TPA = PA Above T
19,000 – 6,460 = 12,540 ft.

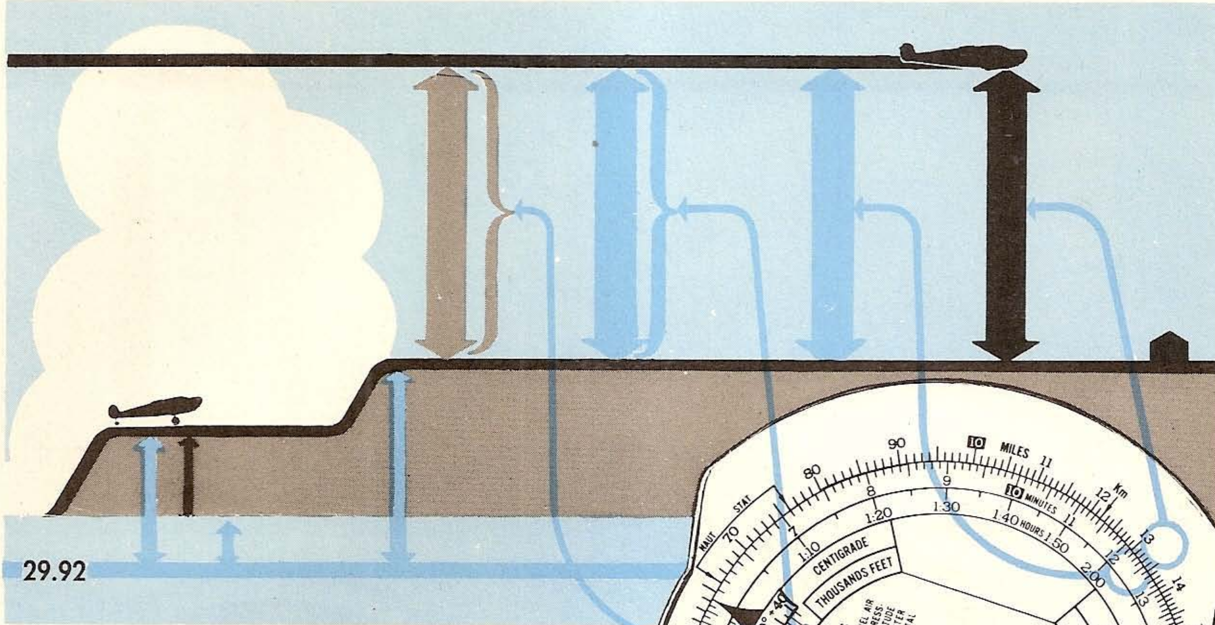
D. Find mean temperature:

$$\frac{\text{Total of Temp. Readings}}{\text{No. of Temp. Readings}} = \text{Mean Temp.}$$

$$\frac{(+106^\circ)}{14} = (+7\tfrac{1}{2}{}^\circ C)$$

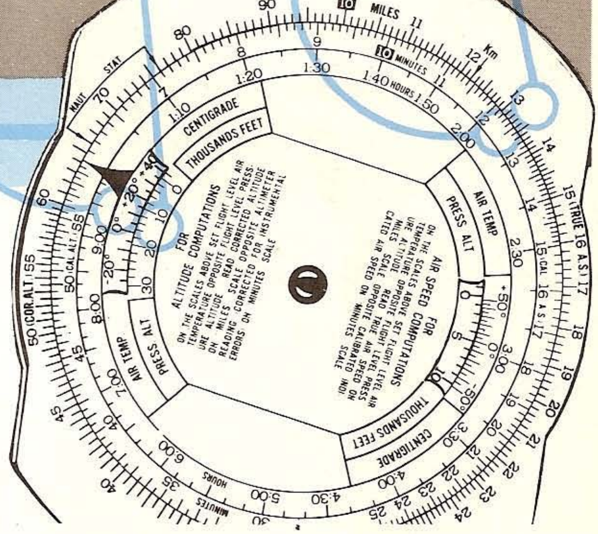
E. Use C-2 or AN computer:

1. Set clamped arm at TPA (6,460 ft.), and lock.
2. Rotate small disc until PA Above T (12,540 ft.), in black figures, is under clamped arm.
3. Set free arm at mean temperature ($+7\tfrac{1}{2}^\circ$).
4. Find BA (13,420 ft.), in light (or red) figures under free arm.



Example No. 1-B

USING E-6B COMPUTER



GIVEN:

Flight level pressure altitude (FLPA) 19,000 ft.

Target elevation (T Elev.) 6,140 ft.

Runway elevation (R Elev.) 5,280 ft.

Runway pressure altitude (RPA) 5,600 ft.

The following temperature readings at the pressure altitudes indicated:

Pressure Altitude	Temperature Readings (Corrected)	Pressure Altitude	Temperature Readings (Corrected)
6,460	+22°C	13,000	+6°C
7,000	+20°C	14,000	+4°C
8,000	+18°C	15,000	+2°C
9,000	+15°C	16,000	0°C
10,000	+13°C	17,000	—2°C
11,000	+10°C	18,000	—4°C
12,000	+ 8°C	19,000	—6°C

FIND:

Bombing altitude (BA).

SOLUTION:

A. Find pressure altitude variation:
RPA – R Elev. = PA Var.
5,600 – 5,280 = (+320 ft.)

B. Find target pressure altitude:
T Elev. + PA Var. = TPA
6,140 + (+320) = 6,460 ft.

C. Find pressure altitude above target:
FLPA – TPA = PA Above T.
19,000 – 6,460 = 12,540 ft.

D. Find mean temperature:

$$\frac{\text{Total of Temp. Readings}}{\text{No. of Temp. Readings}} = \text{Mean Temp.}$$

$$\frac{(+106^\circ)}{14} = (+7\tfrac{1}{2}{}^\circ\text{C})$$

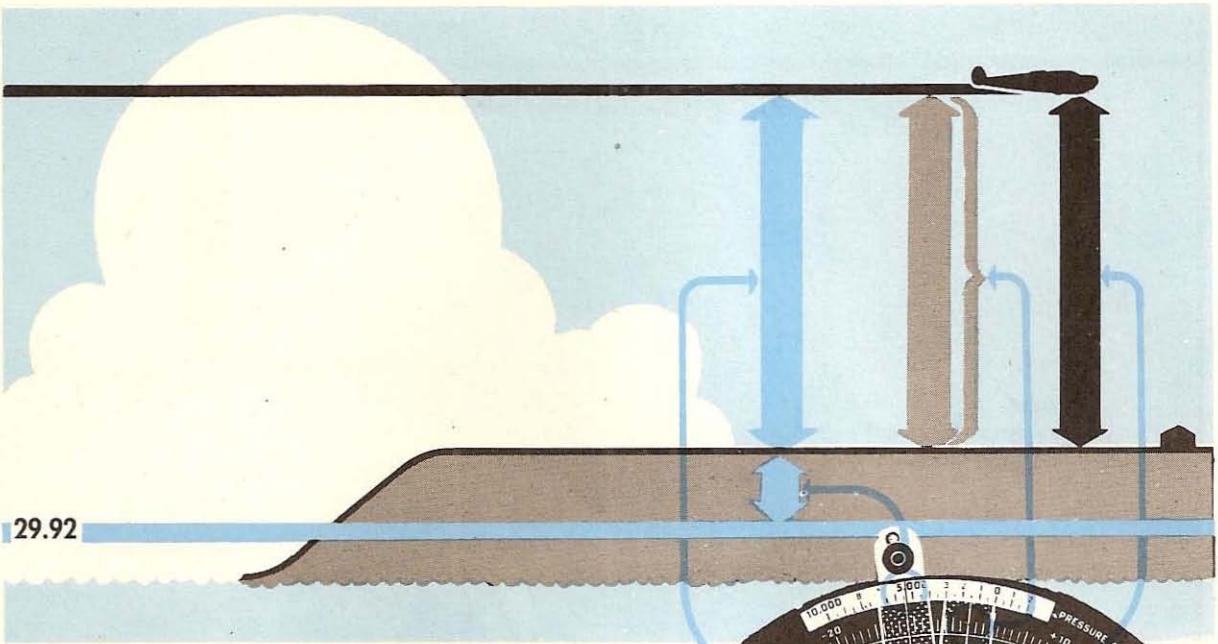
E. Find mean pressure altitude:

$$\frac{\text{FLPA} + \text{TPA}}{2} = \text{MPA}$$

$$\frac{19{,}000 + 6{,}460}{2} = 12{,}730 \text{ ft.}$$

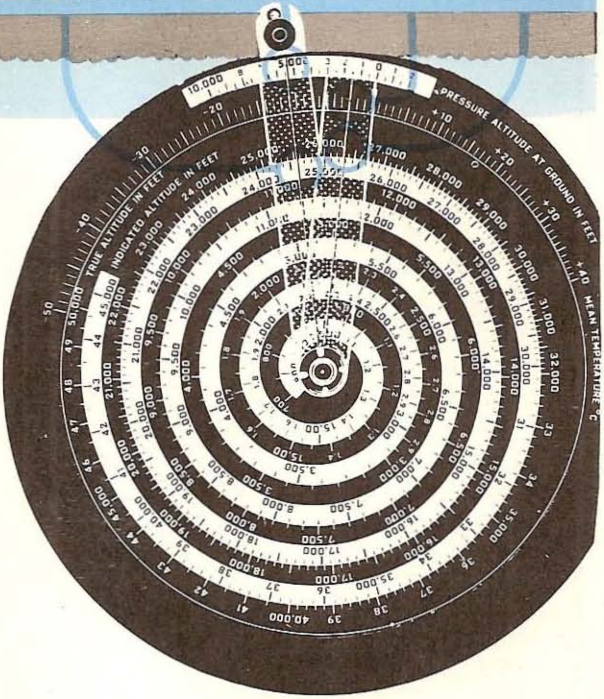
F. Use E-6B computer:

1. Set MPA (12,730 ft.) opposite mean temp. (7½°C) in altitude correction window.
2. Find BA (13,420 ft.) on the outer scale opposite PA Above T (12,540 ft.) on the inner scale.



Example No. 2-A

USING C-2 OR *AN* COMPUTER



GIVEN:

Flight level pressure altitude. (FLPA) 30,000 ft.
Flight level temperature (FL Temp.) corrected –28°C.
Target temperature (T Temp.) +22°C.
Target elevation (T Elev.) 5,900 ft.
Target pressure altitude (TPA) 5,400 ft.

FIND:

Bombing altitude (BA).

SOLUTION:

A. Find pressure altitude above target:

FLPA – TPA = PA Above T
30,000 – 5,400 = 24,600 ft.

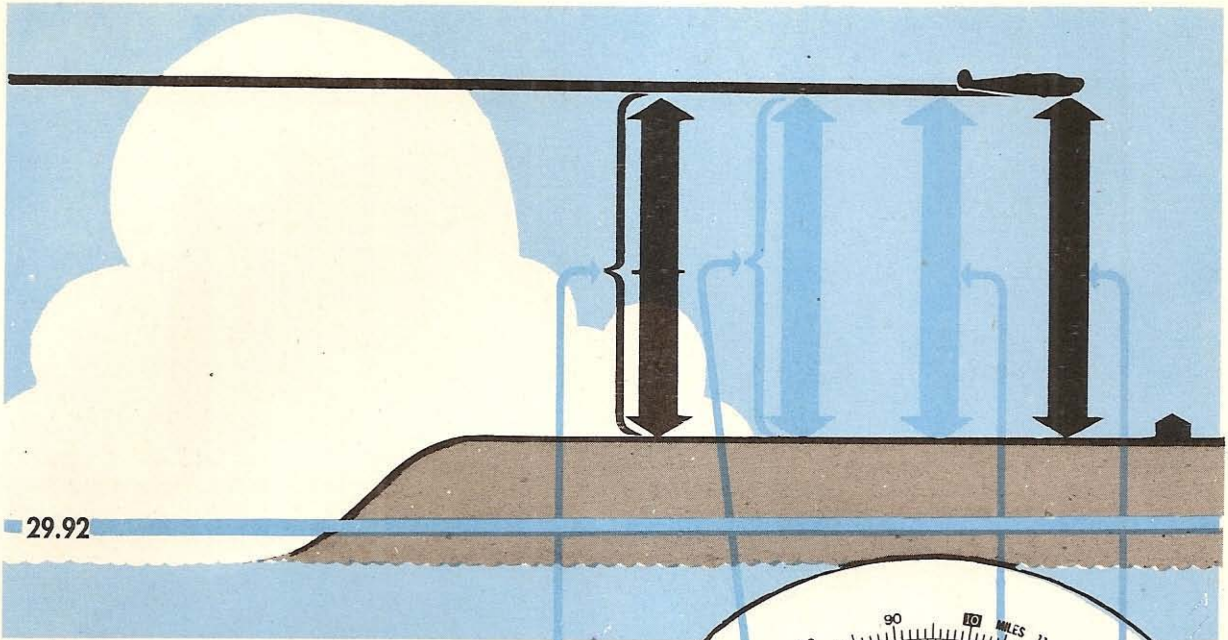
B. Find mean temperature:

$$\frac{\text{T Temp.} + \text{FL Temp.}}{2} = \text{Mean Temp.}$$

$$\frac{(-28^\circ) + (+22^\circ)}{2} = \frac{-6^\circ}{2} = -3^\circ\text{C}$$

C. Use C-2 or AN computer:

1. Set clamped arm at TPA (5,400 ft.), and lock.
2. Rotate small disc until PA Above T (24,600 ft.), in black figures, is under clamped arm.
3. Set free arm at mean temperature (–3°C).
4. Find BA (26,300 ft.), in light (or red) figures under free arm.



Example No. 2-B

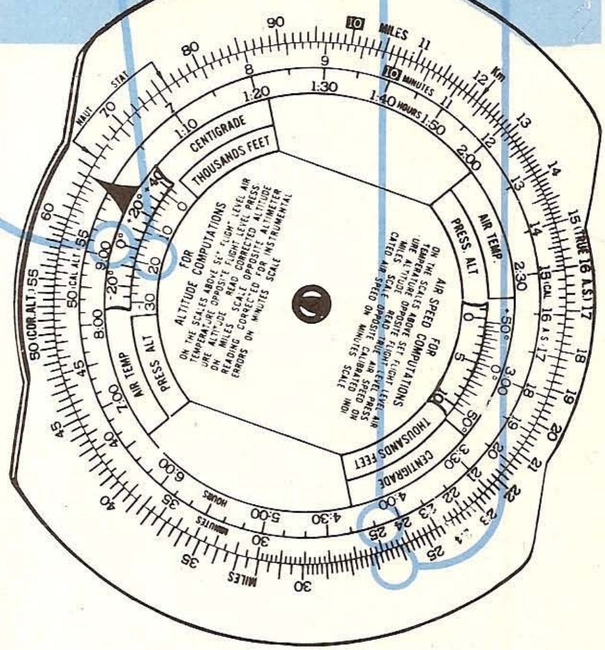
USING *E-6B* COMPUTER

GIVEN:

Flight level pressure altitude (FLPA) 30,000 ft.
Flight level temperature (FL Temp.) corrected –28°C.
Target temperature (T Temp.) +22°C.
Target elevation (T Elev.) 5,900 ft.
Target pressure altitude (TPA) 5,400 ft.

FIND:

Bombing altitude (BA).



SOLUTION:

A. Find pressure altitude above target:
FLPA – TPA = PA Above T
30,000 – 5,400 = 24,600 ft.

B. Find mean temperature:

$$\frac{\text{FL Temp.} + \text{T Temp.}}{2} = \text{Mean Temp.}$$

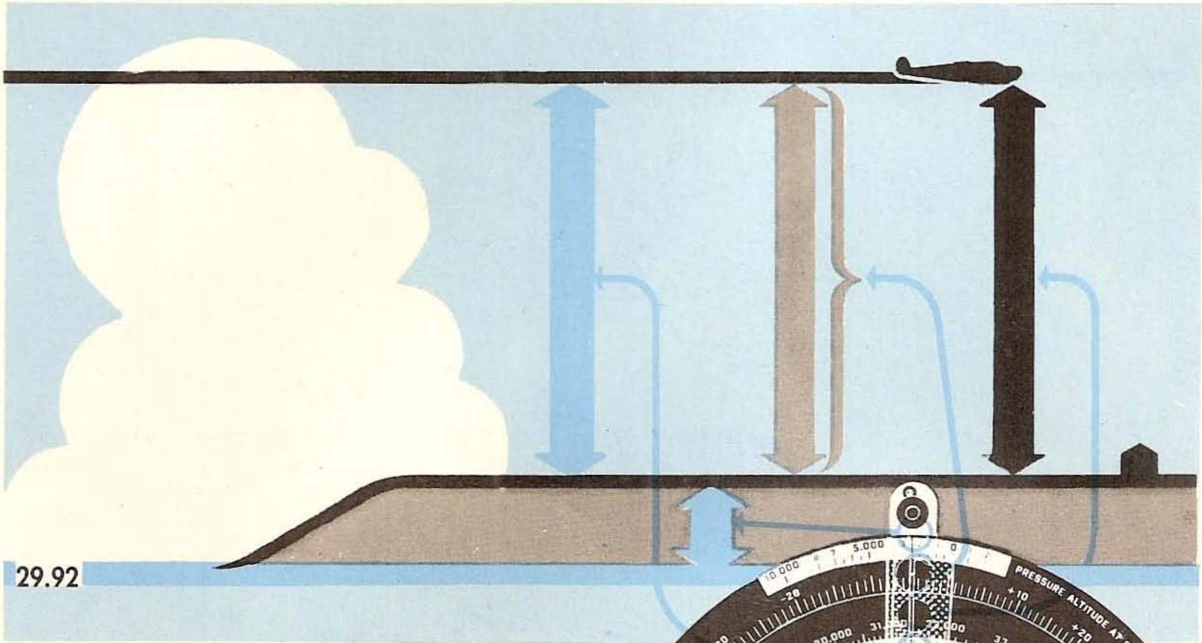
$$\frac{(-28) + (+22^\circ)}{2} = \frac{-6^\circ}{2} = -3^\circ\text{C}$$

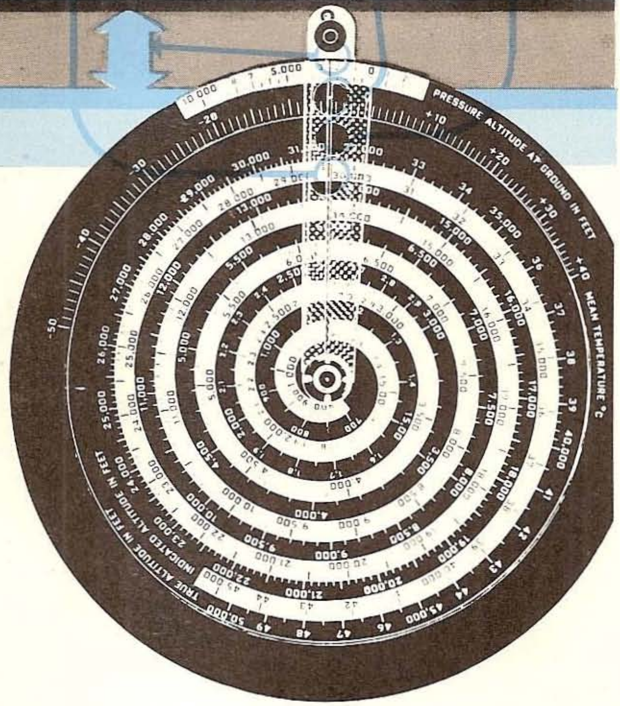
C. Find mean pressure altitude:

$$\frac{\text{FLPA} + \text{TPA}}{2} = \text{MPA}$$

$$\frac{30{,}000 + 5{,}400}{2} = 17{,}700 \text{ ft.}$$

D. Use E-6B computer:
1. Set MPA (17,700 ft.) opposite mean temperature (–3°C) in the altitude correction window.
2. Find BA (26,300 ft.) on the outer scale opposite PA Above T (24,600 ft.) on the inner scale.





Example No. 3-A

USING C-2 OR *AN* COMPUTER

GIVEN:

Flight level pressure altitude (FLPA) 32,000 ft.
Flight level temperature (FL Temp.) corrected −34°C.
Target elevation (T Elev.) 2,400 ft.

FIND:

Bombing altitude (BA).

SOLUTION:

A. Find pressure altitude above target:
FLPA − T Elev. = PA Above T
32,000 − 2,400 = 29,600 ft.

NOTE: Since you do not know target pressure altitude, assume that TPA is the same as T Elev.

B. Find target temperature:

FL Temp. + Temp. Difference = T Temp.

$$\text{FL Temp.} + \frac{(\text{PA Above T} \times 2)}{1{,}000} = \text{T Temp.}$$

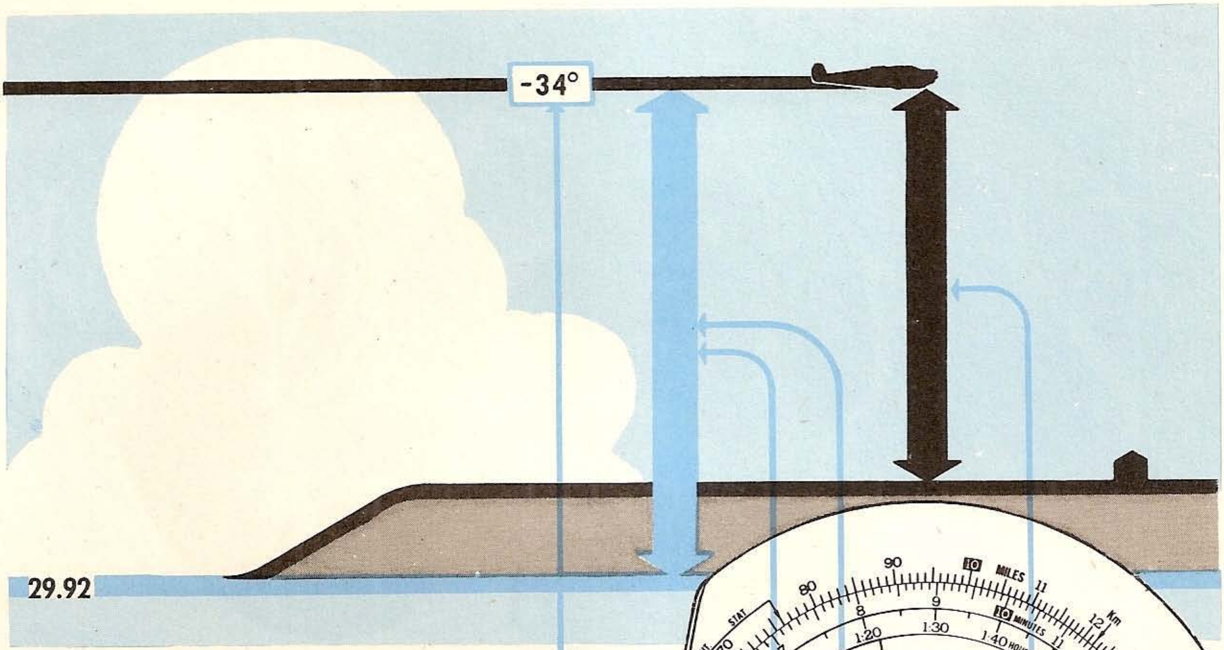
$$(-34^\circ) + \frac{(29{,}600 \times 2^\circ)}{1{,}000} = (+25^\circ\text{C})$$

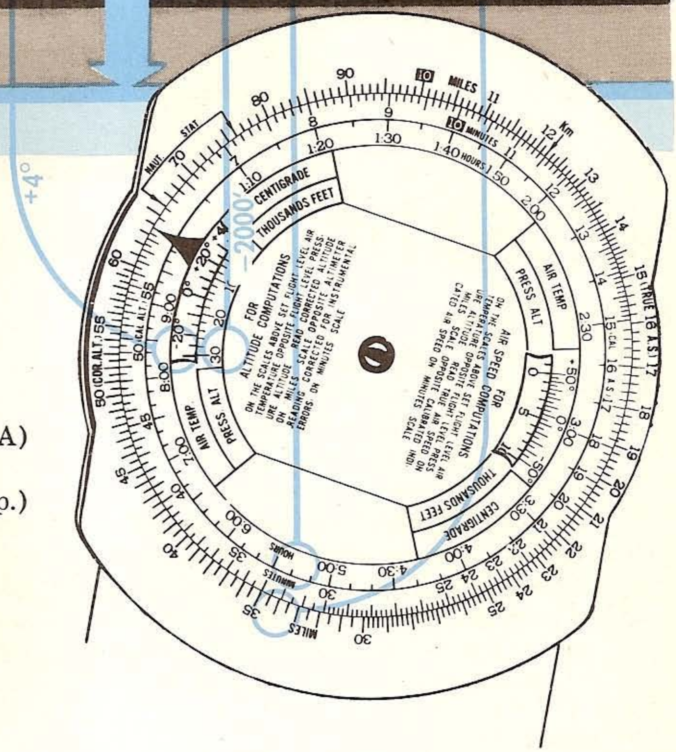
C. Find mean temperature:

$$\frac{\text{FL Temp.} + \text{T Temp.}}{2} = \text{Mean Temp.}$$

$$\frac{(-34^\circ) + (+25^\circ)}{2} = (-4\tfrac{1}{2}^\circ\text{C})$$

D. Use C-2 or AN computer:
1. Set clamped arm at TPA (2,400 ft.), and lock.
2. Rotate small disc until PA Above T (29,600 ft.), in black figures, is under clamped arm.
3. Set free arm at Mean Temperature (4½°).
4. Find BA (31,420 ft.), in light (or red) figures under free arm.





Example No. 3-B

USING *E-6B* COMPUTER

GIVEN:

Flight level pressure altitude (FLPA) 32,000 ft.

Flight level temperature (FL Temp.) corrected –34°C.

Target elevation (T Elev.) 2,400 ft.

FIND:

Bombing altitude (BA).

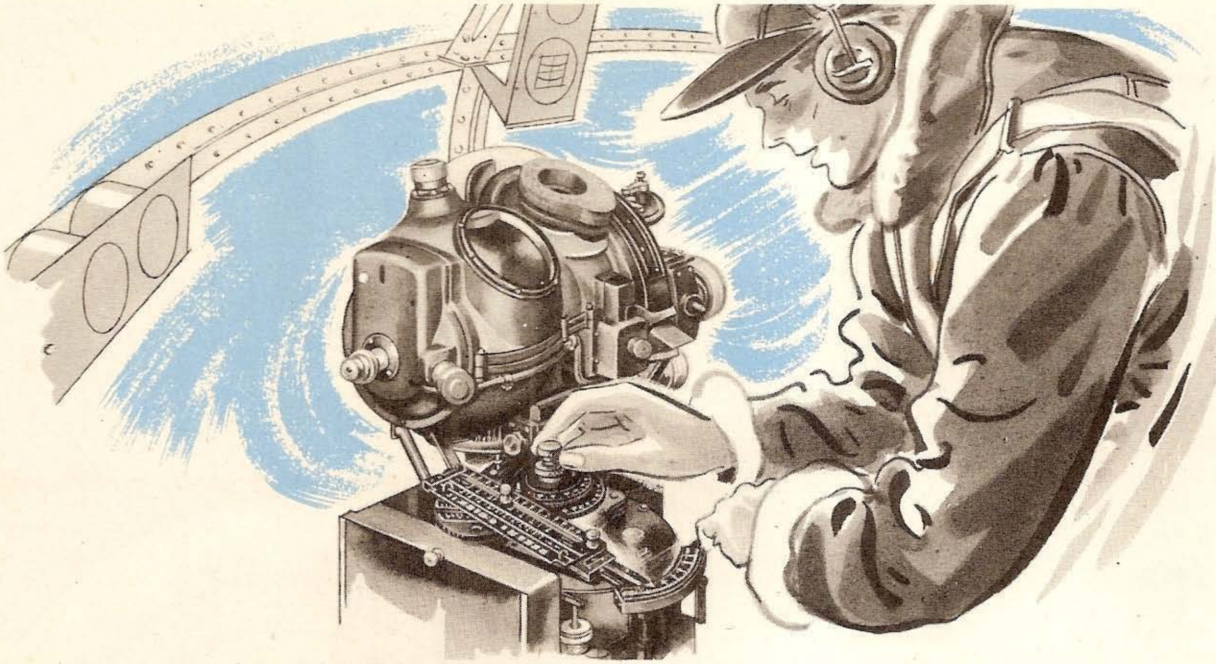
SOLUTION:

A. Use E-6B computer:

1. Set FLPA (32,000 ft.) opposite FL Temp. (–34°C) in altitude correction window.

   NOTE: The pressure scale at the correction window on some E-6B computers ends at 30,000 ft. Therefore, it is necessary to set 30,000 ft. PA opposite (–30°C) temperature in the correction window. By using the standard lapse rate of 2°C per 1,000 ft., you can subtract 2,000 ft. from the altitude and correct the temperature for this altitude difference. As this type of problem is based on the standard lapse rate, setting 30,000 ft. PA opposite (–30°C) sets up the same altitude correction computation as 32,000 ft. PA opposite (–34°C).

2. Find true altitude above sea level (33,800 ft.) on the outer scale opposite FLPA (32,000 ft.) on the inner scale.
3. Find BA (31,400 ft.) by subtracting T Elev. (2,400 ft.) from true altitude above sea level (33,800 ft.).



AUTOMATIC BOMBING COMPUTER (ABC)

Purpose

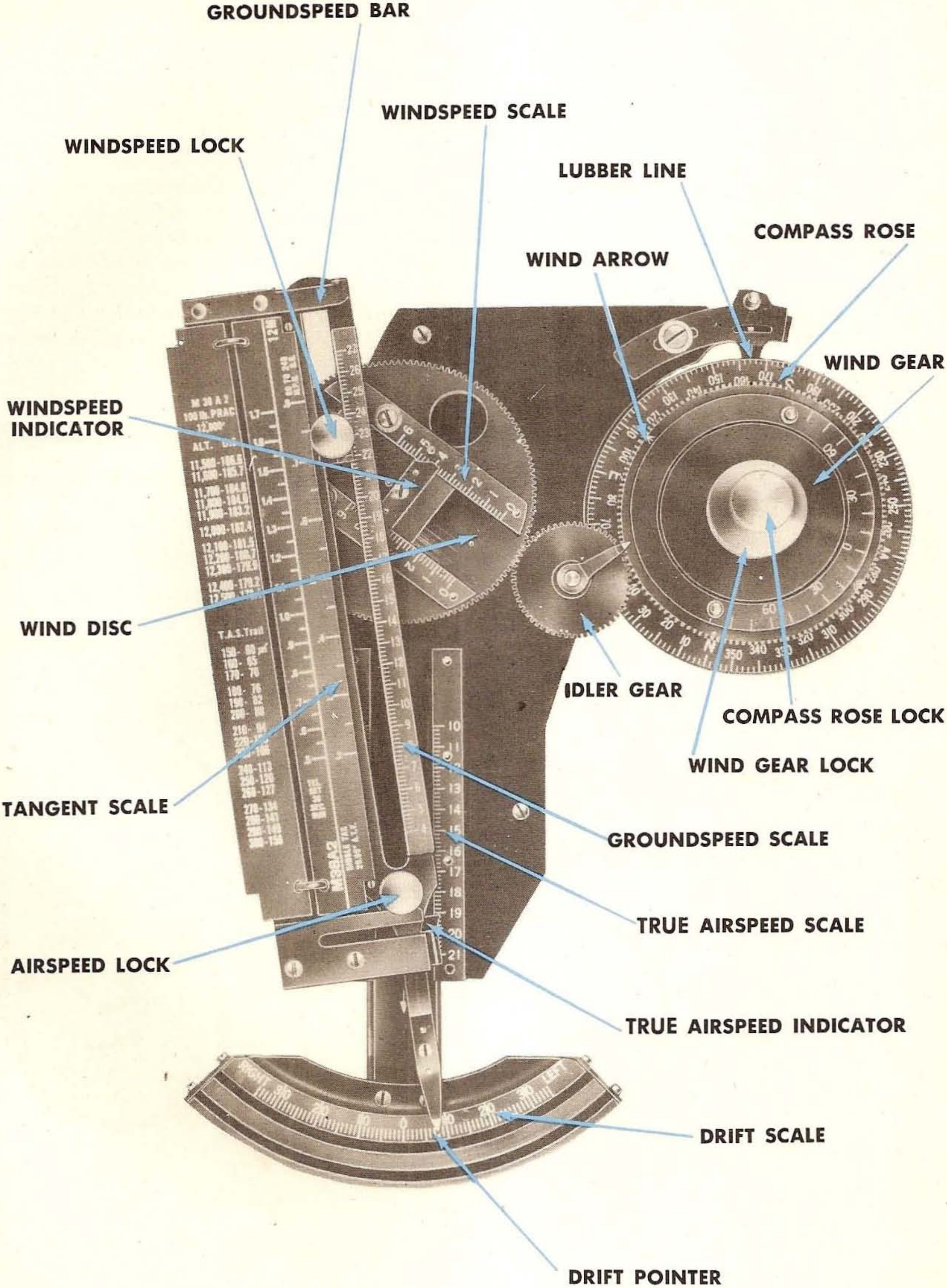
The automatic bombing computer is used with the M-Series bombsight. If you set in the proper data it will solve the vector triangle for you, just as the E-6B does but more rapidly. For this reason it can be used to great advantage in short combat approaches. With the ABC you can find the approximate dropping angle and drift for any heading. You can then pre-set this data into the bombsight and it will be possible for you to make a short bombing run with accurate results.

Description

Since you use the ABC to solve the vector triangle, you must set in certain known values in order to find the unknowns. Set Magnetic Heading on the **compass rose,** under the **lubber line**. The compass rose is locked to the clutch drum of the stabilizer by means of the **compass rose lock.**

You set in wind direction on the compass rose by positioning the **wind arrow** on the **wind gear,** which is mounted on top of the compass rose, and lock it by means of the **wind gear lock**. An **idler gear** connects the wind gear to the **wind disc.** The wind gear and the wind disc are the same size and have the same number of teeth; therefore a turn of one will give an equal turn of the other and in the same direction. On the wind disc is mounted the **wind speed scale** and the **wind speed indicator.** You set the wind speed indicator at the wind speed on the wind speed scale and lock with the **wind speed lock,** which operates freely in the slot of the **groundspeed bar**. On the right side of this bar is the **groundspeed scale**. Attached to the left side of the bar is the **tangent scale.** This scale is selected for the true airspeed, bombing altitude, and the type of bomb used. At the lower end of the slot is the **airspeed lock,** which locks the **true airspeed indicator** on the **true airspeed scale.** On the lower end of the groundspeed bar is the **drift pointer,** which operates freely over the **drift scale.**

When you set the true airspeed and wind on the computer and lock the wind gear to the directional gyro, the wind gear and wind disc are held in a fixed position in space. Therefore the computer automatically determines the drift, groundspeed, and dropping angle for any heading that the airplane flies. You then pre-set this drift and dropping angle into the bombsight for the bombing run.

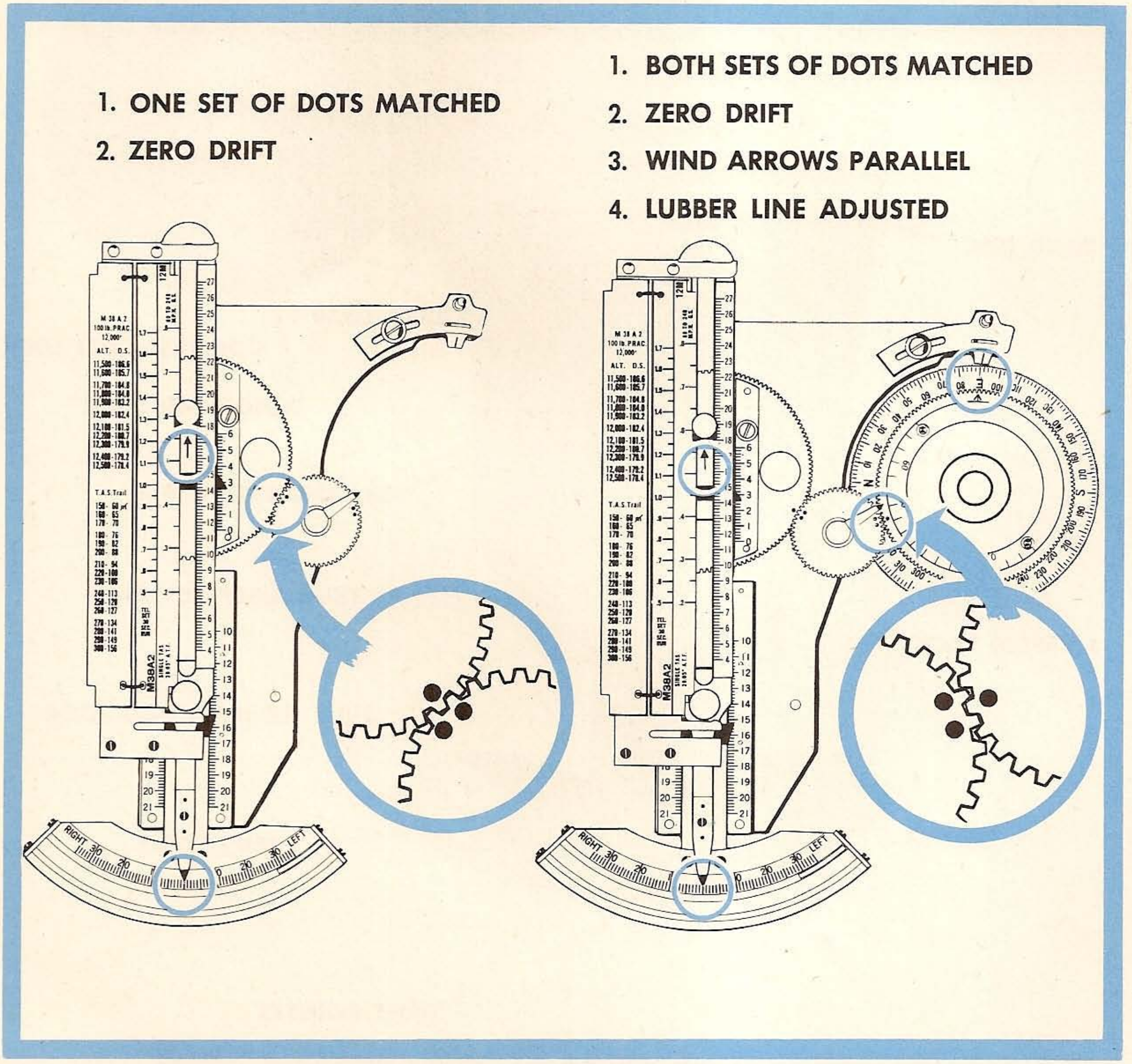

GROUNDSPEED BAR
WINDSPEED SCALE
WINDSPEED LOCK
LUBBER LINE
COMPASS ROSE
WIND ARROW
WIND GEAR
WINDSPEED INDICATOR
WIND DISC
IDLER GEAR
COMPASS ROSE LOCK
WIND GEAR LOCK
TANGENT SCALE
GROUNDSPEED SCALE
TRUE AIRSPEED SCALE
AIRSPEED LOCK
TRUE AIRSPEED INDICATOR
DRIFT SCALE
DRIFT POINTER

INSTALLATION AND ZEROING

The AB Computer is installed on the stabilizer of the M-Series Bombsight by means of a mounting bracket and a compass rose lock. When it is installed correctly you will be able to match the dots on the idler gear with the dots on the wind gear and wind disc. (The dots should match once in 19 turns of the wind gear and wind disc.) If dots do not match properly, remove wind gear by unscrewing compass rose lock and replace it so all dots are properly matched. With the wind disc and wind gear properly matched, the wind arrow on the wind gear is parallel to and points in the same direction as the arrow on the wind disc.

When the drift pointer is set on zero drift and a wind speed is set on the wind speed scale, the lubber line is adjusted to be opposite the point or tail of the wind arrow on the wind gear.

A direct head or tailwind does not cause drift. Therefore, when wind is set on the wind speed scale and the point or tail of the wind arrow is opposite the lubber line, the drift pointer must indicate zero drift. This is a fast check for proper installation and zeroing of the ABC and should be made before each mission.



WIND

You can obtain the wind direction and speed from metro predictions, drift measurements, or drift and groundspeed measurements.

Setting Known Wind on Computer

Metro winds, and winds found using the E-6B computer, are always from a direction measured from true north. Winds set on the ABC must always be from magnetic north. Therefore local variations must be applied to metro and E-6B winds when setting them on the ABC.

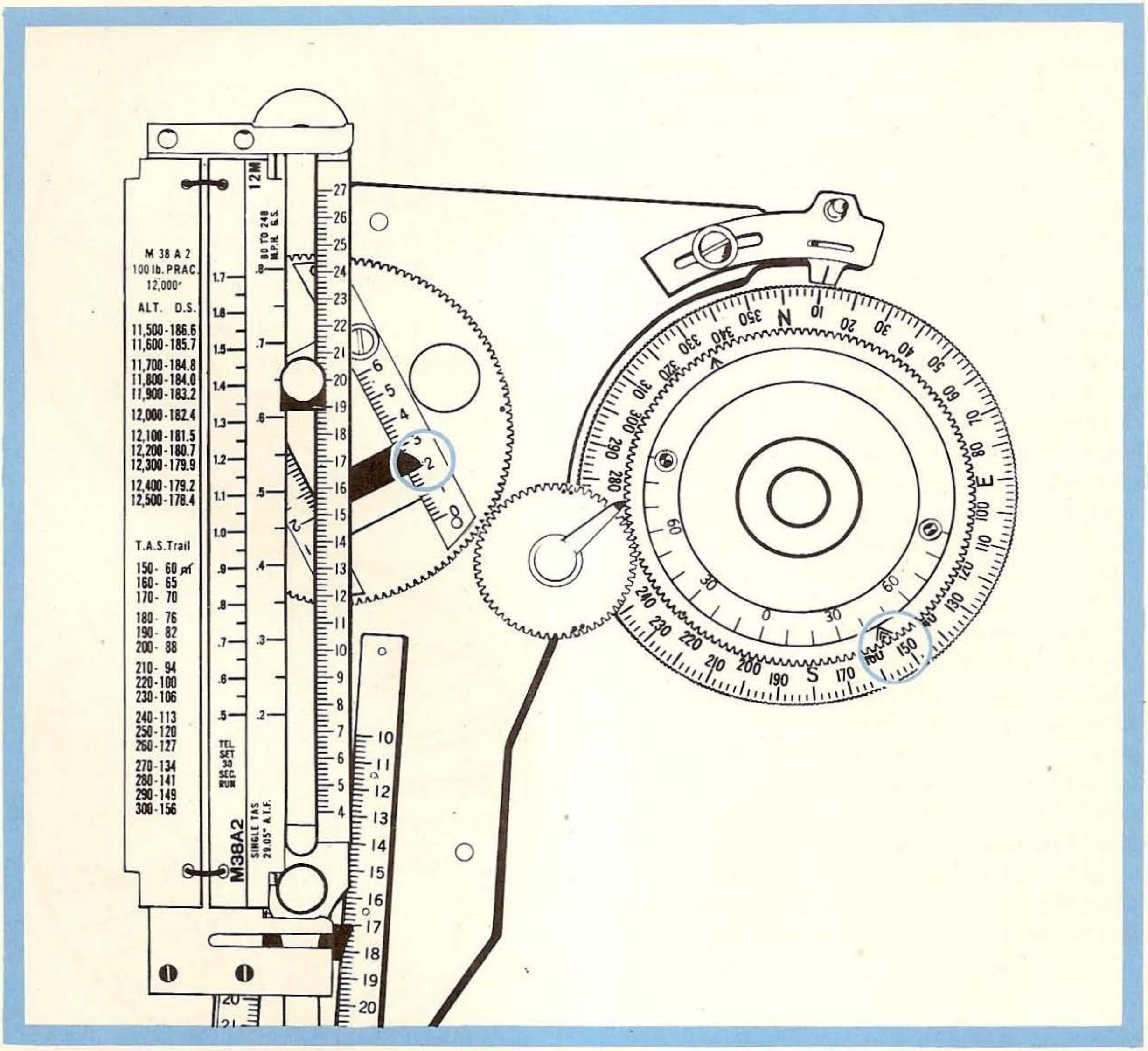
Subtract East Variation from true direction of wind to find magnetic direction of wind.

315°T – 11°E Var. = 304° Mag.

Add West Variation to true direction of wind to find magnetic direction of wind.

140°T + 14°W Var. = 154° Mag.

Set wind direction on the computer, by rotating wind gear until the tail of the wind arrow is opposite the magnetic direction of the wind on the compass rose. Lock wind gear to compass rose with the wind gear lock. Set wind speed on wind speed scale and lock with the wind speed lock.



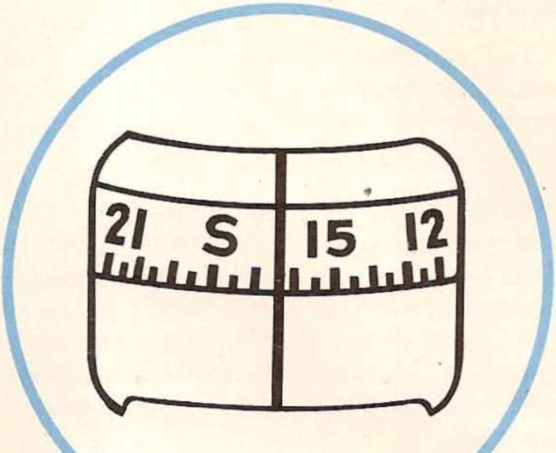
TO FIND THE WIND USING THE BOMBSIGHT AND *AB* COMPUTER

The bombsight can be used to find the drift and dropping angle (or groundspeed) for the heading and at the airspeed and altitude the airplane is flying. You can find the magnetic direction and speed of the wind by setting this drift, dropping angle (or groundspeed), magnetic heading, and the true airspeed on the AB Computer.

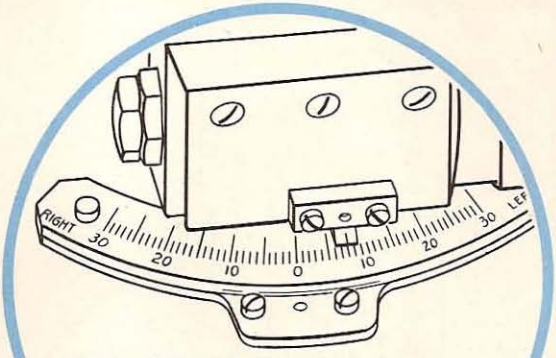
The airplane is flown on any constant heading, airspeed, and at the bombing altitude either by C-1 autopilot or manually. You uncage the gyro and, using a small sighting angle, swing the sight as a drift meter to determine the drift. To determine the drift, you rotate the sight until objects on the ground appear to move along or parallel to the fore and aft crosshair. You turn the sight away from the direction in which the objects on the ground seem to be moving.

With the sight set on the drift angle, continue along the same heading and at the same airspeed. Synchronize for rate over terrain the approximate altitude of the target to find the tangent of the dropping angle.

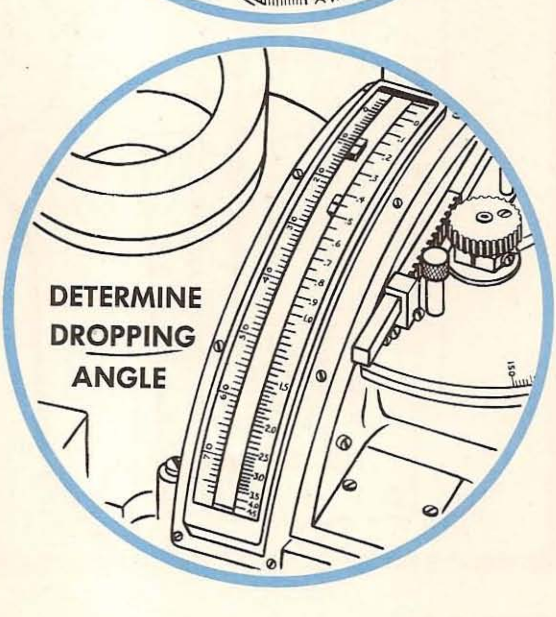
Select the tangent scale for the bombing altitude and true airspeed flown and the type of bomb to be used and attach it to left side of the groundspeed bar. Loosen all four locks. Set true airspeed on the true airspeed scale and lock. Set magnetic heading on compass rose under lubber line and lock compass rose lock. Turn wind arrow to the approximate direction of the wind. When you have right drift the wind is from the left and you point the wind arrow to the right. With left drift the wind arrow is pointed to the left. Set drift pointer at drift determined from sight. Hold drift pointer in this position and rotate wind gear to position groundspeed indicator at tangent of the dropping angle from sight. Lock the wind speed lock and the wind gear lock. The magnetic direction and speed of the wind is now set on the ABC. You should complete this entire operation before turning off the heading on which the wind is determined.



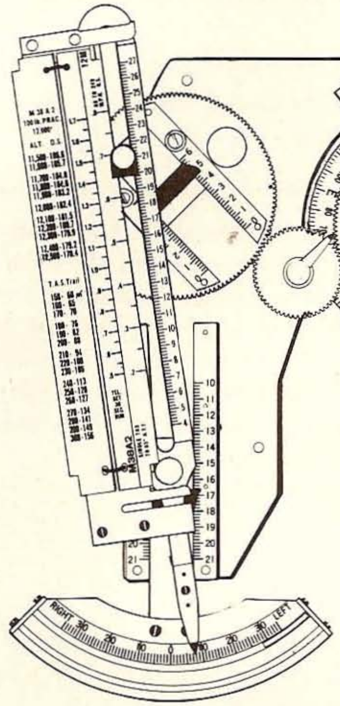
CONSTANT HEADING

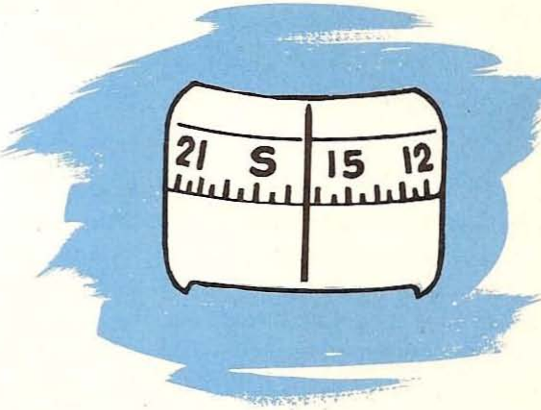


DETERMINE DRIFT

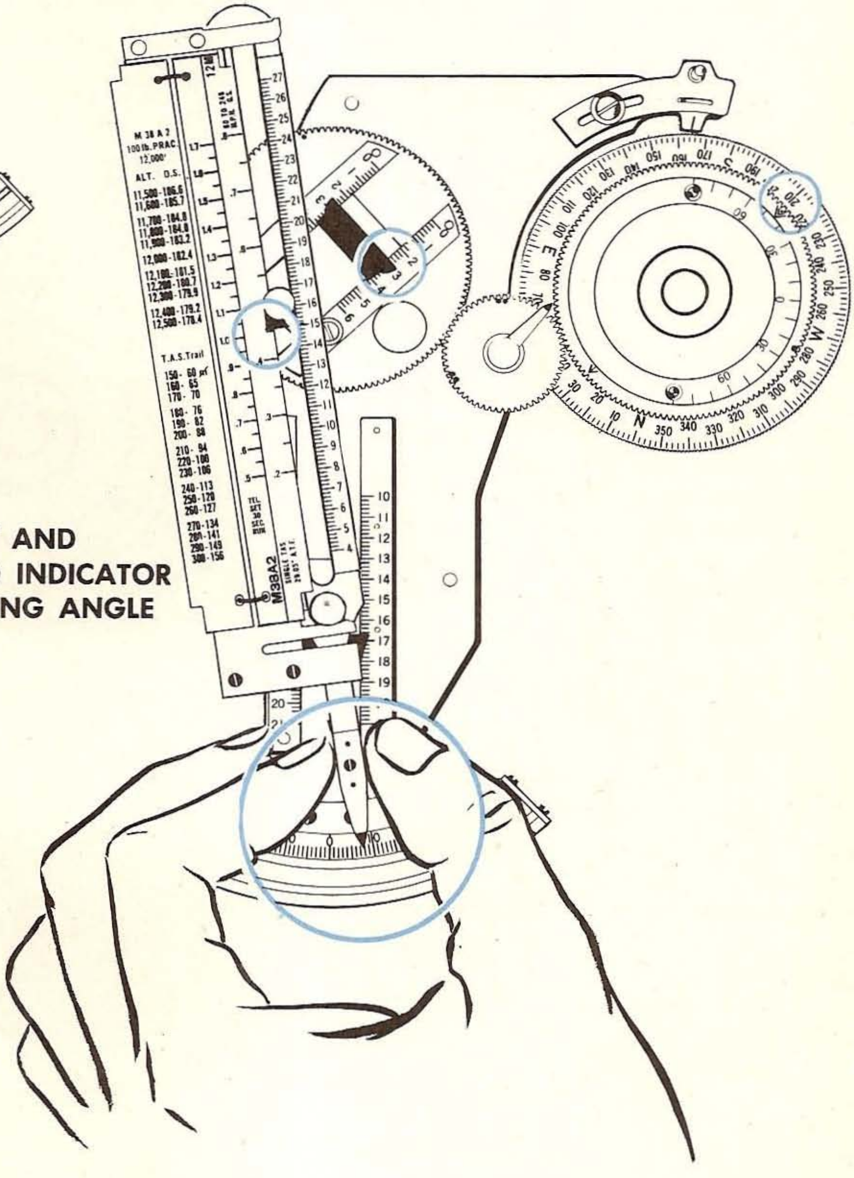

DETERMINE DROPPING ANGLE

TURN WIND ARROW TO APPROXIMATE DIRECTION OF THE WIND





HOLD POINTER ON DRIFT AND POSITION GROUNDSPEED INDICATOR AT TANGENT OF DROPPING ANGLE



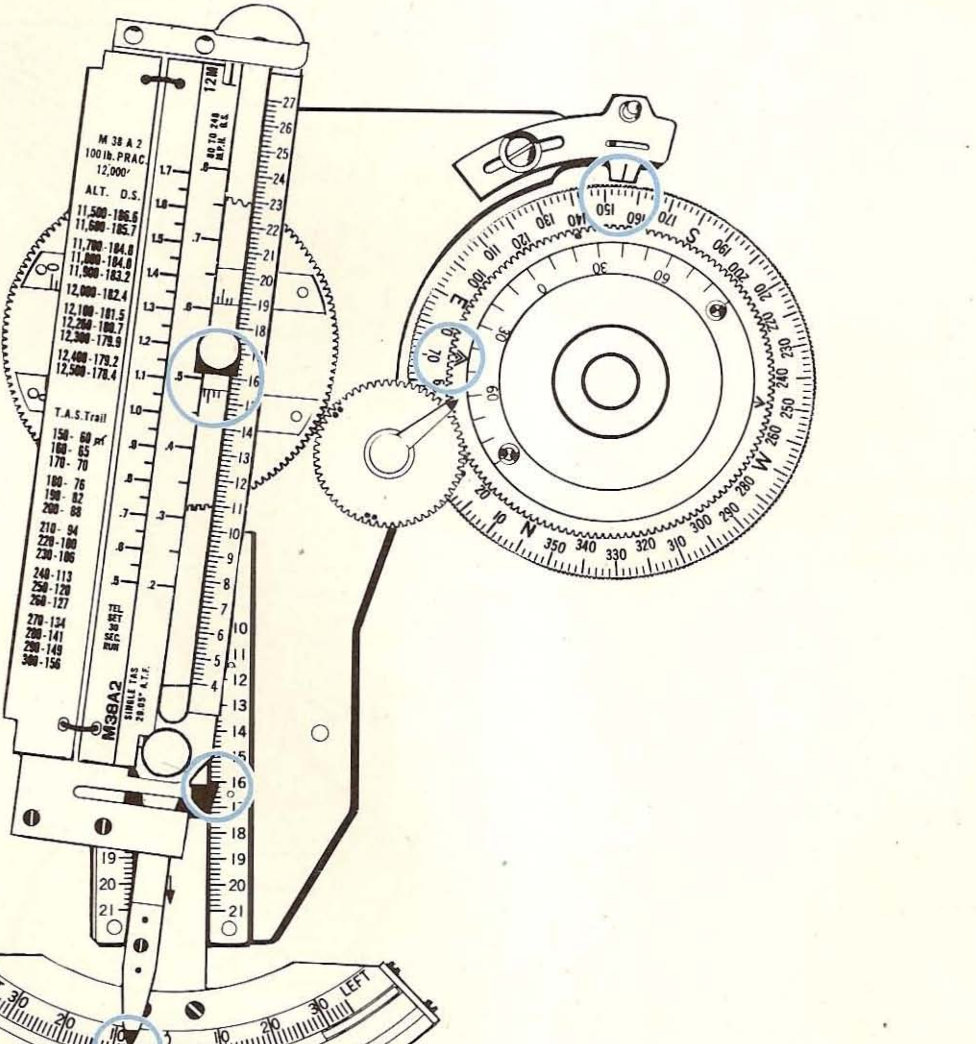
How to Use It

Zero the computer prior to take-off. Attach the proper tangent scale. Set true airspeed on true airspeed scale and lock. Set magnetic direction and speed of wind. Set magnetic heading of the airplane under the lubber line.

The groundspeed indicator will now indicate the tangent of the dropping angle for any magnetic heading of the airplane. The drift pointer will indicate the drift for any magnetic heading of the airplane. The wind arrow will indicate the direction of the wind at all times. This is useful when you are planning evasive action.

To Find Information on Another Heading

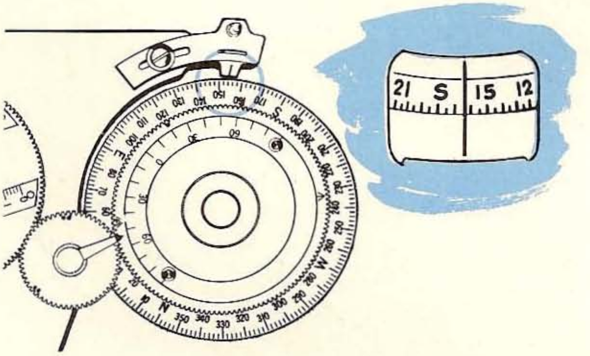
If you wish to know the drift and dropping angle for a magnetic heading other than the one on which you are flying, loosen the compass rose and turn it until the desired magnetic heading is under the lubber line. After finding this information, re-set the compass rose to the magnetic heading of the airplane.

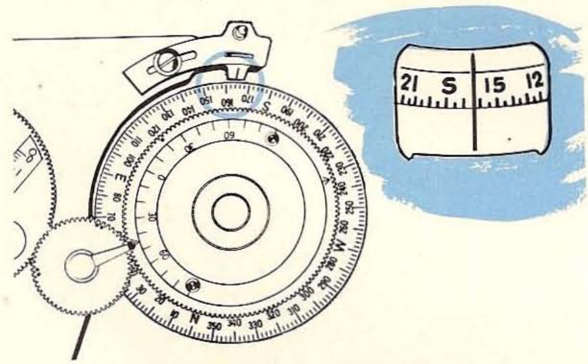


CORRECTION FOR PRECESSION

The stabilizer gyro precesses about 10° for every 360° turn in the same direction. This causes the magnetic heading indicated on the compass rose of the ABC to be incorrect. Thus the ABC will not indicate the proper drift and tangent of the dropping angle for the magnetic heading of the airplane, unless an adjustment is made.

To correct for this precession, unlock the compass rose lock and re-set the magnetic heading of the airplane under the lubber line. Do this shortly before the turn over the initial point.



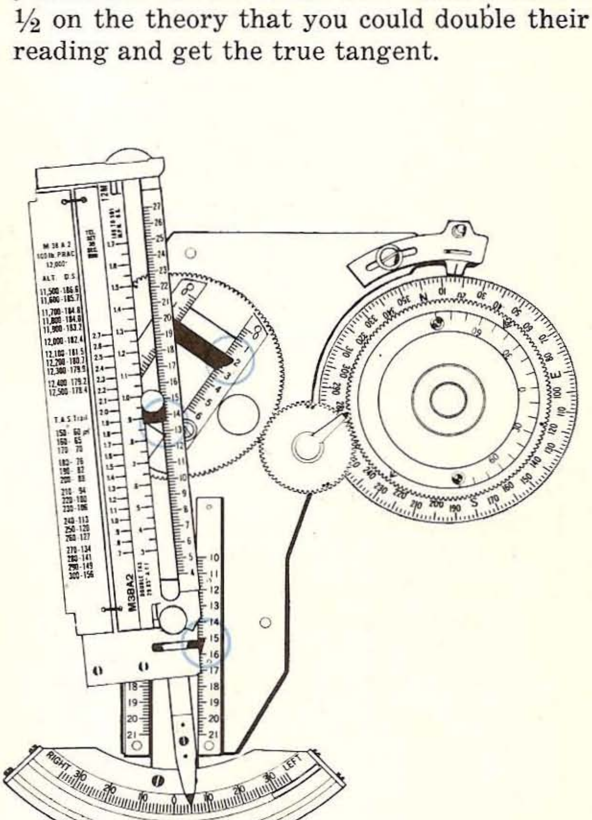


WHEN TRUE AIRSPEED EXCEEDS 210 MPH

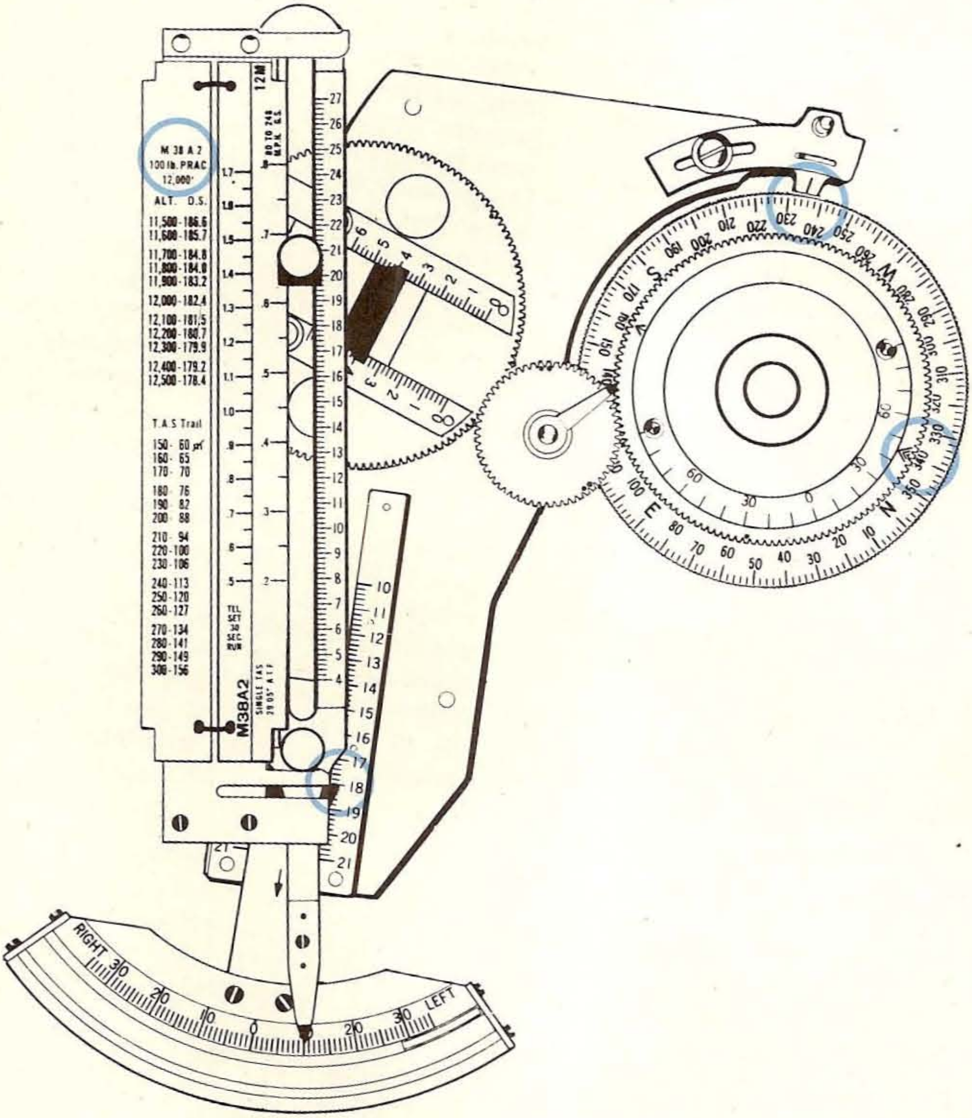
The true airspeed scale on your computer is graduated from 100 to 210 mph. However, you can use it just as well for true airspeeds up to 420 mph. If your true airspeed exceeds 210 mph, set the true airspeed indicator at one-half (½) the true airspeed. Remember, if the wind speed is set into the computer, it, too, will be set at one-half (½) its true value. Now, if you were reading the wind speed or groundspeed from the computer, you would double the indicated values.

For example, if your true airspeed is 300 mph, set the true airspeed indicator at 150. Suppose the wind speed is 40 mph; set the wind speed indicator at 20. Then, if you found the groundspeed indicator at 135, you would know that the groundspeed you are flying is 270 mph.

Whenever the true airspeed exceeds the limits of the true airspeed scale, you must be very careful in working out the tangent of the dropping angle. Some of the detachable tangent scales provided with the computer have a small ½ printed at the top. These are the ones you **must** use when the true airspeed is more than 210 mph. These ½ tangent scales are **graduated to give the correct tangent readings** when using ½ settings of true airspeed and wind speed. Therefore **do not double** the tangent value given on this scale. Since the tangent values are not constant, you cannot use the scales that are not marked ½ on the theory that you could double their reading and get the true tangent.



Example: TO FIND WIND



VEN:

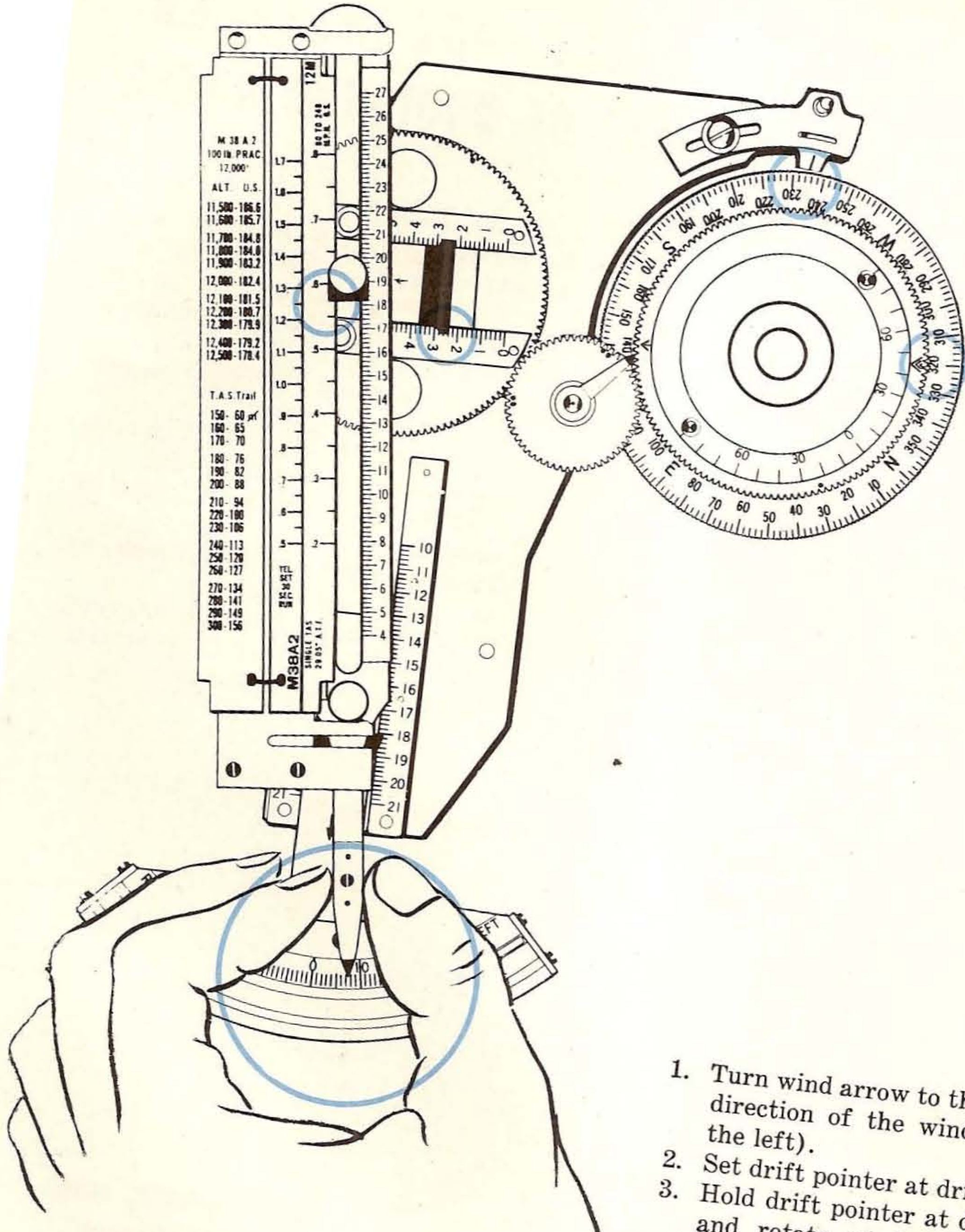
Bombing Altitude 12,000 ft.
True Airspeed 180 mph.
Type of Bomb M38A2.
Magnetic Heading 235°.
Drift 7½°L.
Tangent of Dropping Angle 0.57.

Vind Direction.
Vind Speed.

SOLUTION:

A. 1. Check zero of the computer.
   2. Attach the tangent scale for the bombing altitude (12,000 ft.), true airspeed (180 mph), and type of bomb (M38A2).

B. 1. Loosen all four locks.
   2. Set true airspeed (180 mph) on the true airspeed scale and lock.
   3. Set magnetic heading (235°) on the compass rose under the lubber line and lock.



1. Turn wind arrow to the approximate direction of the wind (pointing to the left).
2. Set drift pointer at drift (7½°L).
3. Hold drift pointer at drift (7½°L). and rotate wind gear to position groundspeed indicator at tangent of the dropping angle (0.57).
4. Lock the wind speed lock.
5. Lock the wind gear lock.

D. 1. Find magnetic wind direction **(320°)** on the compass rose at the tail of the wind arrow.
   2. Find wind speed **(24 mph)** on the wind speed scale at wind speed indicator.
   3. Computer will now indicate the drift and tangent of dropping angle for any heading.

Example: TO FIND DRIFT, GROUNDSPEED AND TANGENT OF DROPPING ANGLE

GIVEN:

Bombing Altitude 12,000 ft.
True Airspeed 180 mph.
Type of Bomb M38A2.
Magnetic Heading 13°.
Magnetic Wind from 320° at 24 mph.

FIND:

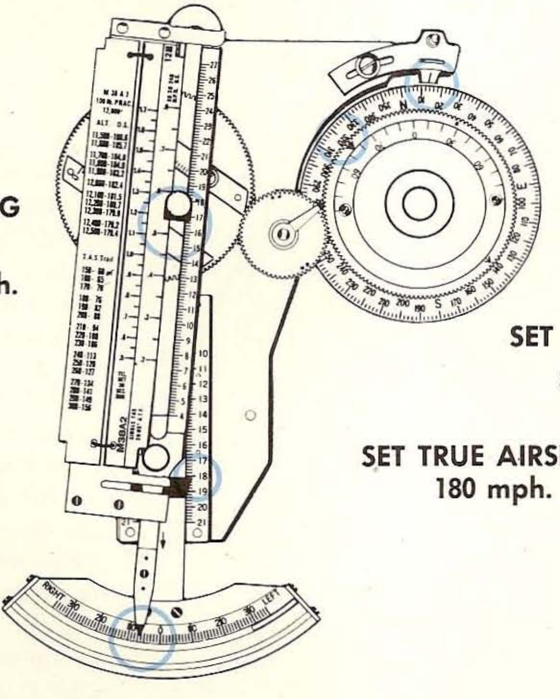
Drift.
Groundspeed.
Tangent of Dropping Angle.

SOLUTION:

A. 1. Check zero of the computer.
2. Attach the tangent scale for the bombing altitude (12,000 ft.), true airspeed (180 mph), and type of bomb (M38A2).

B. 1. Set magnetic wind (from 320° at 24 mph) on the computer and lock. (This wind is already set on the computer from the previous problem.)
2. Set true airspeed (180 mph) on true airspeed scale and lock.
3. Set magnetic heading (13°) on compass rose under the lubber line.

C. 1. Find the drift (**6½°R**) at the drift pointer.
2. Find the groundspeed **(167 mph)** at the groundspeed indicator.
3. Find the tangent of the dropping angle (**0.53**) on the tangent scale at the groundspeed indicator.



SECTION 3

C-I Autopilot

INTRODUCTION

The autopilot is an electronic-mechanical robot which automatically flies the airplane in straight and level flight, or maneuvers it in response to controls which you or your pilot operate. You use it on most of your bombing missions. Although its main purpose is to give you a stabilized bombing platform, it is also used to relieve pilot fatigue and as a navigational aid.

When you use it with the M-series bombsight, you control the course of the airplane. Your course corrections cause the autopilot to make the proper turns. Since the response of the autopilot is quicker and more accurate than that of the human pilot, you will have lower circular errors when you use it. But to get maximum performance from the autopilot, you must know how it works and how to set it up for proper operation. You will be expected to set up the autopilot on many missions. When you leave the bombardier school to join a combat crew the chances are you will be the only man in the crew who understands the operation of the autopilot. You will have to teach your pilot and co-pilot all you know about it.

How It Works

To replace the human pilot, the autopilot must do the same work as various parts of the pilot's body.

The Autopilot "Eyes"

A human pilot watches the horizon or his instruments to see if the airplane is flying straight and level.

The "eyes" of the autopilot are two gyros. One is the directional gyro in the bombsight stabilizer. The other, which has its spin axis in the vertical, is called the flight gyro and is usually located near the center of gravity of the airplane.

The cases which hold these gyros are attached to the airplane. When the airplane tilts, the cases move with the airplane but the gyros tend to maintain their fixed position in space. Two wipers are placed in a fixed position to the flight gyro—one around the roll axis and one around the pitch axis. Another wiper is placed in a fixed position to the directional gyro—around the yaw axis. These wipers are similar to the PDI brush of the bombsight. Each of these three wipers rides on a potentiometer mounted to the gyro case. These potentiometers are just coiled wire. If the wiper moves from its center or "dead" spot on the potentiometer, it unbalances an electric bridge circuit.

So when the airplane tilts, the gyro and wiper maintain their position in space, but the potentiometer—which is fastened to the airplane—moves under the wiper.

In this way, the autopilot "sees" when the airplane is not flying straight and level.

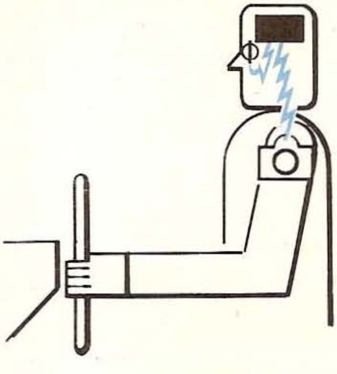
The Autopilot "Brains"

Just as the pilot's eyes send a signal to his brain, the gyros of the autopilot, through wipers and potentiometers, send an electric signal to an "electric brain," the amplifier.

The Autopilot "Nerves"

A human pilot's brain must receive and send signals through his nervous system so the proper muscles of his body will react to apply a force on the airplane's controls to correct the attitude of the airplane's flight.

The autopilot "nerves" are a system of electric bridge circuits and wires which carry signals between the various units.



The Autopilot "Muscles"

Signals from the amplifier cause servo units in the autopilot system to operate. These servo units correspond to the human pilot's muscles. They are attached by cables to the airplane's control surfaces.

Thus, when the airplane deviates from straight and level flight, the gyros signal the amplifier, which in turn sends the proper signals to the servo units. This causes the servo units to move the controls mechanically in the proper direction and return the airplane to straight and level flight.

COURSE CONTROL

Also, the autopilot bridge circuits contain potentiometers and wipers which can be **deliberately** moved by pilot or bombardier, to cause the autopilot to turn the airplane when course corrections are desired.

Limitations

The autopilot cannot do everything that the human pilot can. It has some limitations. First of all, it does not correct for drift. If the pilot does not crab the airplane to make the correction before the beginning of the bombing run, you must make drift corrections during the run. You do this with the course knobs. The course knob and PDI mechanism of the sight are connected to the autopilot. With the course knobs you can bank the airplane up to 18°. Similarly, with a control on his instrument panel, the pilot can make a coordinated bank as large as 40°.

The autopilot will keep the airplane crabbed once you or the pilot have made the corrections, but it cannot compensate for any wind changes.

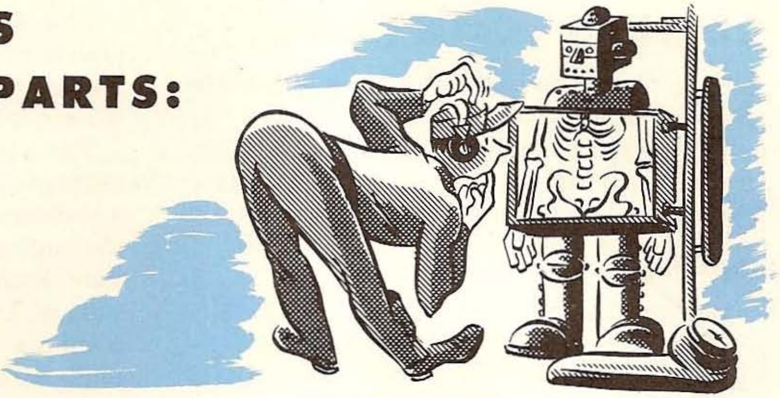
The autopilot does not maintain a constant altitude. If you were flying at 10,000 ft. and a sudden updraft blew the plane to 10,300 ft., the autopilot would maintain the new altitude. Remember, the autopilot keeps the **attitude** of the plane the same, but it does not maintain a **constant altitude.** However, the pilot can use controls of the autopilot to make small changes in altitude without readjusting the whole system.

When you change the altitude or airspeed appreciably you must readjust the autopilot. This is necessary because changes in altitude or airspeed change the attitude at which the airplane must fly to hold a straight and level course. At higher altitudes, where the air is less dense, the nose of the airplane has to be pointed upward more than at lower altitudes.

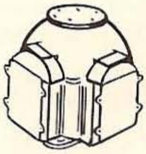
Remember

AUTOPILOT DOES NOT MAINTAIN CONSTANT ALTITUDE OR CORRECT FOR DRIFT

THE AUTOPILOT'S MAIN PARTS:

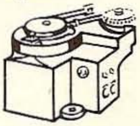


Flight Gyro



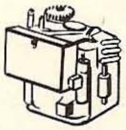
This gyro, which has its spin axis in the vertical, provides stability about the pitch and roll axis of the airplane.

Directional Gyro



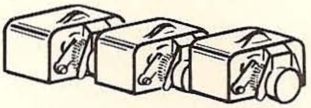
Its spin axis is in the horizontal. It provides stabilization about the airplane's yaw axis.

Directional Panel



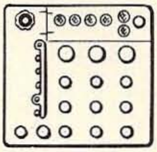
This unit, on the bombsight stabilizer, makes it possible for you to turn the airplane with the bombsight.

Servo Units



There are three of these—one for each axis of the airplane. All of them are built alike. Each has a cable drum driven by an electric motor. They supply the force to move the airplane's control surfaces.

Autopilot Control Panel (ACP)

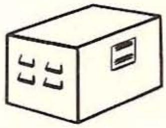


Various switches and knobs for engaging parts of the autopilot and adjusting it for proper flight are on this panel.

Turn Control

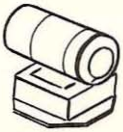
This knob is located on the ACP and you use it to make coordinated turns with as much as 40° of bank.

Amplifier



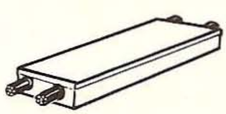
This unit receives electric signals from the bridge circuits (wipers and potentiometers), amplifies them, and relays them to the proper servo unit for control action.

Rotary Inverter



This is a motor generator unit which takes direct current from the airplane's power supply and changes it to alternating current for use in the amplifier and bridge circuits.

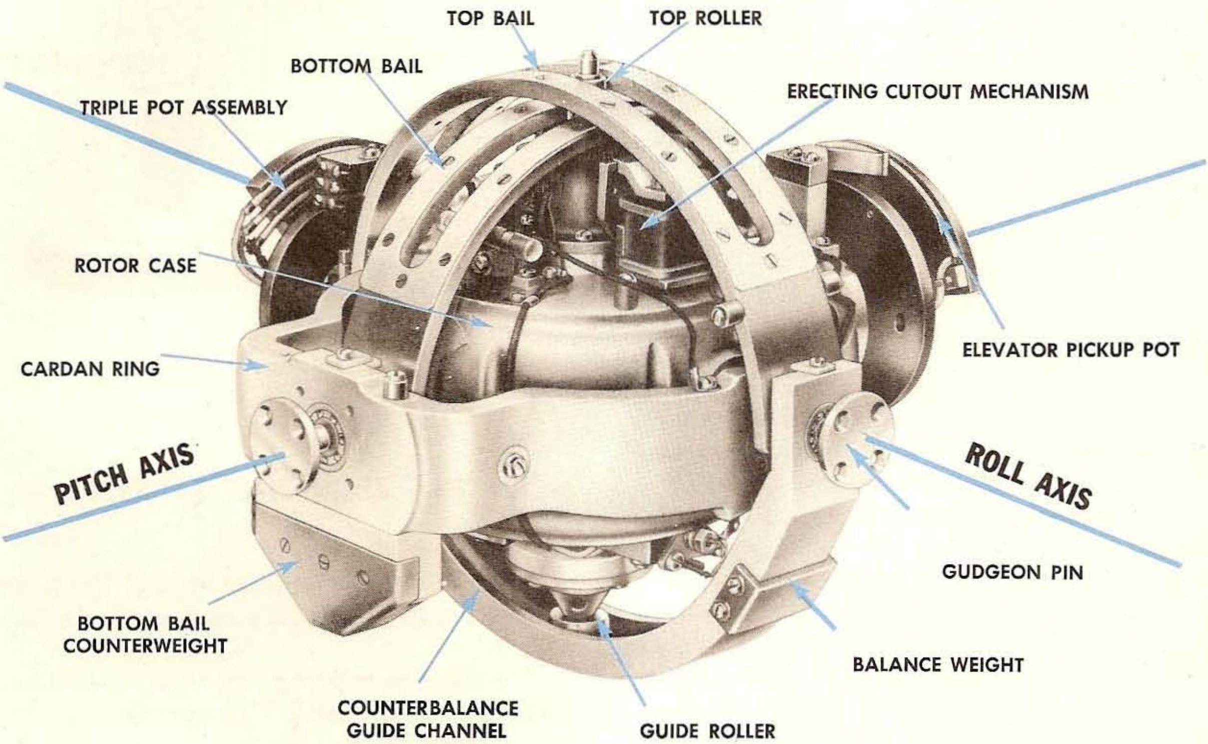
Junction Box



This provides a central location for making wiring connections between the various control units.

The C-1 autopilot operates on a 24-volt direct current. However, airplanes with 12-volt circuits are equipped with the B-1 autopilot. The C-1 and B-1 autopilots are identical except for the fact that they operate on different voltages.

CONSTRUCTION



Flight Gyro

The main purpose of the flight gyro is to serve as a vertical reference for the autopilot. The flight gyro detects any motion of the airplane around the roll and pitch axes. It is mounted near the airplane's center of gravity and rotates at approximately 7,500 rpm.

Because this gyro serves as a vertical reference, it must be kept in the vertical. This is done by an erecting system which holds the gyro within one degree of the vertical.

THE ERECTING SYSTEM

The erecting system is fairly simple in operation. It has two rollers geared to and in line with the gyro's spin axis.

Two arc-shaped metal bails, slotted down their centers, curve across the top of the gyro. A roller rides in each slot. There is very small clearance between the rollers and the inner surfaces of the slots.

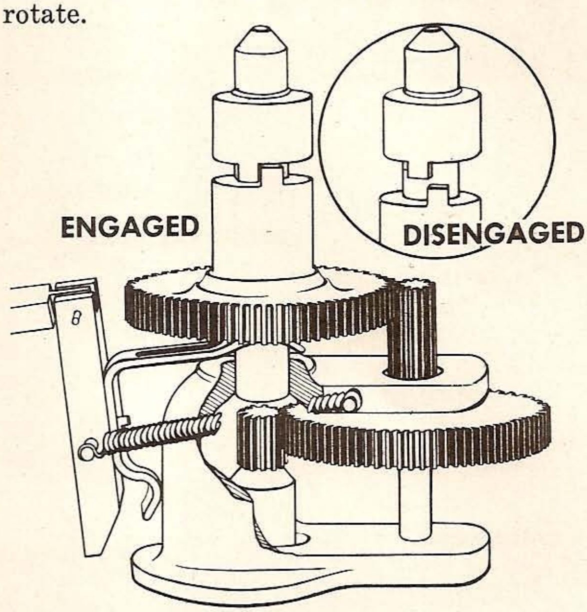
The Bails

The bails are at right angles to each other, mounted on the cardan by pivots in their ends like the bail of a bucket. The top bail is mounted fore and aft and precesses the gyro about the roll axis. The bottom bail is mounted laterally and precesses the gyro about the pitch axis. Pivoted about the pitch axis with the top bail is the counterbalance guide channel. Also arc-shaped like the bails, it curves under the gyro. The guide roller, which extends from the bottom of the gyro, rides in the counterbalance guide channel. The counterbalance guide channel counterbalances the weight of the top bail and other parts of the gyro unit. The counterweight for the bottom bail is a fixed weight on the underside of the cardan.

The Rollers

There are two rollers, one of which fits in the slot of the bottom bail. The other fits in the slot of the top bail. These rollers are mounted on the same stationary spindle.

The rollers are geared through intermediate gears to the gyro's axle and turn in the same direction at 1/32 of the gyro's speed. Both rollers are free to revolve around the spindle, but the bottom roller is the only one free to move up and down it. The bottom roller has lugs on its upper side which mesh with lugs on the lower side of the top roller. Spring tension holds the bottom roller upward so that the lugs mesh. Thus the bottom roller turns the top roller. If the bottom roller is not held upward, the top roller does not rotate.

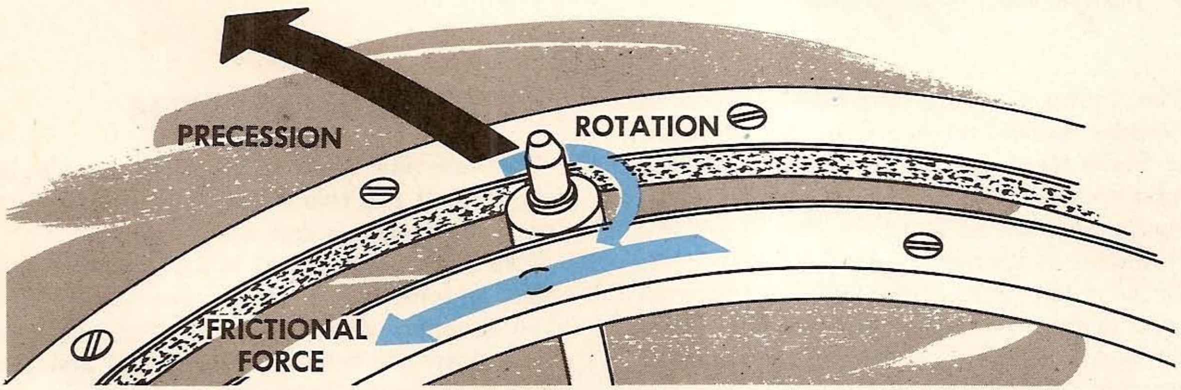


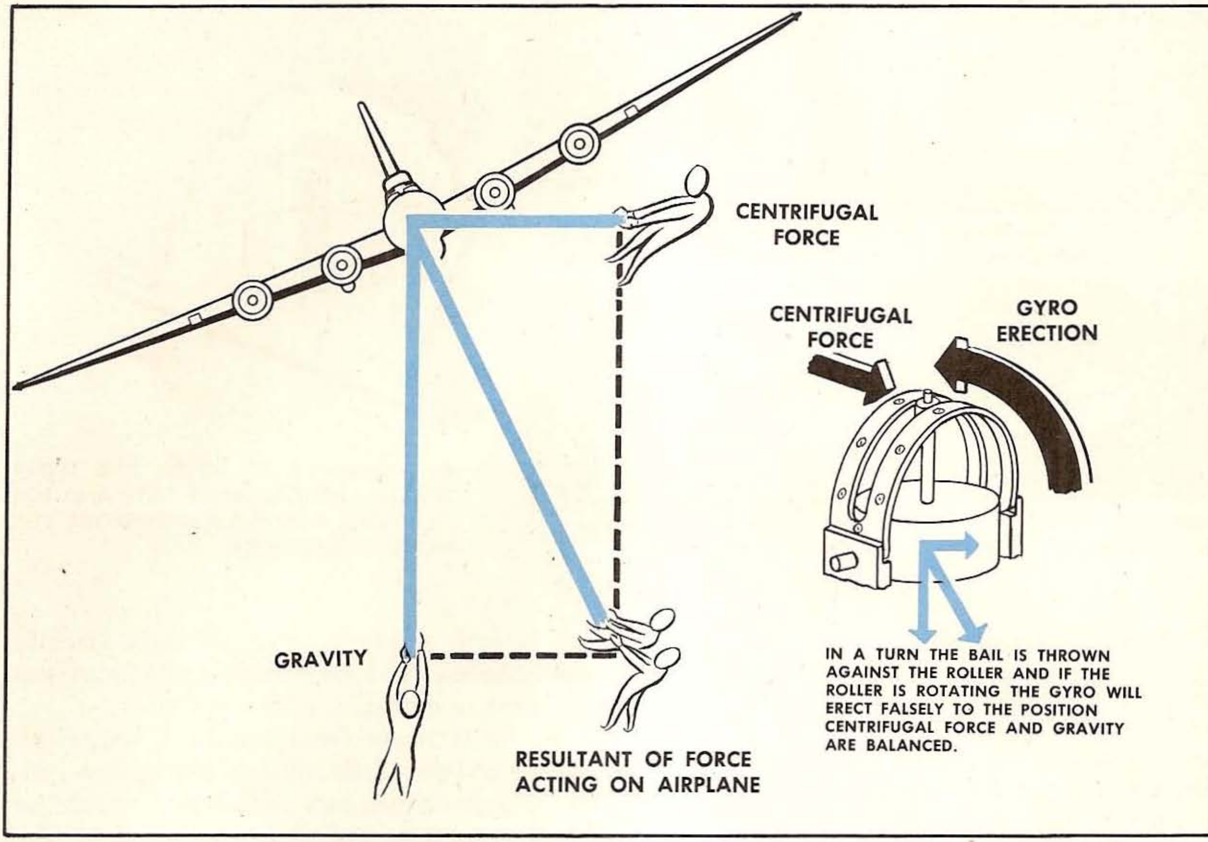
HOW THE ERECTING SYSTEM WORKS

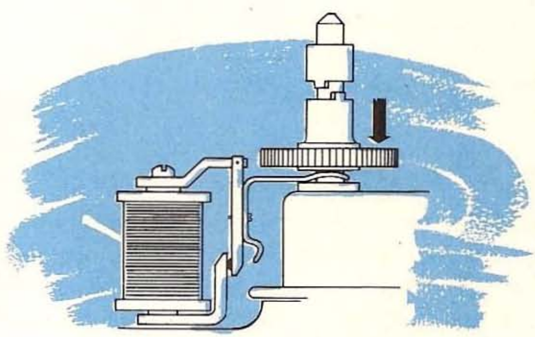
When the gyro precesses around the pitch axis, the bottom bail falls against the bottom roller.

The roller is rotating and rubs against the cork face of the bail. This produces a frictional force in the direction of the slot. As the roller is attached to the gyro, this force is applied directly to the gyro. From the law of precession, you know that the gyro is thus precessed at a right angle to the slot in the bail and back to the vertical.

The top roller and bail work in the same way when the gyro precesses about roll axis.







ERECTING CUTOUT MECHANISM

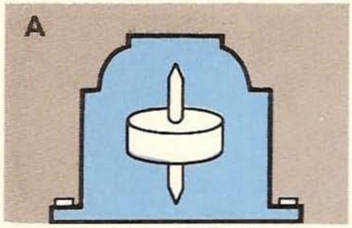
When the airplane makes a turn, centrifugal force throws the top bail against the top roller. If the top roller were rotating, it would cause the gyro to precess toward the center of the turn. This would place the gyro in a false vertical.

To keep the top roller from rotating during a planned turn, the autopilot has a device to separate the rollers by relieving the spring tension on the bottom roller, which causes the drive. This device is called the erecting cutout mechanism. Each time turns are made from the turn control or the directional panel, a switch energizes a clapper magnet. This magnet attracts an arm attached to the spring, disengaging the bottom or drive roller from the top roller. After the turn, the magnet is de-energized and spring tension again shoves the bottom roller against the top roller causing it to rotate again.

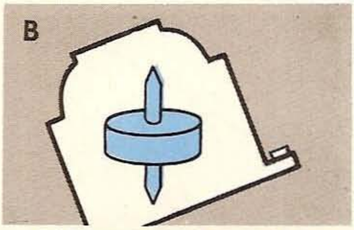
THE CONTROL MECHANISM

As the airplane rolls or pitches, the flight gyro holds its position inside the gyro housing, which is fastened to the airplane. Thus the position of the gyro, in relation to the housing, changes as often as the airplane varies from straight and level flight.

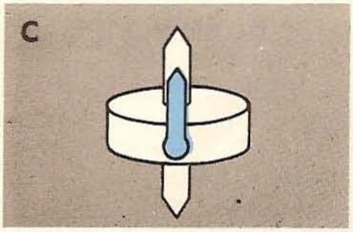
The potentiometers (pots) are attached to the inside of the gyro housing, and the wipers are attached to the gyro. Thus, when the airplane rolls or pitches, changing the relative positions of the housing and gyro, the pots move under the wipers.



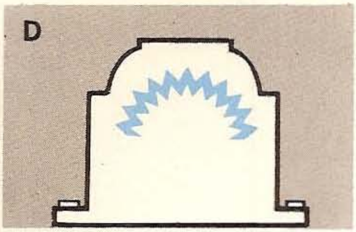
CASE IS FASTENED TO AIRPLANE



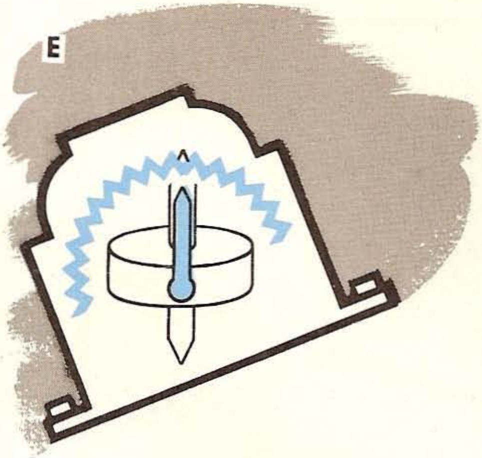
CASE TILTS WITH AIRPLANE - ROTOR REMAINS VERTICAL



WIPER IS IN FIXED POSITION IN RELATION TO ROTOR



POT IS ATTACHED TO CASE



AS AIRPLANE TILTS, ROTOR AND WIPER REMAIN VERTICAL WHILE CASE AND POT TILT WITH AIRPLANE, THEREFORE POT MOVES UNDER WIPER.

The Elevator Pickup Pot

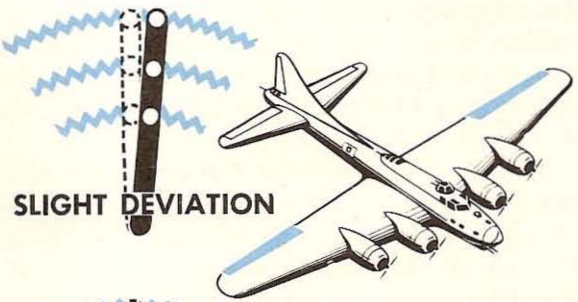
The elevator pickup pot is attached to the housing around the pitch axis. If the airplane moves around the pitch axis, the pot is moved under the wiper, which is attached to the cardan of the gyro. This causes the wiper to move from its zero position relative to the pot, unbalancing an electrical circuit and thereby signaling the autopilot to make the proper correction in the elevator control surfaces.

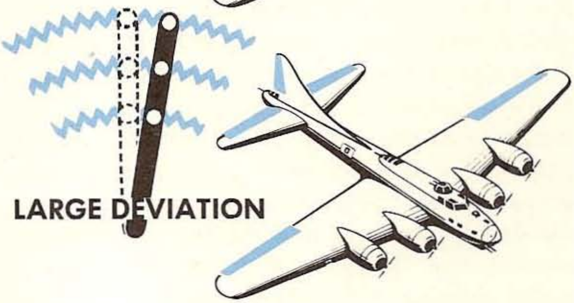
Triple Pot Assembly

Although elevator alone corrects for deviations around the pitch axis, all three control surfaces are used to correct for deviations around the roll axis. Therefore, three pots (aileron pickup, rudder compensation, and up-elevator) known as the triple pot assembly are mounted to the gyro case around the roll axis. A wiper for each pot is attached to the counterbalance guide channel and is stabilized by the flight gyro.

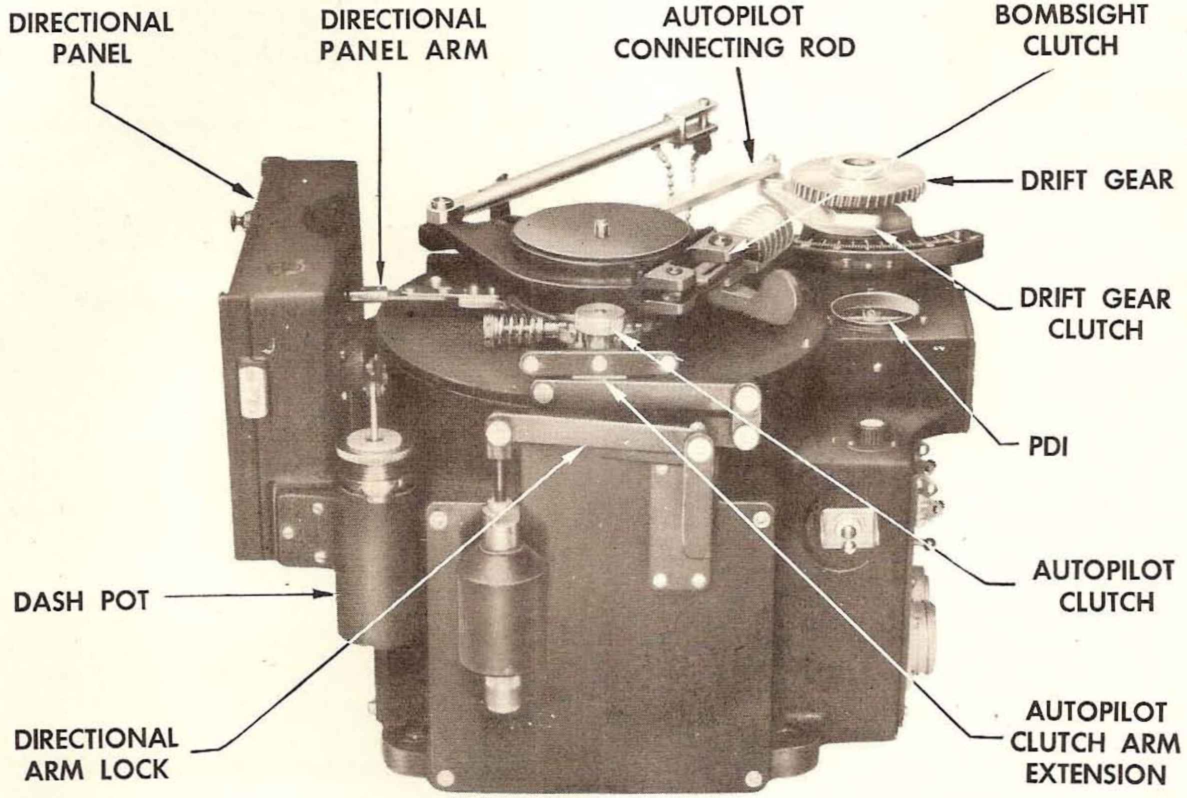
Since the pots are attached to the gyro case, any deviation of the airplane around the roll axis will move the pots under their stabilized wipers. In small deviations the aileron pot and wiper unbalances the aileron bridge circuit and causes corrective control to be driven in before the rudder and elevator circuits are unbalanced. In large deviations, however, all three pots move under their wipers to such a position that all three circuits are unbalanced, and all three control surfaces are used to correct for the deviation.

In turns made from the turn control or directional panel, the aileron pickup and rudder compensation pots and wipers unbalance their respective circuits so as to drive the controls to a streamlined position as the airplane approaches the desired degree of bank. The up-elevator pot and wiper unbalance the elevator bridge circuit and drive in up-elevator so that the airplane will not lose altitude during the turn.





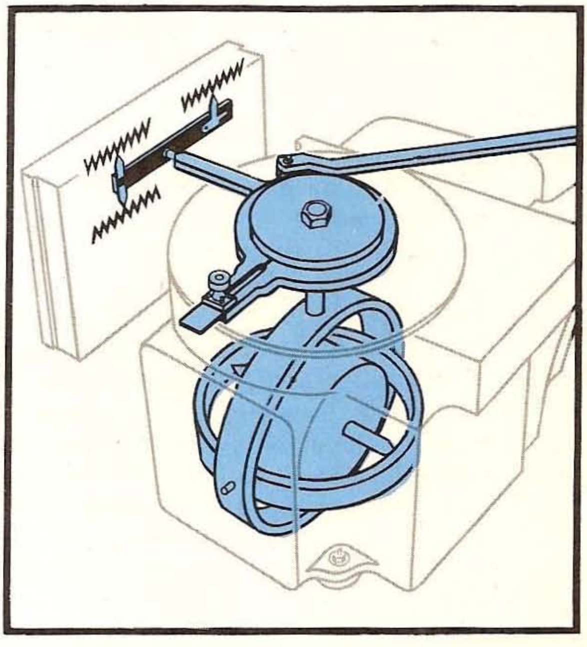
Directional Gyro
AND DIRECTIONAL PANEL

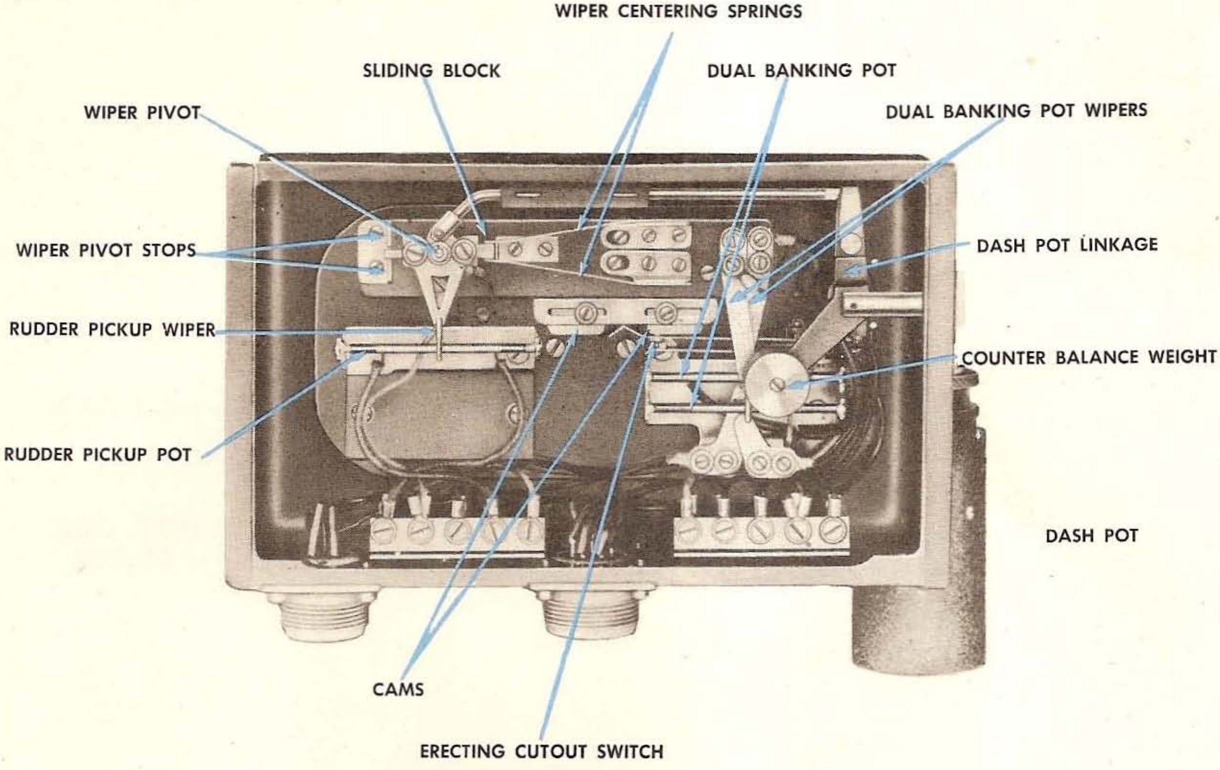


The directional gyro in the bombsight stabilizer gives the autopilot stabilization in yaw. This stabilization is brought about through a potentiometer system similar to the systems on the flight gyro.

The directional gyro stabilizes the autopilot clutch mechanism when the autopilot clutch is engaged. Since the wipers are linked to the clutch, they are also stabilized. The pots are mounted inside the housing of the directional panel, which is attached to the side of the stabilizer.

When the airplane deviates around the yaw axis, the directional gyro and the wipers hold the same position in space while the pots, being mounted on the directional panel housing, move under the wipers. There are two pots mounted in the directional panel. One is the rudder pickup pot and the other is the dual banking pot.



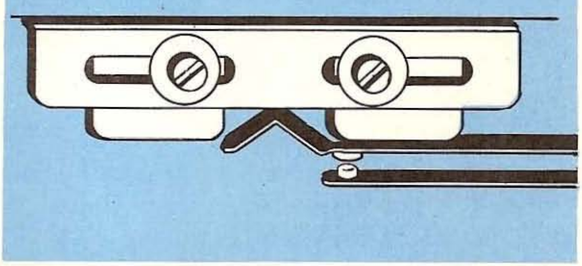


The autopilot clutch is connected to the directional panel by the directional panel arm. The directional panel arm is connected to a sliding block. Attached to the sliding block are three wipers, one for the rudder pickup pot and two for the dual banking pot. Since the wipers are stabilized by the directional gyro, any movement of the airplane around the yaw axis will move the pots under the wipers.

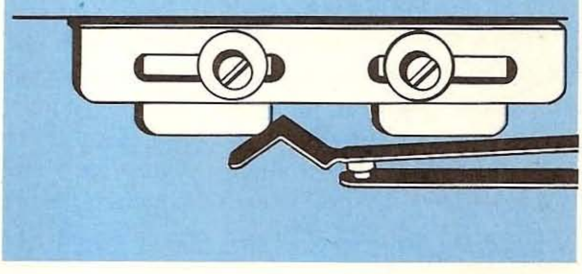
Although the rudder control surface is the main control used for corrections in yaw, the aileron control surface is also used to make the correction smooth. Therefore, for aileron control, the dual banking pot wipers are mounted to the block.

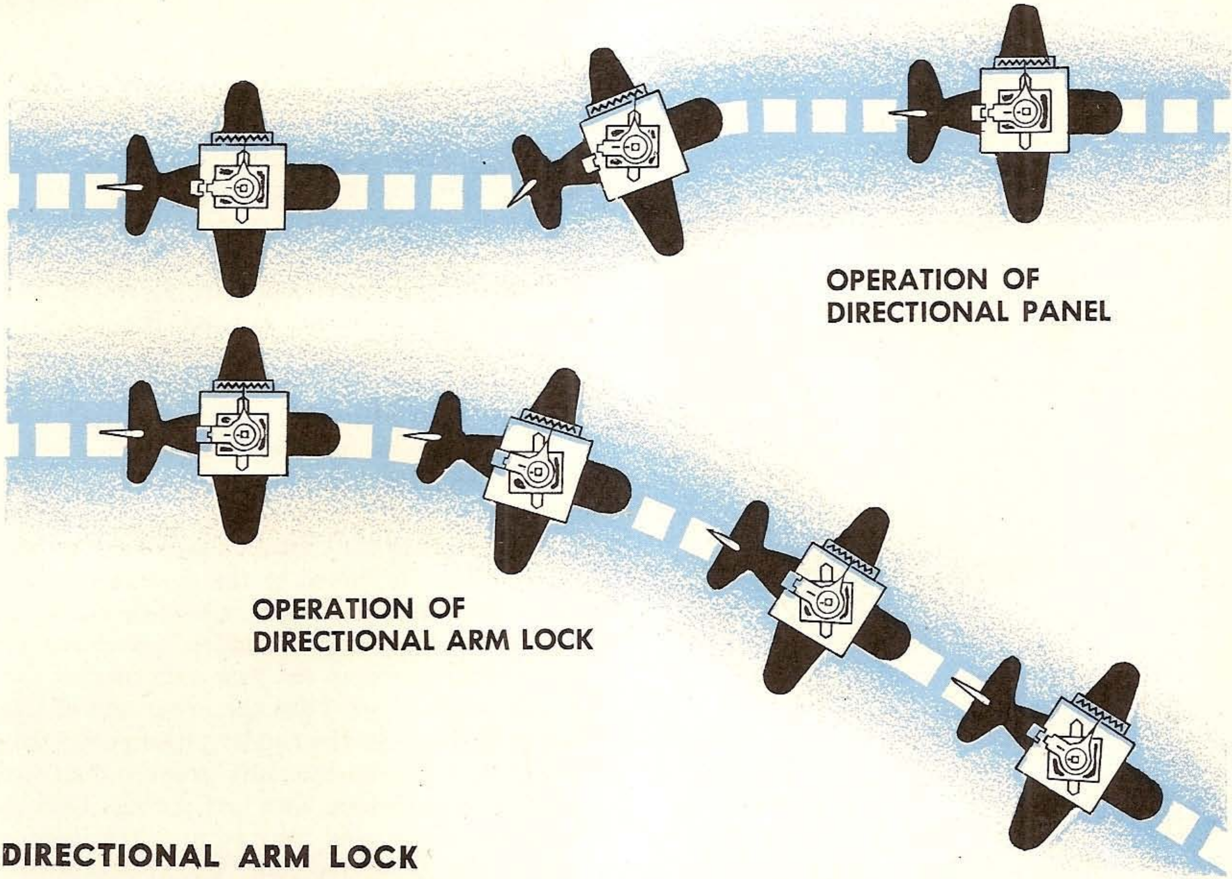
Fastened to the directional panel directly above the dual banking pot is a spring leaf switch which is operated by cams attached to the sliding block. These cams are so spaced that whenever the slide is moved one-eighth inch or more in either direction from center the switch is closed and the erecting cutout mechanism is energized. This prevents the gyro from precessing out of the vertical during a turn.

ERECTING CUTOUT SWITCH OPEN



ERECTING CUTOUT SWITCH CLOSED





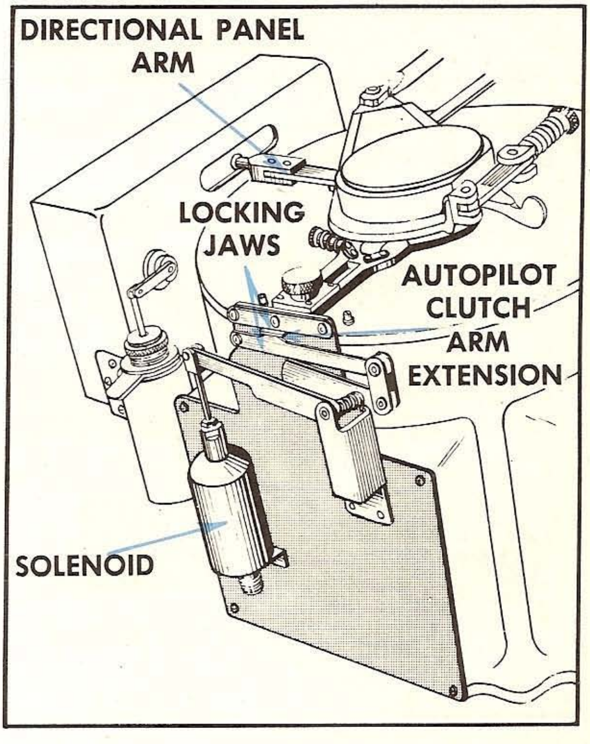
OPERATION OF DIRECTIONAL PANEL

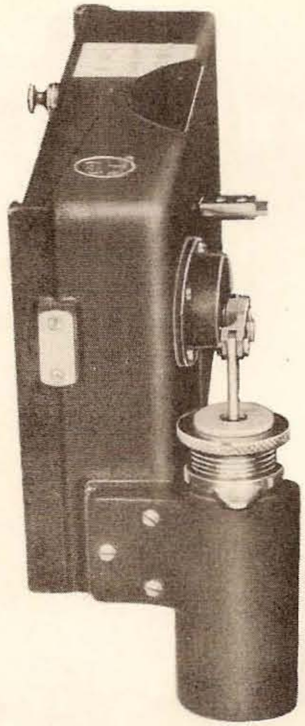
OPERATION OF DIRECTIONAL ARM LOCK

DIRECTIONAL ARM LOCK

Suppose you want to turn the airplane with the turn control knob. The directional panel arm mechanism, if it were free to move, would produce a signal which would cancel out part or all of the turn control signal. Therefore, the autopilot has an electro-magnetic device, the directional arm lock, which locks the directional panel arm mechanism during a turn control turn. It is mounted to the stabilizer and locks the autopilot clutch and directional panel arm in a fixed position.

When the turn control knob is turned it closes a switch. This switch completes a circuit to a solenoid which pulls the strong locking jaws of the pivoted directional arm lock down over the extension of the autopilot clutch arm. With the autopilot clutch arm thus locked to the stabilizer case, the autopilot clutch slips as the airplane turns, since the gyro holds its position. As soon as the turn control knob is turned back to its center position, the solenoid is de-energized and the autopilot clutch arm and autopilot clutch are released. The gyro will then stabilize the airplane on the new heading.





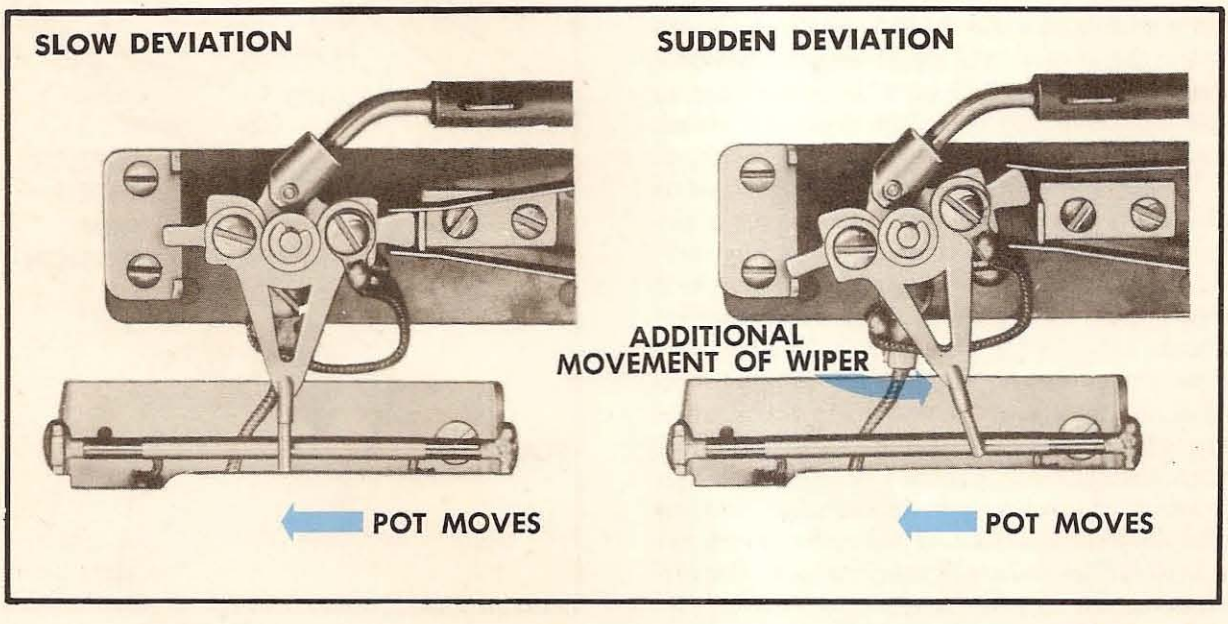
DASH POT

The dashpot is linked to the rudder pickup pot wiper in the directional panel in such a way that it produces an extra initial rudder correction signal proportional to the speed of turn axis deviation. It consists of a piston, working in an oil-filled cylinder, which is connected through linkage to the rudder pickup pot wiper.

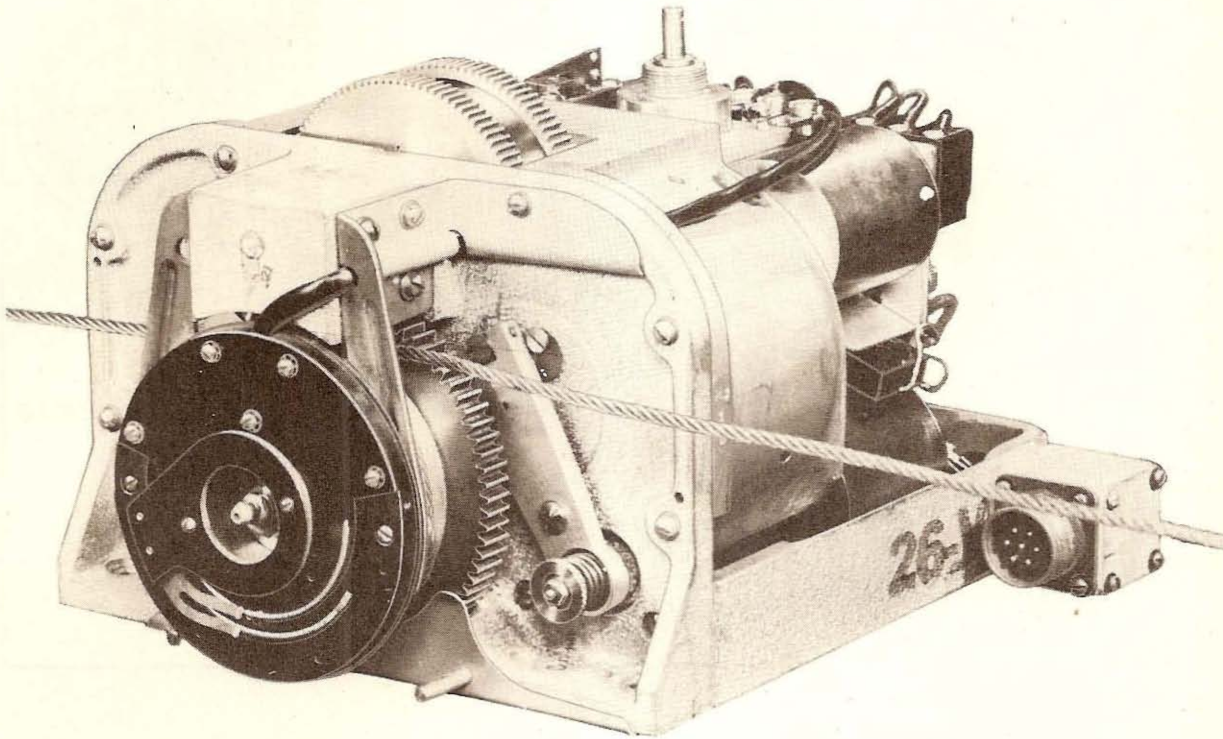
The oil resists any movements of the piston. The cylinder may be adjusted and locked to regulate the piston's ease of movement. This adjustment governs the size of an opening through which the oil flows at the bottom of the cylinder. When you screw the cylinder up, you increase the size of the opening, thus decreasing the resistance encountered by the piston when it moves against the oil. The rudder pickup wiper is affected by the dashpot in proportion to the abruptness of the airplane's deviation.

To understand how this affects the rudder pickup wiper, you must know how the wiper is mounted. It is mounted by a pivot on the sliding block of the directional panel. The top of the wiper is linked to the dashpot piston. Since the top of the wiper is held by the linkage to the piston, any sudden movement of the airplane around the yaw axis rotates the wiper on its pivot. Thus the lower end of the wiper moves over the rudder pickup pot a distance that is proportionally greater than the airplane's deviation. Two leaf springs tend to hold the wiper, and they return it to center after they have overcome the resistance of the oil to the piston.

In slow deviations, the springs are strong enough to overcome the restraining effects of the dashpot. Thus the movements of the wiper and slide are the same.



Servo Units



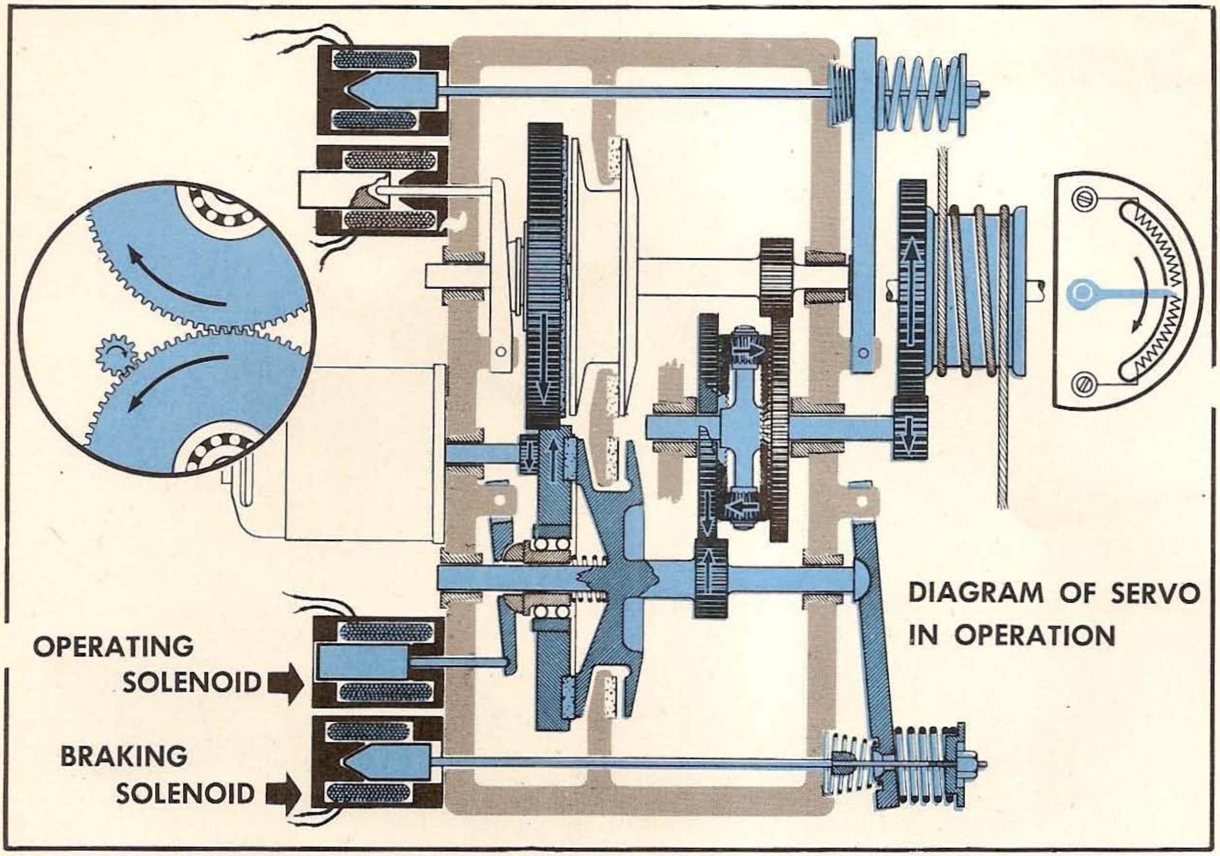
The servo units of the autopilot supply the mechanical force necessary to move the control surfaces of the airplane. There are three servo units—one for each of the airplane's control surfaces. The units are identical and are connected to the control surfaces by flexible steel cables. These cables fit on cable drums which are part of the servo units.

The servos in the autopilot are very similar to the torque unit of the stabilizer. An electric motor drives the cable drum through a system of gears and clutches. When the autopilot is in operation, the motor runs continuously and drives two gears. The gears operate freely on separate shafts, and turn in opposite directions. For each gear there is a clutch which engages the motor to the cable drum. To operate each clutch there is an operating solenoid, energized by a relay in the amplifier. The relays are operated by signals from a discriminator tube in the amplifier.

The direction the servo drives the control surfaces is determined by the discriminator tube which closes one of the relays. When one of the relays is closed, its respective operating solenoid is energized, engaging the corresponding clutch to one of the rotating gears. Thus the motor is engaged to the cable drum and the control surface is moved.

If the other relay had been closed, the other operating solenoid would have been energized and its clutch would have been engaged to the other rotating gear. This would have made the control surface move in the opposite direction.

Into whatever position the control surface is moved, it is locked there by two braking solenoids in the servos. It remains locked in that position until the controls are moved again.

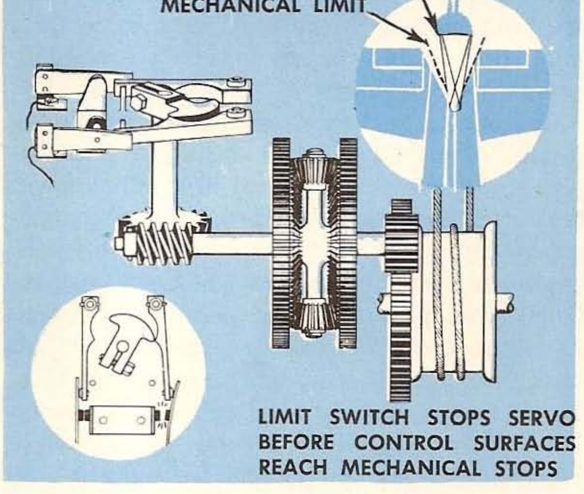


A **balance pot** is attached to each of the servos. A wiper for each of the balance pots is attached to the cable drum and moves over the pot as the cable drum turns. Through this pot and wiper the original signal is gradually balanced out as the proper amount of control is driven in.

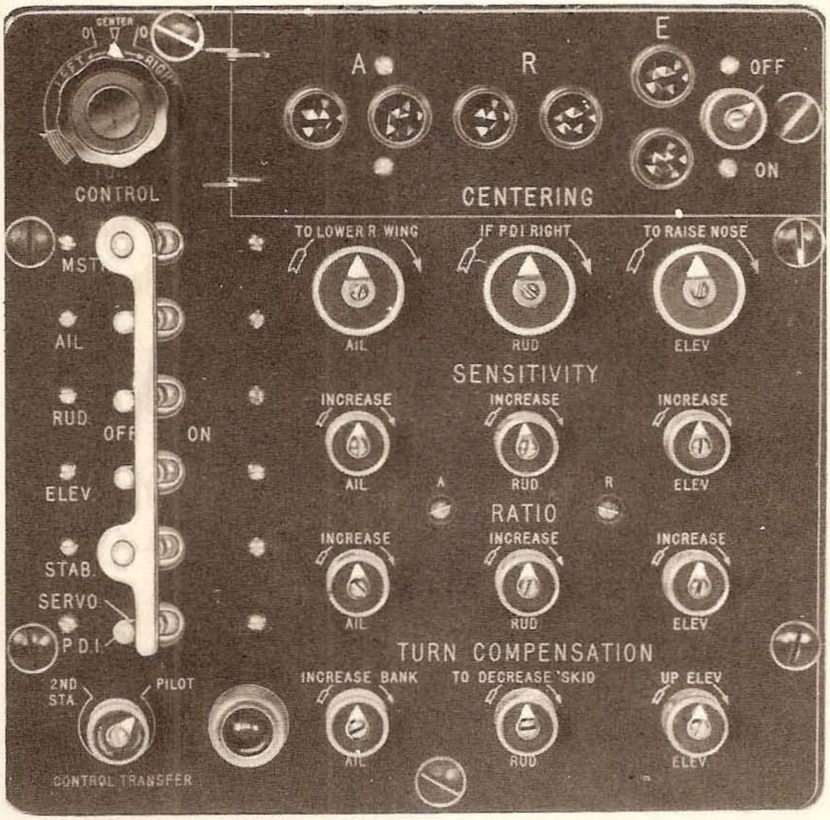
When the bridge circuit is completely balanced the operating solenoid is de-energized. This disengages the clutch, stopping the drive to the controls. The controls are locked in this position by the two braking solenoids until the circuit is again unbalanced.

A limit switch is incorporated in each of the servo units, as a safety factor, to prevent the servos from driving and jamming the control surfaces against their stops. When the switch is closed, either operating solenoid can be energized. A cam, geared to the cable drum, opens the limit switch as the control surfaces are driven near their stops. This breaks the circuit to the energized solenoid and stops the servos' drive.

Another safety factor of the autopilot is found in the construction of the servo unit. It is built in such a way that the pilot can overpower the servos and manually control the airplane while the autopilot is engaged.



The Autopilot Control Panel



The autopilot control panel (ACP) is a box on which are mounted the switches, lights and knobs used to operate and adjust the autopilot.

The switches are on the left side of the box. They are:

1. The master switch (MSTR) which completes the electrical circuit to the rotary inverter, the servo motors, the amplifier, and the flight gyro.
2. The stabilizer switch (STAB), which completes the circuit to the directional gyro of the bombsight stabilizer.
3. The servo-PDI switch (SERVO-PDI), which completes the circuit to the torque unit of the bombsight stabilizer and the pilot director indicator.
4. The aileron engaging switch (AIL).
5. The rudder engaging switch (RUD).
6. The elevator engaging switch (ELEV).

These last three switches complete the circuits to the braking solenoids of their corresponding servos, thereby engaging the autopilot to the airplane's control surfaces.

The master and stabilizer switches are operated simultaneously by the master bar, which makes it impossible to engage one switch without engaging the other.

The aileron, rudder, elevator, and servo switches can be turned on or off individually. But when they are on, their levers rest against the master bar. Thus it is possible, by throwing the master bar, to disengage all of the switches simultaneously. This throws the autopilot entirely out of operation and returns the airplane to the pilot's control. Thus this use of the master bar is one of the safety factors of the autopilot.

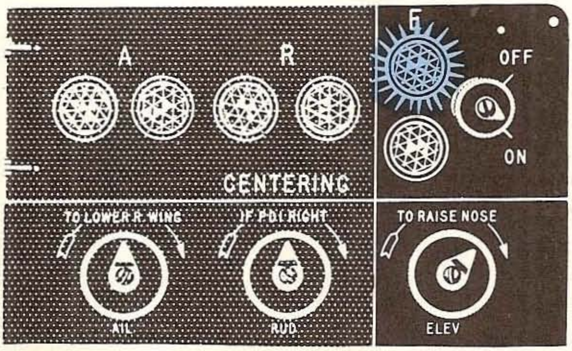
The ACP is divided into three vertical rows of knobs and lights. Each of the vertical rows has two tell-tale lights and four knobs which are used to adjust the autopilot control around each of the axes. The three rows, from left to right, control the aileron, rudder, and elevator, respectively.

The uppermost knobs of each row are the **centering knobs.** You use these knobs to establish an electrical trim which will coincide with the mechanical trim of the airplane, before engaging the autopilot. The pilot mechanically trims the airplane and then adjusts the centering knobs so as to align the electric trim with the mechanical trim. The centering knobs are, in effect, electrical trim tabs.

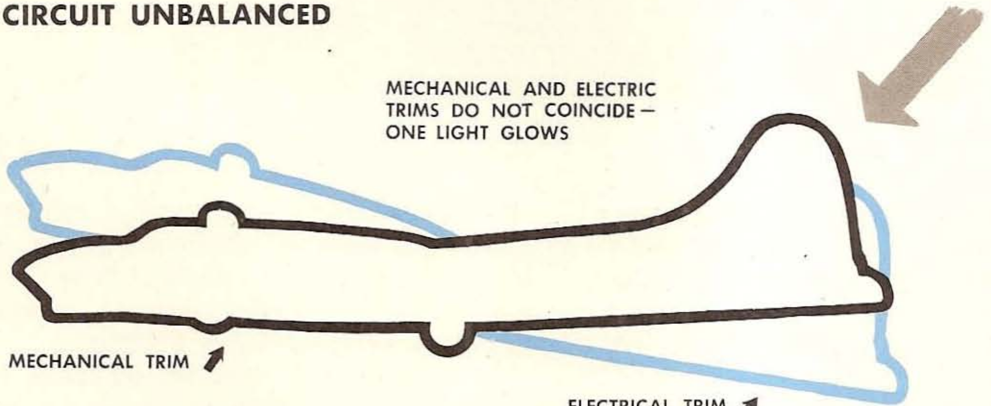
Directly above the centering knobs are three pairs of lights, a pair for each axis. These are the tell-tale lights that are used in conjunction with the centering knobs to align the electric and mechanical trims. When the electric and mechanical trims do not coincide, the circuit is unbalanced and causes one of the tell-tale lights to glow. The intensity of the tell-tale lights can be regulated from a complete blackout to a maximum brilliance by the tell-tale lights switch, which is located in the upper right hand corner of the ACP.

After the airplane is trimmed mechanically, you turn the centering knob until both tell-tale lights are out. This means that the mechanical and electric trims now coincide. Now you engage the aileron engaging switch. This operation is the same for each of the control surfaces.

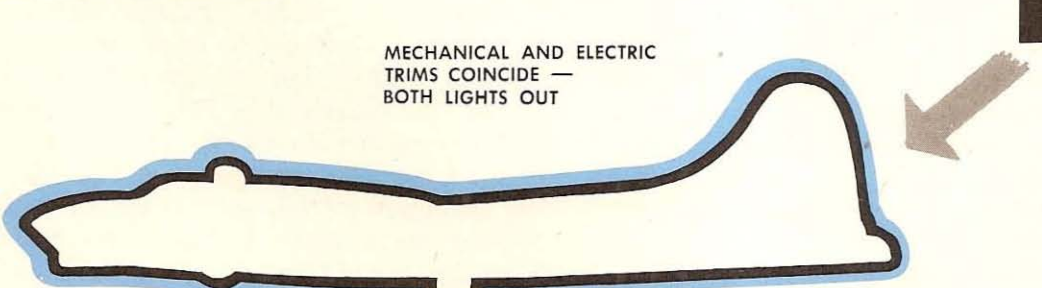
Any deviation of the airplane will cause the servos to move the controls and bring the airplane back to the position of electrical trim.



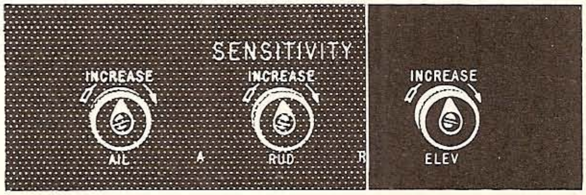
CIRCUIT UNBALANCED



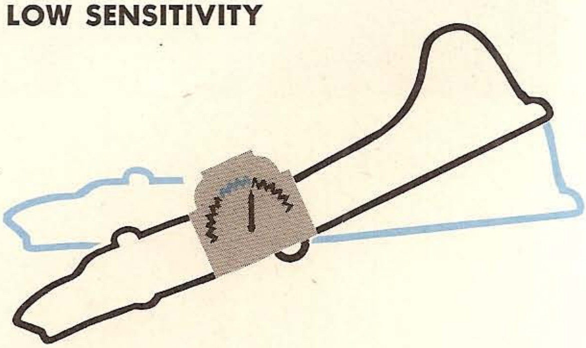
CIRCUIT BALANCED



Immediately below the centering knobs are the **sensitivity knobs,** one for each axis. These knobs regulate the extent of deviation permitted before the autopilot will move the controls to correct for it. This is done by adjusting the intensity of an electric signal which opposes the signal sent to the amplifier. Therefore, with a low sensitivity setting, the airplane has to deviate farther before a signal large enough to overcome the opposing current passes through the amplifier and operates the servo.

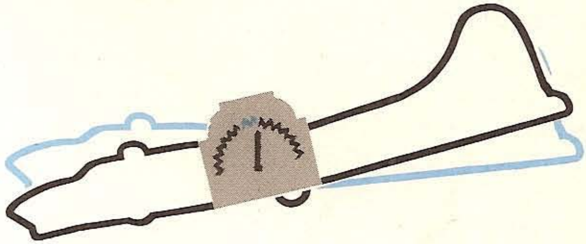


LOW SENSITIVITY



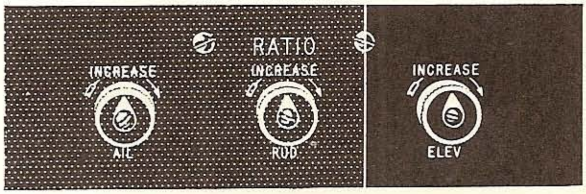
LARGE DEVIATION NECESSARY FOR CORRECTIVE SIGNAL TO BE EFFECTIVE

HIGH SENSITIVITY

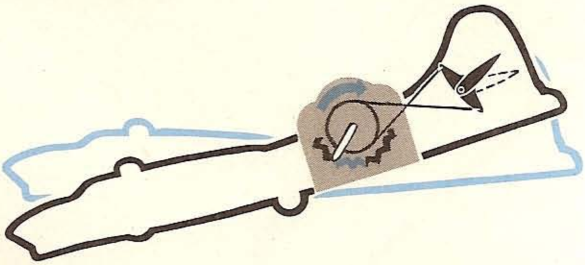


SMALL DEVIATION CAUSES CORRECTIVE SIGNAL

The **ratio knobs** are directly beneath the sensitivity knobs. You use them to regulate the amount the autopilot will move the control surfaces for any given deviation of the airplane. This is done by adjusting the voltage drop of the balance pot, thus determining how far the servo must drive to balance out the original signal.

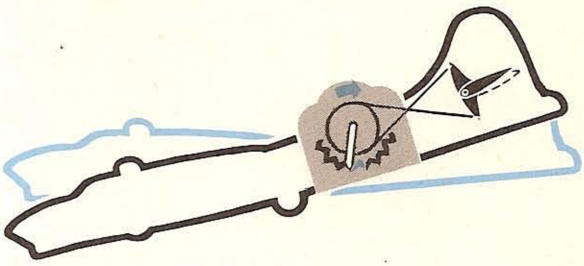


HIGH RATIO



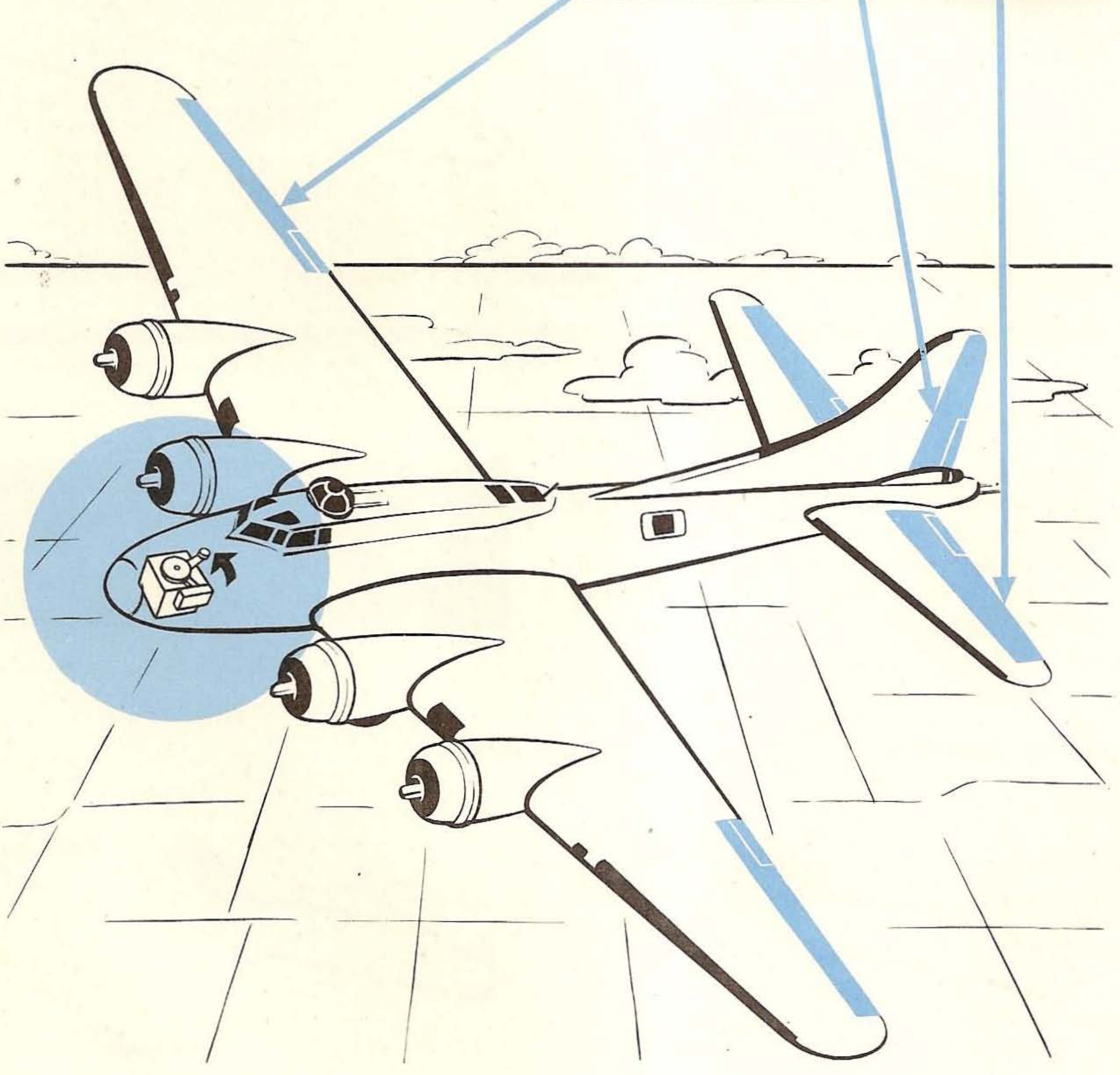
LARGE MOVEMENT OF CONTROL SURFACES

LOW RATIO

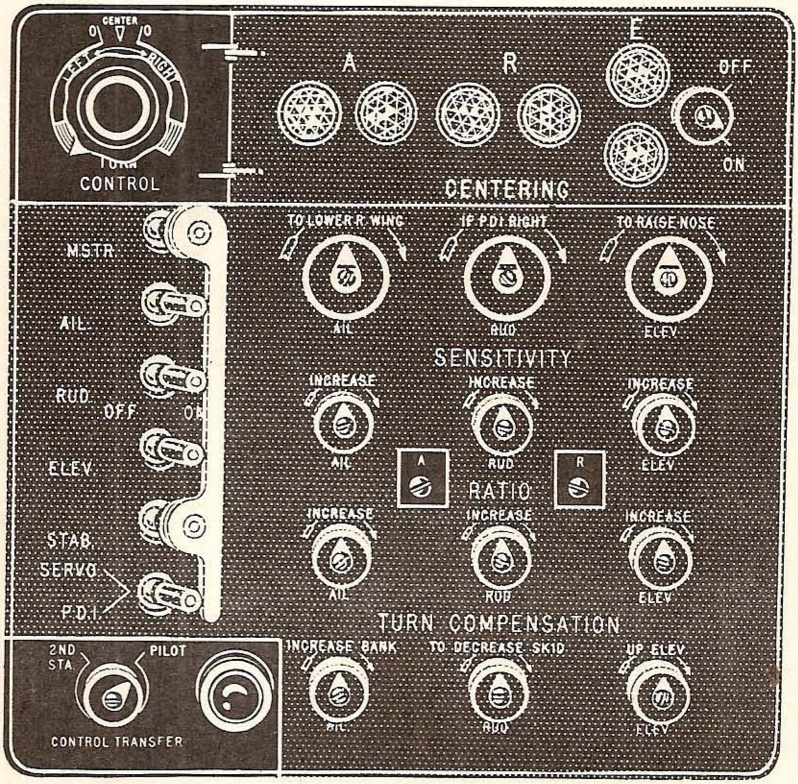


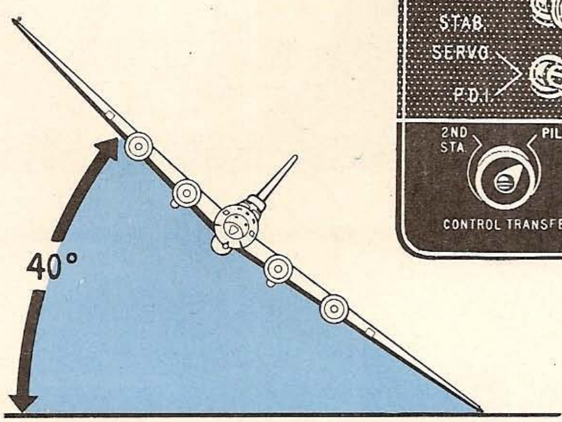
SMALL MOVEMENT OF CONTROL SURFACES

The bottom knobs in each row are the **compensation knobs.** These knobs are used to obtain a coordinated turn from the directional panel. This is done by adjusting the intensity of the signal from the various pots. The aileron compensation knob determines the degree of bank obtained from the dual banking pot. The rudder compensation knob determines the amount of rudder to be used in a turn, so that the airplane will not skid or slip. The elevator compensation knob regulates the amount of **up**-elevator to be used in a turn so that the airplane will neither gain nor lose altitude. This knob also regulates the amount of **up**-elevator used in a turn from the turn control.



Turn Control





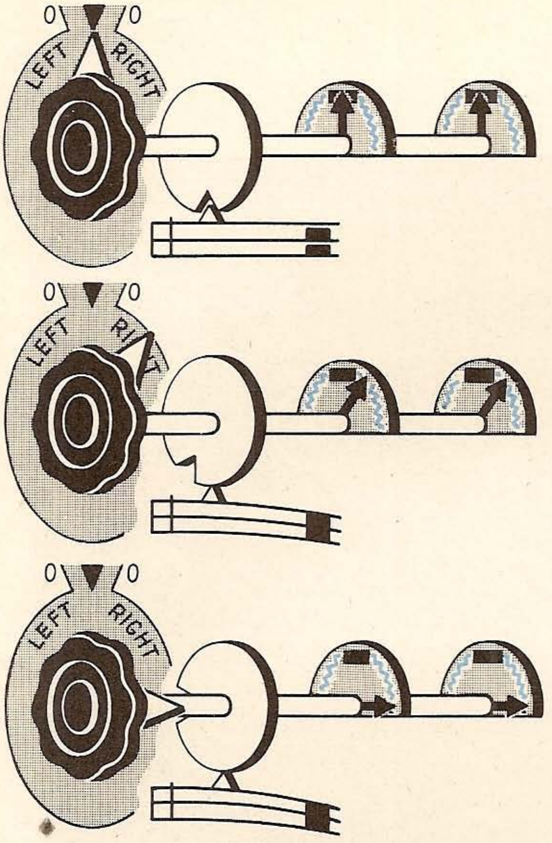
The turn control in the upper left-hand corner of the ACP makes it possible to turn the airplane when it is under the control of the autopilot. Using the turn control you can make a coordinated turn with any amount of bank up to 40°. In newer airplanes there are also remote turn controls for the bombardier and navigator.

The turn control consists of the aileron control pot, the rudder control pot, and their wipers.

When you turn the knob, the wipers are displaced on the pots, thus unbalancing the aileron and rudder bridge circuits and causing the servos to move the controls. Also, as you turn the turn control knob off the center position, it closes a cam switch which energizes the directional arm lock on the stabilizer and the erecting cutout mechanism on the flight gyro.

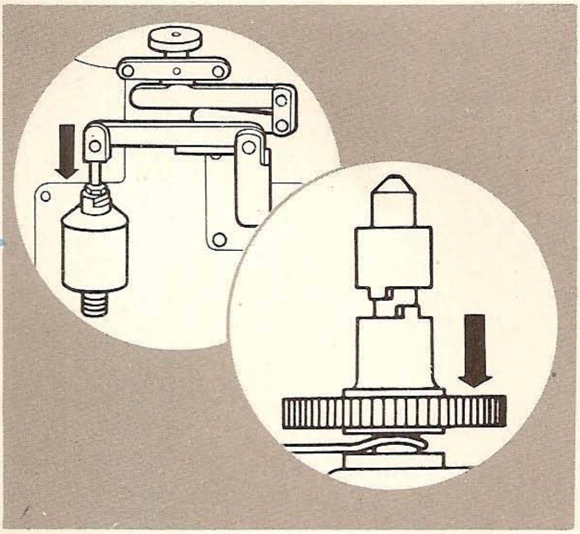
The center position of the turn control is between the two zero marks. When you rotate the knob to zero after a turn, you feel a small "hump" in the otherwise smooth rotation of the knob. This "hump" warns you to let the airplane return to straight and level flight before you center the knob to open the cam switch.

When you turn the knob to either of the 30° marks, you feel a small "hump" similar to those at the zero positions. The "hump" at the 30° positions warns you that the air-

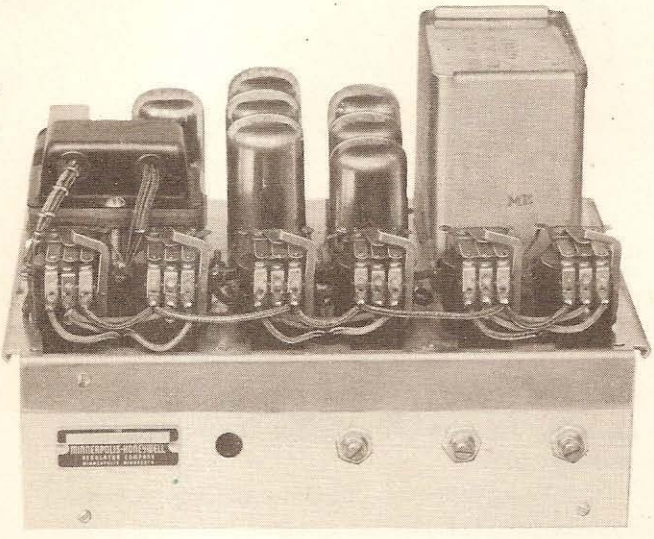


plane is nearing the maximum 40° bank.

The complete turn control unit includes the aileron and rudder turn control trimmers near the center of the ACP and the remote control transfer with its indicator light in the lower left hand corner of the ACP. The turn control trimmers are adjusted to obtain a coordinated bank and turn when the turn control is used.



The Amplifier



The main purpose of the amplifier is to magnify the signals from the various bridge circuits. It also controls and determines the direction in which the servos move the control surfaces of the airplane.

It has seven tubes and six relays. There is one rectifier tube which changes alternating current to direct current for the other tubes.

There are three amplifier tubes — one for each control surface. These tubes magnify the incoming signals.

The other three are discriminator tubes—

one for each control surface. These tubes analyze the incoming signals and determine in which direction the control surfaces must be driven. Each of the discriminator tubes operates a pair of relays which, in turn, controls the operation of one of the three servo units.

A relay is merely an electrically controlled switch. When closed, the relay completes a circuit to an operating solenoid. The solenoid, in turn, engages one of the servo clutches.

For instance, as the airplane deviates around the pitch axis, the elevator pickup pot moves under the wiper. This unbalances the elevator bridge circuit and a signal is sent to the amplifier. This signal is amplified and sent to the discriminator tube, which analyzes it and closes the proper relay. This energizes the proper operating solenoid, which engages the corresponding servo clutch. This moves the elevator control surface and returns the airplane to level flight.

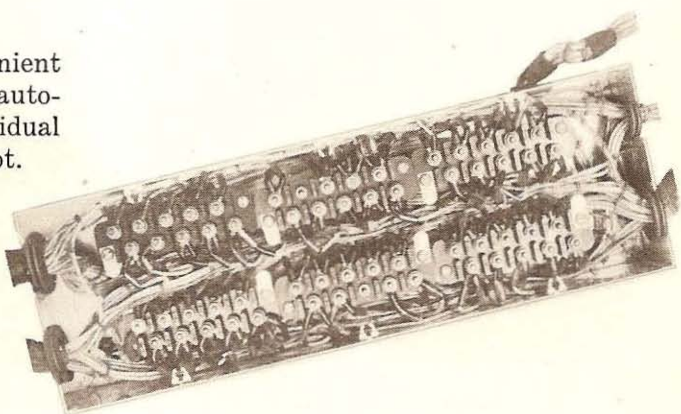
One relay completes the circuit to the clutch which moves the elevator up and the other to the clutch which moves the elevator down.

Rotary Inverter

The rotary inverter, a generator operating on a 26-volt direct current, provides an alternating current of 19 volts, 105 cycles, necessary for the operation of the autopilot.

Junction Box

The junction box provides a convenient place to connect the various units of the autopilot. It is also useful in making an individual check on each of the units in the autopilot.



THE COMPLETE SYSTEM

DEVIATION

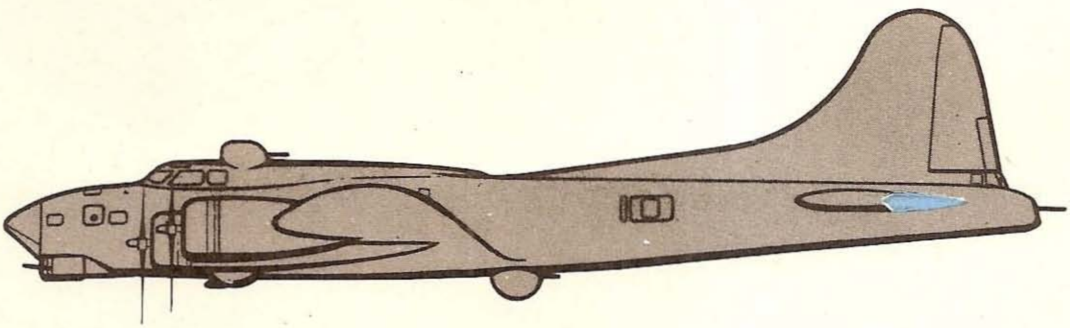
Suppose a sudden gust of wind throws the airplane nose upward. Since the elevator pickup wiper is stabilized by the flight gyro and the elevator pickup pot is attached to the gyro case, the pot is moved under the wiper. This unbalances the elevator bridge circuit and a signal is sent to the elevator amplifier tube.

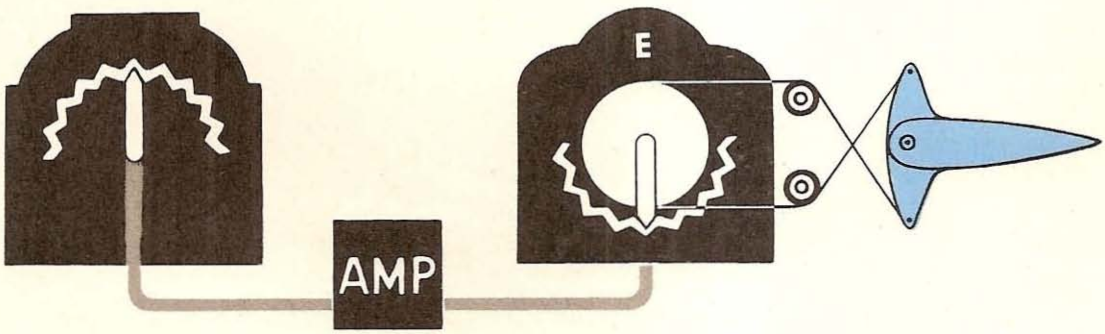
This tube amplifies the signal and sends it to the elevator discriminator tube, which analyzes the signal and determines which relay is to be closed. A signal from the discriminator tube closes the down elevator relay. When the relay is closed, it completes a circuit to the operating solenoid in the servo unit. The solenoid engages its clutch, linking the servo motor to the cable drum. This causes the cable drum to turn, moving the elevator surfaces down.

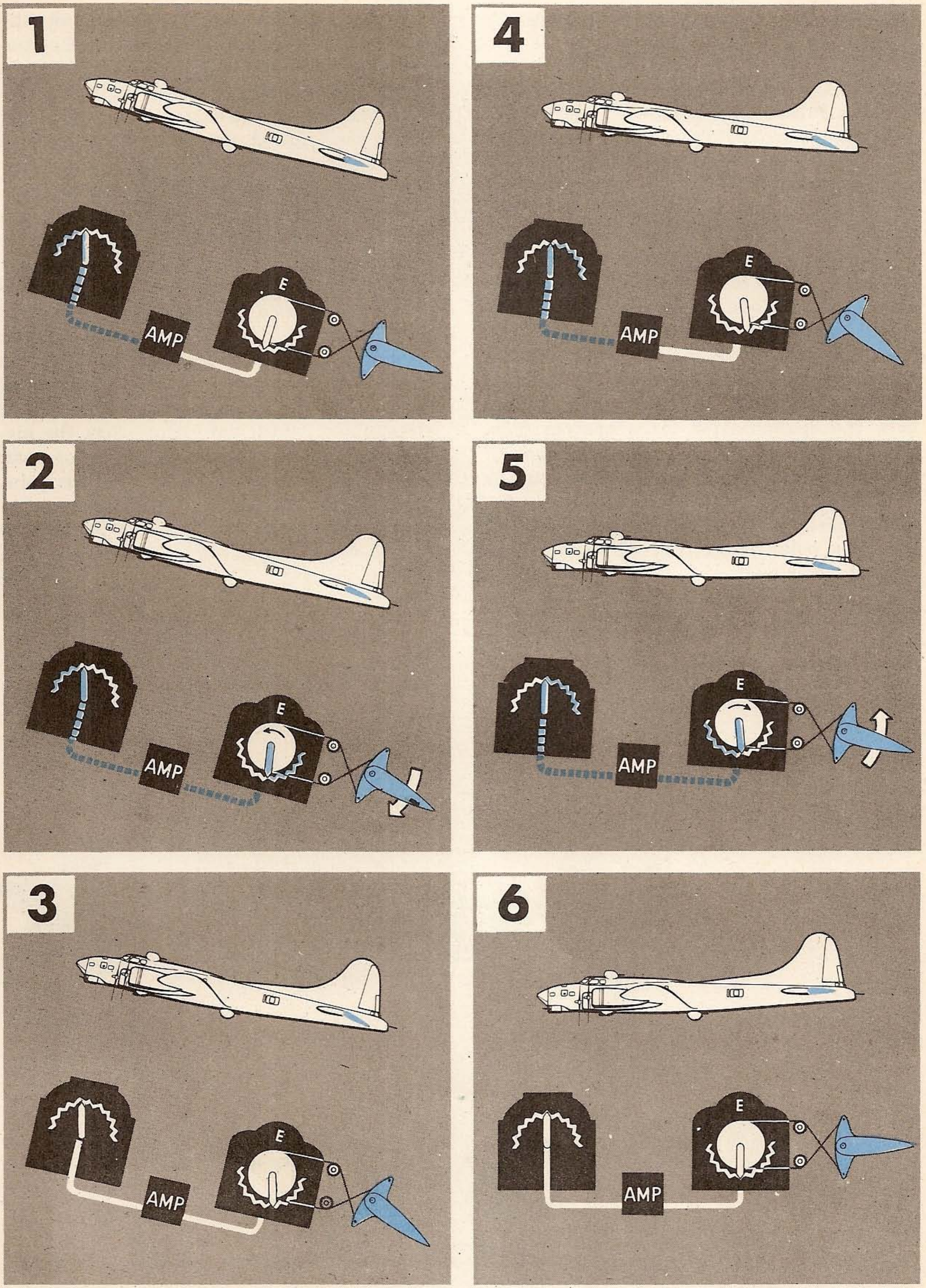
As the cable drum turns, the balance wiper moves over the balance pot in the servo unit and **begins** to balance out the original signal. When the original signal is completely balanced out the servo stops driving, but the elevator control already driven in remains in use.

As the airplane begins to return to level flight, the elevator pickup pot is again moved under its wiper but in the opposite direction. This creates an opposite signal and the elevator control surfaces are moved up as the airplane approaches level flight, thus preventing over-control.

Remember that this entire sequence of action is almost simultaneous. The autopilot functions in a similar manner for deviations about the roll and turn axes. When necessary, all three controls—aileron, rudder, and elevator—will function at the same time.



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INTENTIONAL BANK AND RECOVERY USING THE TURN CONTROL

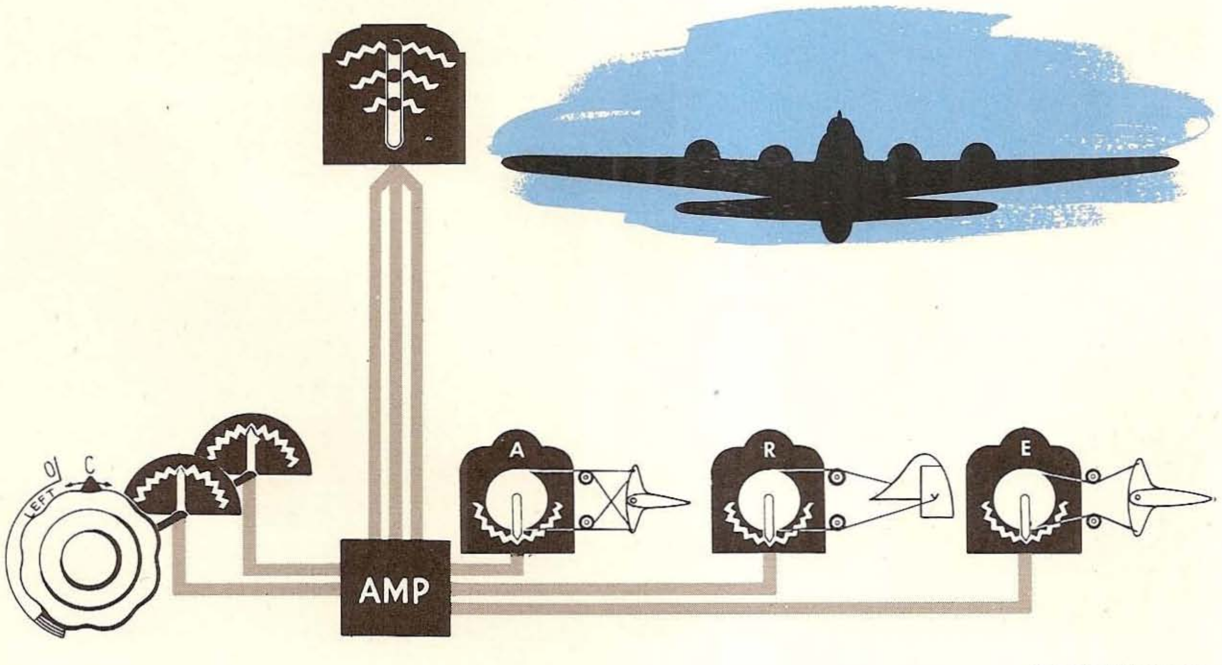
When you use the turn control to turn the airplane, it does two things:

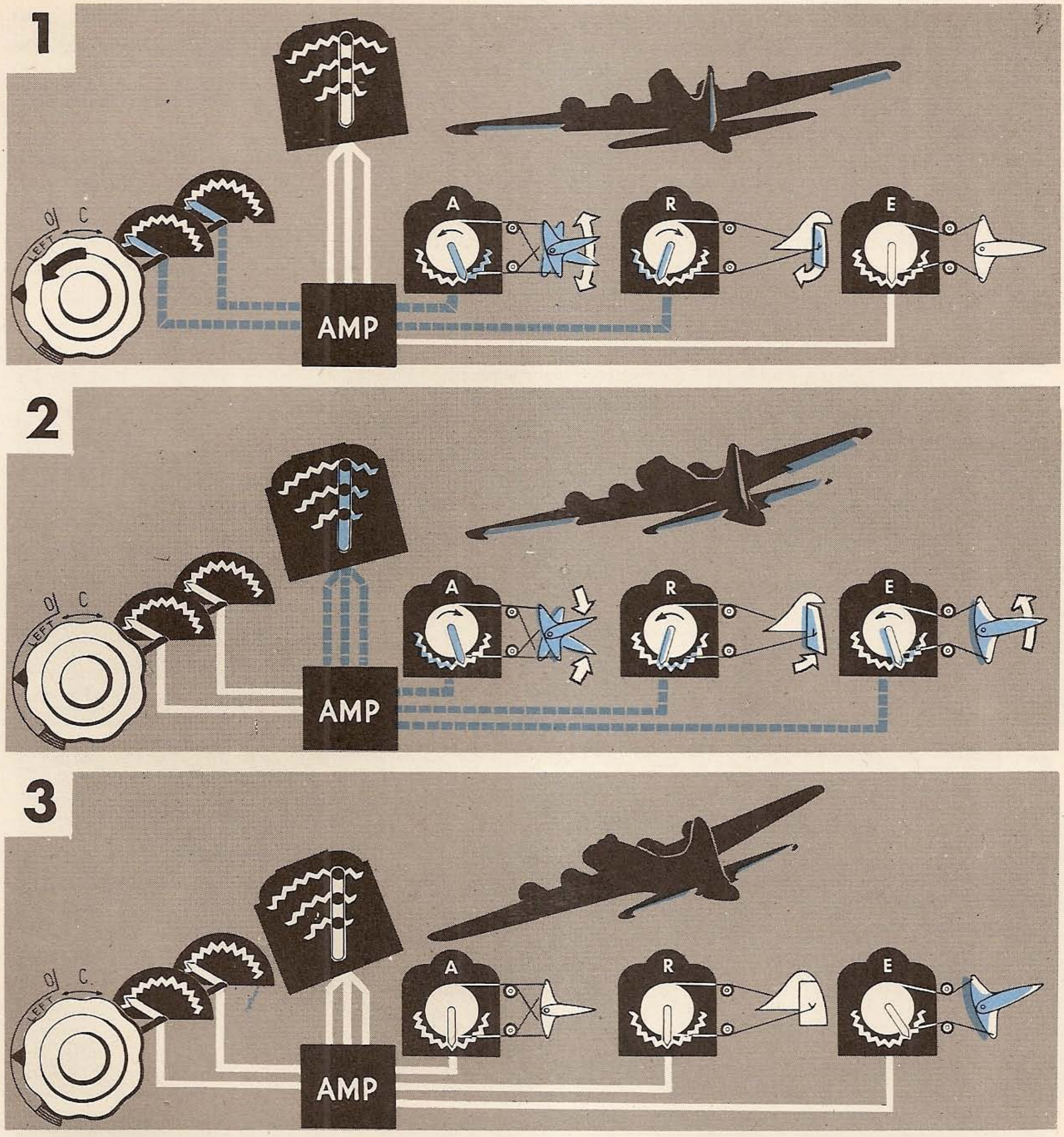
1. As you move it from center to zero, the cam switch is closed and the erecting cutout and directional arm lock are operated. Thus the autopilot clutch is locked and the bottom roller is disengaged from the top roller.

2. When you turn the turn control knob past zero, wipers connected to the knob move over the aileron and rudder control pots. This unbalances the aileron and rudder bridge circuits and thus sends signals to the aileron and rudder amplifier tubes.

After the amplifier tubes magnify the signals, the discriminator tubes analyze them and energize the proper solenoid in each of the two servos. The servos move the controls to bring the airplane into the turn, and at the same time displace the balance pot wipers out toward a point where they will balance the turn control signal.

As the airplane goes into the bank, the aileron pickup pot and the rudder compensation pot on the flight gyro case are displaced under their stabilized wipers. This displacement plus that of the balance pot wipers soon equals the original displacement of the turn control wipers, thus canceling the turn control signals and causing the servos to stop. However, the airplane controls are now in a position to cause the airplane to increase its bank. As it does so, the gyro pots are farther displaced under their wipers, causing a new signal opposite to the original turn control signal. This causes the controls to be driven back toward streamlined position. But the airplane continues to increase its degree of bank until the controls are completely streamlined, which will occur when the airplane reaches the maximum degree of bank called for by the turn control. At this point the displacements of the gyro pots are equal to those of the turn control, and the balance pots show no displacement. The servos then cease to operate.



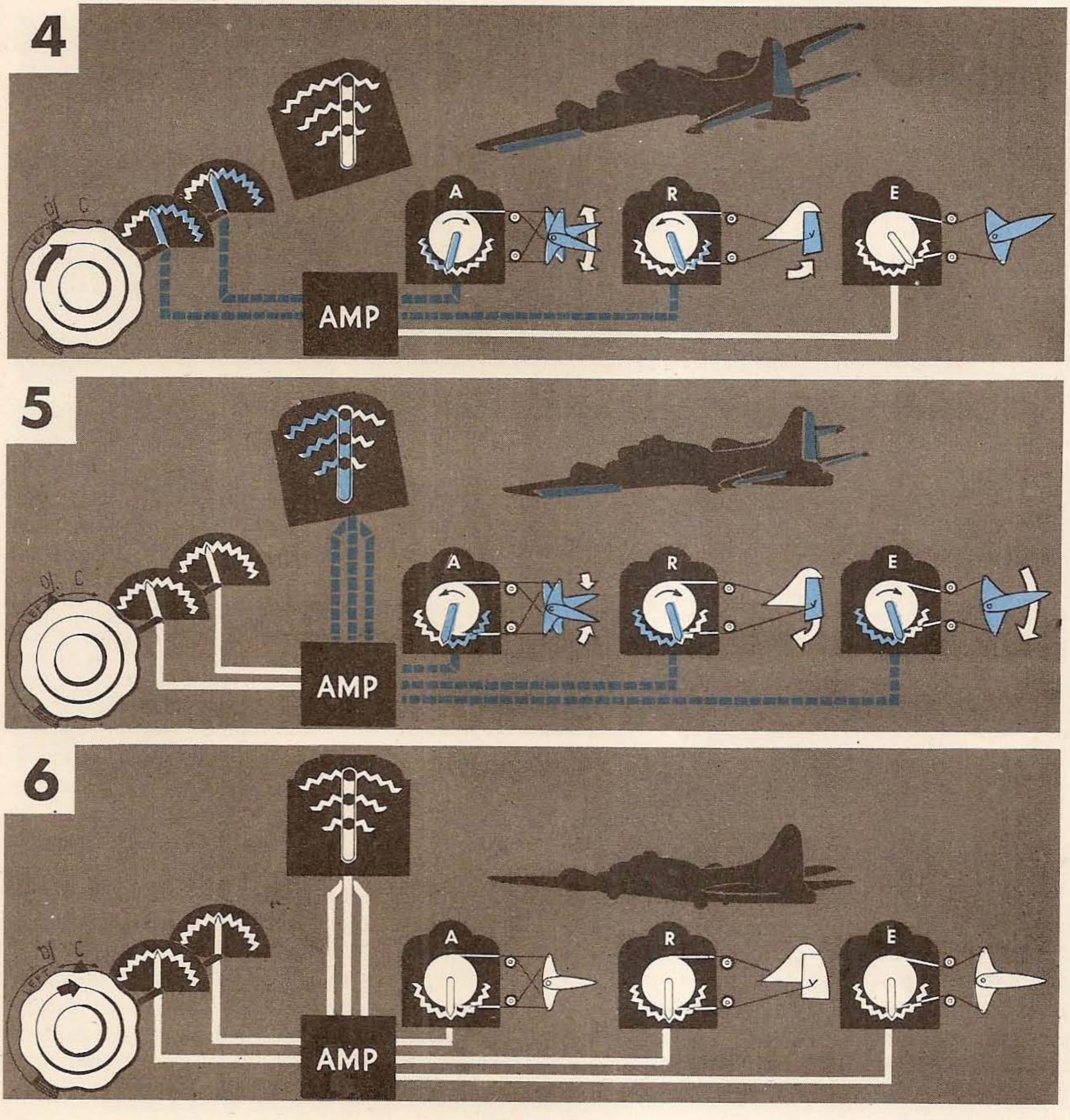


You will recall that there are three pots mounted in the front of the gyro case—the aileron pickup pot, the rudder compensation pot, and the **up-elevator pot**. As the airplane is banked, the up-elevator pot and wiper unbalance the elevator bridge circuit. This results in enough up-elevator to prevent loss of altitude during the turn. The elevator balance pot balances out the up-elevator signal when the proper amount of control has been driven in.

Thus, when the airplane is in the midst of its bank, the aileron and rudder control surfaces are streamlined, the up-elevator control remains in use, and **all** bridge circuits are **balanced.**

In recovering from the turn, the action of the autopilot is exactly the reverse. As you move the turn control toward the zero position, signals are created that move the aileron and rudder controls out of streamline and in the direction opposite to that of the original turn. As the airplane comes out of the bank, the triple pot assembly—aileron, rudder, and elevator pots—moves under the stabilized wipers. This creates signals which cause the servos to move the controls back toward a streamlined position as the airplane returns to straight and level flight. When the airplane reaches level flight, the bridge circuits are balanced and the control surfaces are streamlined.

When you move the turn control knob from zero to center, the erecting cutout switch and the directional arm lock switch are opened. Thus the autopilot clutch is again free to stabilize the airplane about the yaw axis and the bottom roller is engaged to the top roller.



INTENTIONAL BANK AND RECOVERY THROUGH THE DIRECTIONAL PANEL

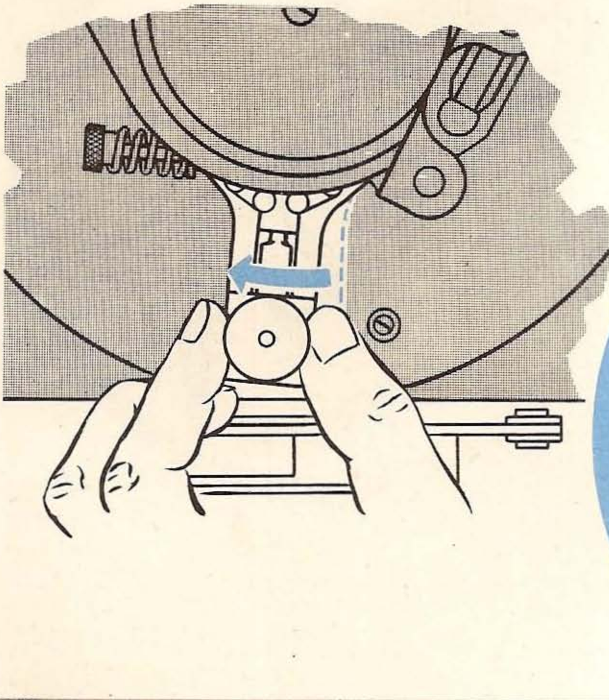
A turn made by the bombardier must be made through the directional panel if his compartment is not equipped with a turn control. There are two methods by which a turn can be made through the directional panel. Each of these methods uses the autopilot clutch disengaged.

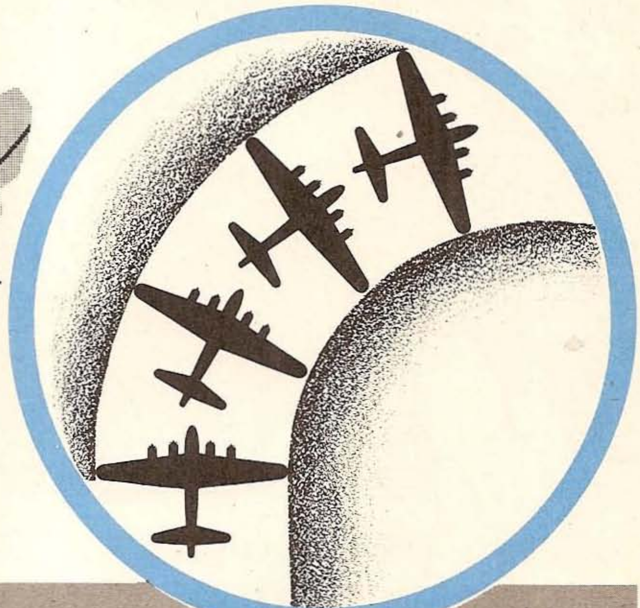
The first method is very simple. You manually move the autopilot clutch. This can be done either by taking hold of the autopilot clutch arm and displacing the clutch or by swinging the bombsight. This is similar to steering a bicycle. If you displace the clutch to the left, the airplane turns right, and vice versa.

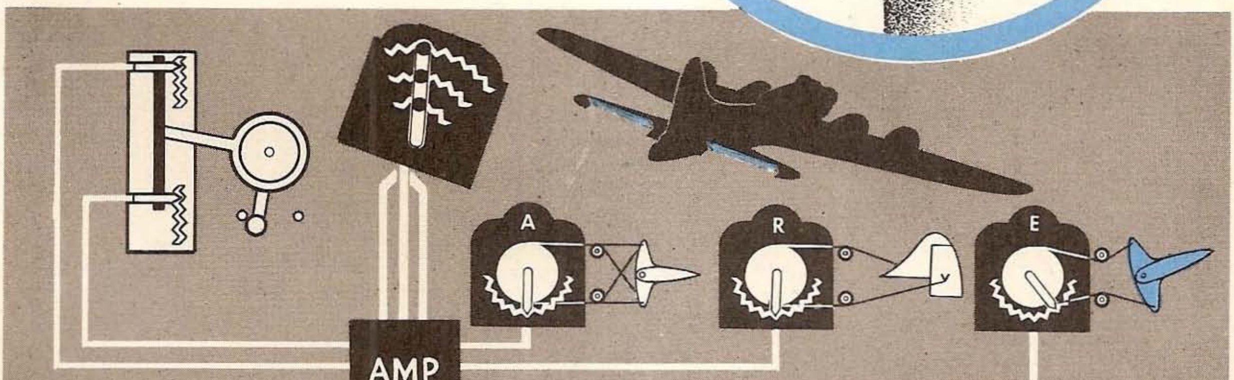
The mechanism which accomplishes this result is equally simple. The autopilot clutch is linked by the directional panel arm to the sliding block in the directional panel. Since the rudder pickup and dual banking pot wipers are attached to the sliding block, any movement of the autopilot clutch displaces the wipers on their respective pots.

As you displace the clutch from center, the sliding block closes the erecting cutout switch and moves the wipers over their pots, thus unbalancing the aileron and rudder bridge circuits. The autopilot responds to this unbalanced condition in exactly the same manner as it does to a turn originating from the turn control.

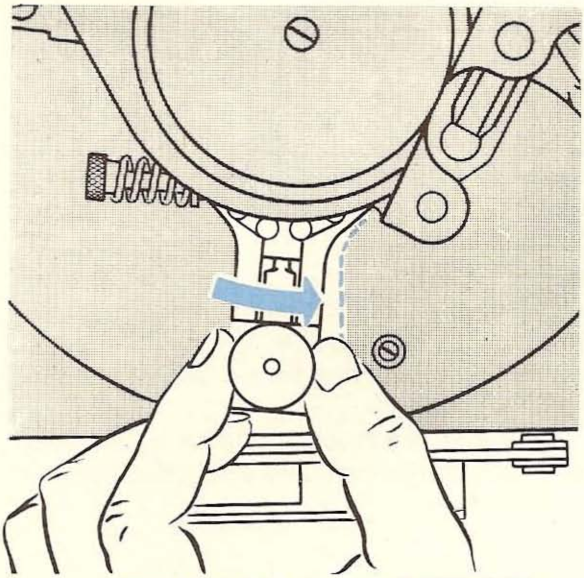
As long as the autopilot clutch is displaced from center, the autopilot holds the airplane in the turn.



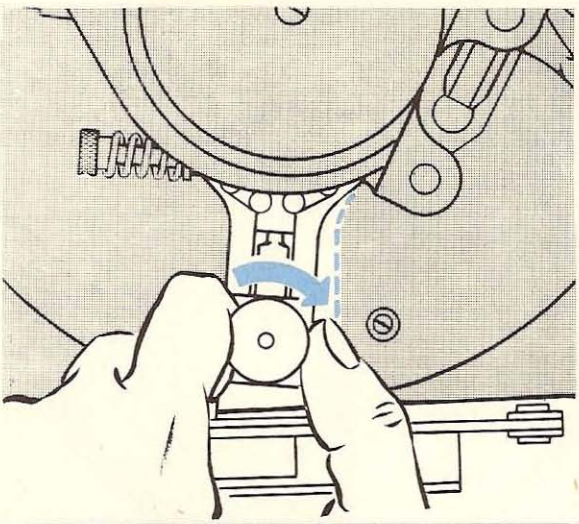




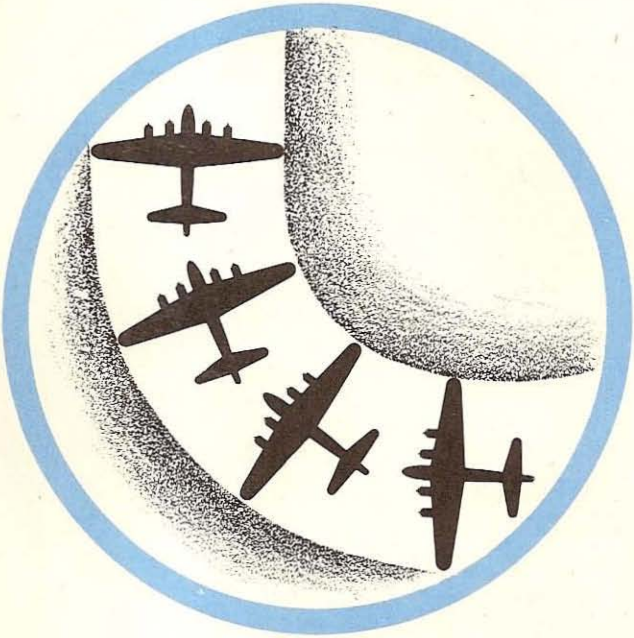
RETURN TO CENTER MANUALLY

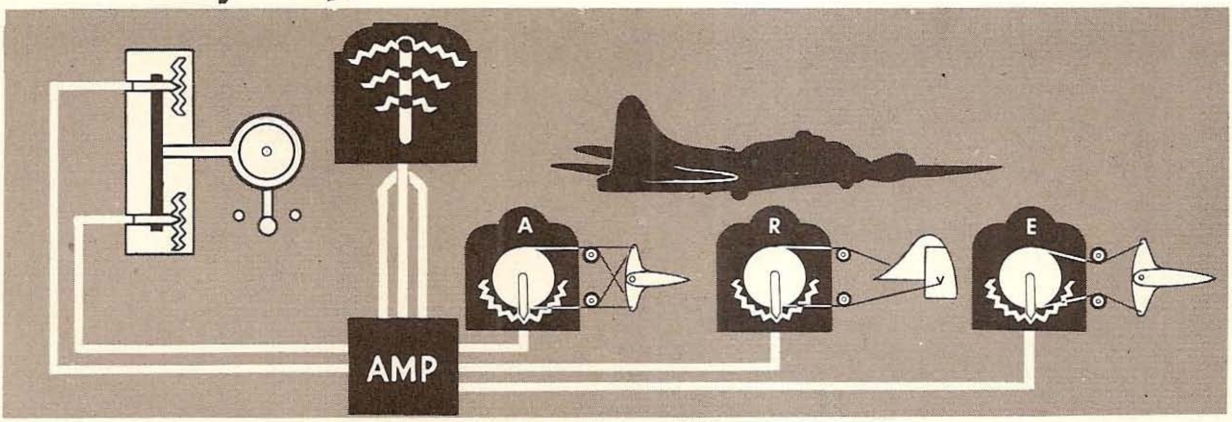


OR ENGAGE AUTOPILOT CLUTCH

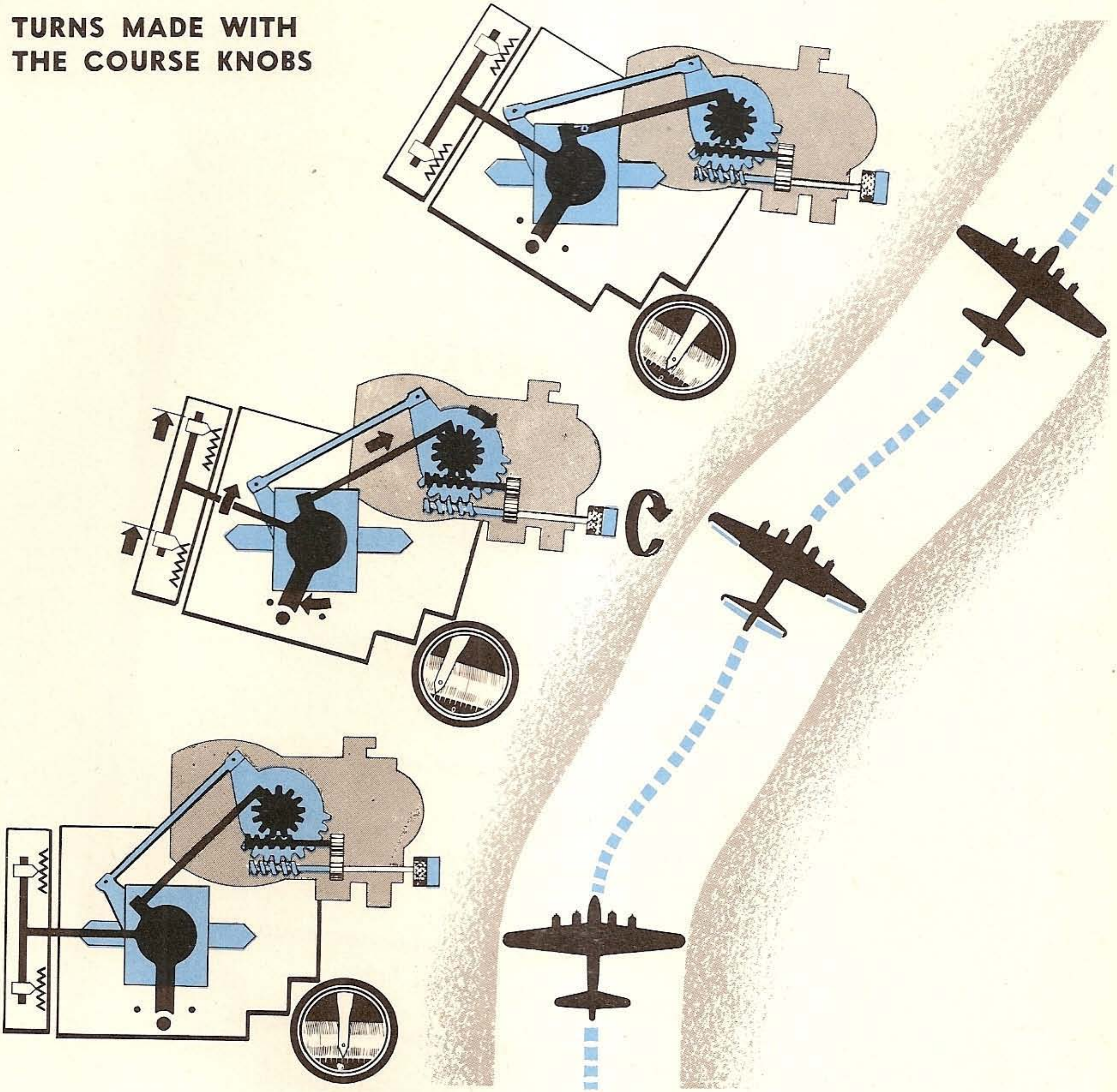


To recover from the turn, the autopilot clutch must be returned to center. This can be done by two methods, either by returning it manually or by engaging it at its displaced position and allowing the autopilot to return the airplane to level flight so as to center the autopilot clutch. As the clutch reaches center, the erecting cutout switch is opened.





TURNS MADE WITH THE COURSE KNOBS



The second method is to move the autopilot clutch with the course knobs of the bombsight. The course knobs are indirectly linked to the autopilot clutch and the directional panel wipers, and can be used to turn the autopilot through the directional panel. The bombsight clutch must be engaged and the autopilot clutch disengaged when using the course knobs of the bombsight. When you move the directional panel wipers by turning the course knobs, the airplane turns to the right or left in much the same way as if you had moved the autopilot clutch manually.

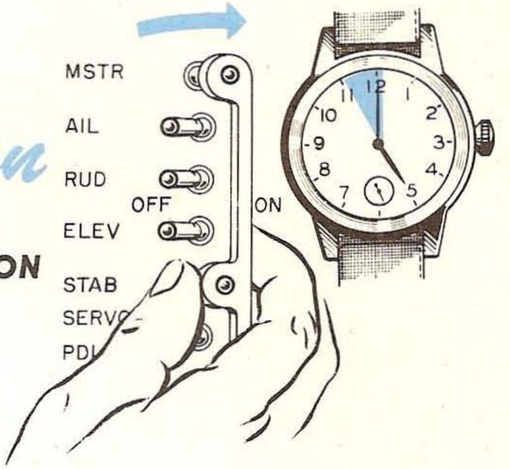
However, there is one very important difference. When you cease to turn the course knobs, the directional gyro immediately stabilizes the whole steering mechanism, including the autopilot clutch and the directional panel wipers. Then, as the airplane turns in response to the turn signals, it moves the center of the pots back under the stabilized wipers, thus taking out the turn signals and causing the airplane to resume straight and level flight on the new heading. The airplane would continue to turn only if you continued to turn the course knobs.

OPERATION

PREFLIGHT INSPECTION

1. Turn autopilot master switch ON.
2. Center turn control.
3. Turn knobs on ACP to "pointers up" position.
4. Turn Servo-PDI switch ON.
5. Disengage bombsight clutch and engage autopilot clutch with PDI on center.
6. Operate airplane controls manually, observing tell-tale lights.
7. Turn aileron, rudder, and elevator engaging switches ON, observing tell-tale lights.
8. Rotate each centering knob, observing controls.
9. Rotate turn control knob, observing controls.
10. Disengage autopilot clutch, displace to each side, observing controls. Engage autopilot clutch.
11. Turn autopilot master switch OFF.

Preflight Inspection



1. TURN AUTOPILOT MASTER SWITCH ON

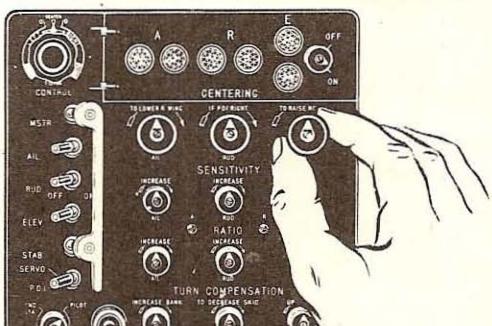
When you turn the autopilot master switch ON, you complete circuits to the amplifier, servo motors, flight gyro, directional gyro, and the rotary inverter. You must wait five minutes before turning other switches ON.

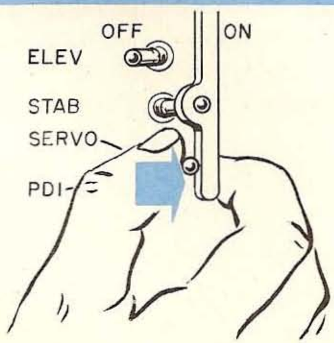
2. CENTER TURN CONTROL

When you place the turn control knob at center, you open the erecting cutout switch and the directional arm lock switch. Therefore, the flight gyro will be erected to the vertical and the directional arm lock will not be energized. This also places the wipers in the turn control at the center of their pots.

3. TURN KNOBS ON ACP TO "POINTERS UP" POSITION

Make sure pointers are not loose. The autopilot should be in approximate adjustment with the pointers at "pointers up" position.



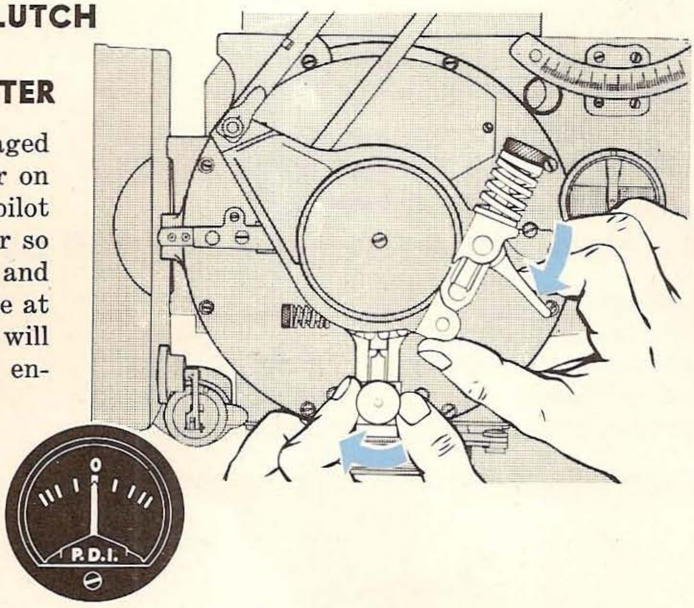


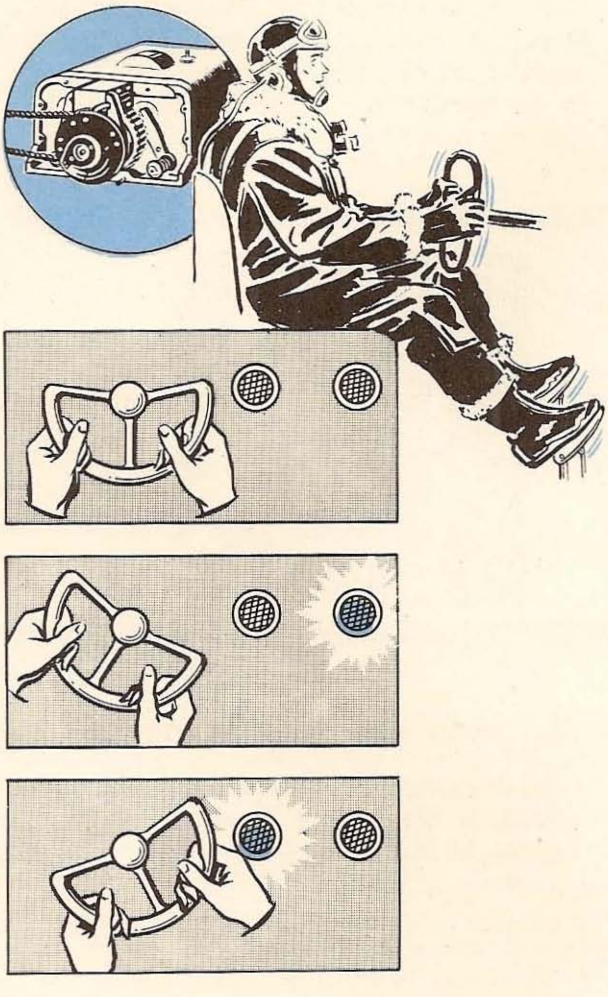
4. TURN SERVO-PDI SWITCH ON

By turning this switch ON, you complete circuits to the PDI and the torque unit of the bombsight stabilizer.

5. DISENGAGE BOMBSIGHT CLUTCH AND ENGAGE AUTOPILOT CLUTCH WITH PDI ON CENTER

The bombsight clutch should be disengaged before take-off to prevent excessive wear on the torque unit and bombsight. The autopilot clutch is engaged with the PDI on center so the erecting cutout switch will be open and the wipers of the directional panel will be at the center of their pots. The autopilot will not function properly with both clutches engaged or disengaged at the same time.



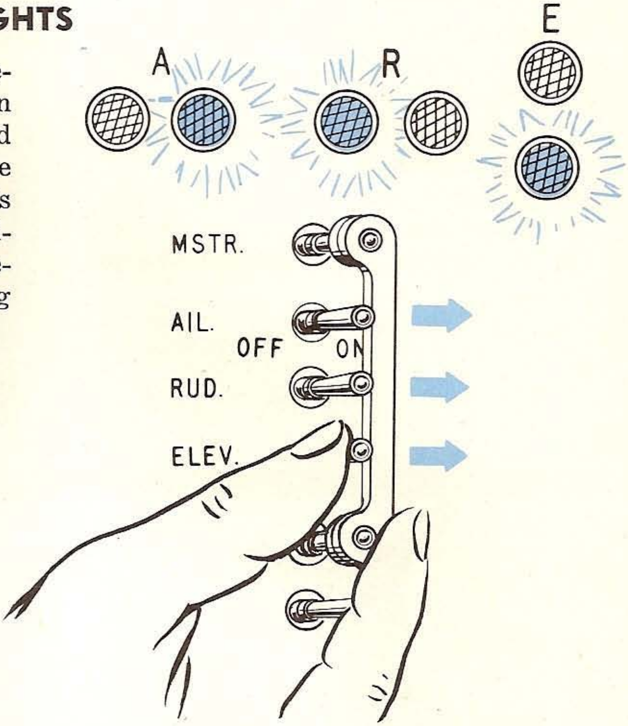


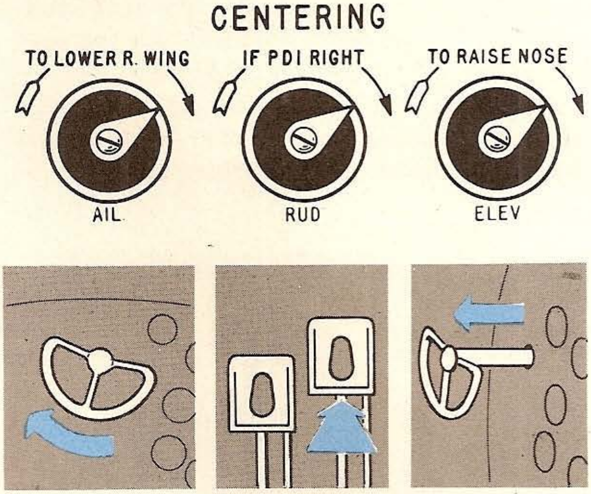
6. OPERATE AIRPLANE CONTROLS MANUALLY, OBSERVING TELL-TALE LIGHTS

Operate the airplane controls manually to move the control surfaces through their extreme ranges of movement several times. This will slide the servo unit balance pot wipers over their respective pots and should clean off any dust or dirt that is on the pots. As you move the controls, observe the tell-tale lights. When the controls are near the streamlined position, the lights will flicker. When controls are at the extreme ends of their ranges, the lights may go out as the pot wipers run off the winding. At any intermediate position one light or the other should be ON. If the lights flicker at the intermediate position, the corresponding pots need cleaning. Dirt between the wipers and pots causes the lights to flicker by breaking the contact between wiper and pot.

7. TURN THE AILERON, RUDDER AND ELEVATOR ENGAGING SWITCHES ON, OBSERVING TELL-TALE LIGHTS

As you engage these switches the corresponding lights should come on, flicker, then go out as the controls move into streamlined position. At first the lights will glow because the circuits are unbalanced. As the controls are moved by the servo to streamlined position, the circuits become balanced and consequently the lights go out as no signal is being sent to the amplifier.



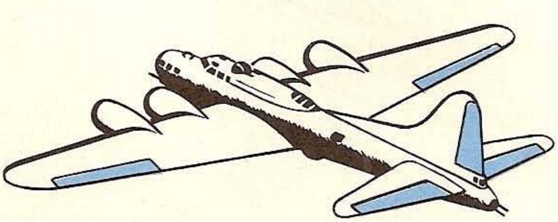


8. ROTATE EACH CENTERING KNOB, OBSERVING CONTROLS

As you turn the centering knobs the circuits are unbalanced and the controls are moved by the servos. As you turn the aileron centering knob clockwise, the control wheel should turn to the right. When you turn it counter-clockwise, the control wheel should turn to the left.

As you turn the rudder centering knob clockwise, the right rudder pedal should move forward. When you turn it counter-clockwise, the left rudder pedal should move forward.

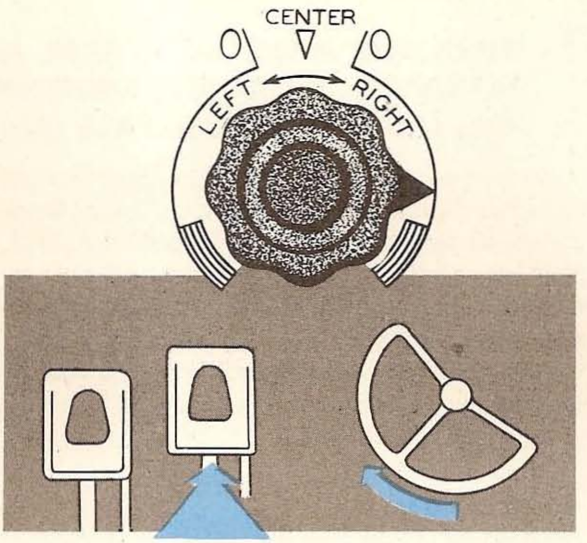
As you turn the elevator centering knob clockwise, the control column should move to the rear. When you turn it counter-clockwise, the control column should move forward.

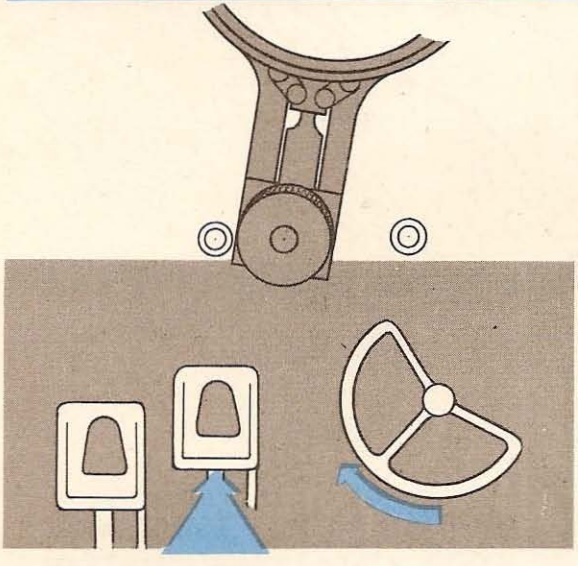


9. ROTATE TURN CONTROL KNOB, OBSERVING CONTROLS

When you rotate this knob clockwise, you unbalance the rudder and aileron bridge circuits. Therefore, the right rudder pedal should move forward and the control wheel should turn to the right.

When you rotate the knob counter-clockwise, the left rudder pedal should move forward and the control wheel should turn to the left.





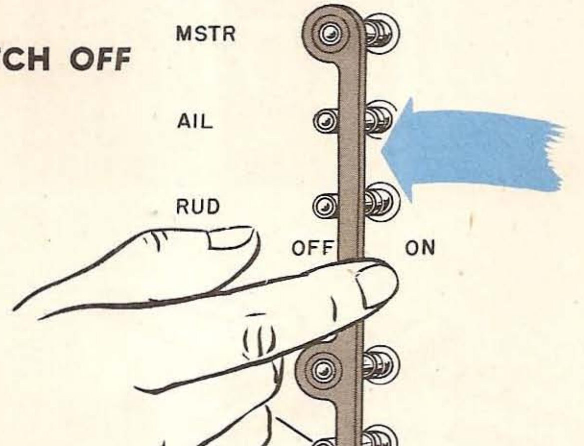
10. DISENGAGE AUTOPILOT CLUTCH, DISPLACE TO EACH SIDE, OBSERVING CONTROLS. ENGAGE AUTOPILOT CLUTCH

When you disengage the autopilot clutch and place it against the left stop, the rudder and aileron bridge circuits are unbalanced through the directional panel; the right rudder pedal should move forward and the control wheel should turn to the right.

As you place it against the right stop, the left rudder pedal should move forward and the control wheel should turn to the left.

11. TURN AUTOPILOT MASTER SWITCH *OFF*

When you turn the autopilot master switch OFF, you turn off all other switches which engage units of the autopilot. This prevents running down the airplane battery and any accidental control by the autopilot during take-off.



ENGAGING PROCEDURE

Before Take-Off:

1. Center turn control.
2. Turn knobs on ACP to "pointers up" position.
3. Engage autopilot clutch and disengage bombsight clutch.

After Take-Off:

4. Turn autopilot master switch ON. (Wait 10 minutes before turning other switches ON.)
5. Manually trim airplane for straight and level flight.
6. Turn Servo-PDI switch ON.
7. Turn tell-tale lights switch ON.
8. Center PDI.
9. Adjust aileron centering knob until both aileron tell-tale lights are out.
   Turn aileron switch ON.
   Readjust aileron centering knob to level wings.
10. Adjust rudder centering knob until both rudder tell-tale lights are out.
    Turn rudder switch ON.
    Readjust rudder centering knob to center PDI.
11. Adjust elevator centering knob until both elevator tell-tale lights are out.
    Turn elevator switch ON.
    Readjust elevator centering knob for level flight.

FLIGHT ADJUSTMENTS

1. Centering.
2. Sensitivity.
3. Ratio.
4. Dashpot.
5. Turn Compensation.
6. Turn Control.

Engaging Procedure

BEFORE TAKE-OFF

1. CENTER TURN CONTROL. ALSO MAKE SURE THAT CONTROL TRANSFER KNOB IS AT "PILOT"

2. TURN KNOBS ON ACP TO "POINTERS UP" POSITION

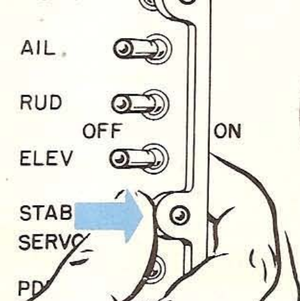
This should be done unless the knobs are known to be properly adjusted. Always make sure pointers are not loose.

3. ENGAGE AUTOPILOT CLUTCH AND DISENGAGE BOMB-SIGHT CLUTCH

AFTER TAKE-OFF

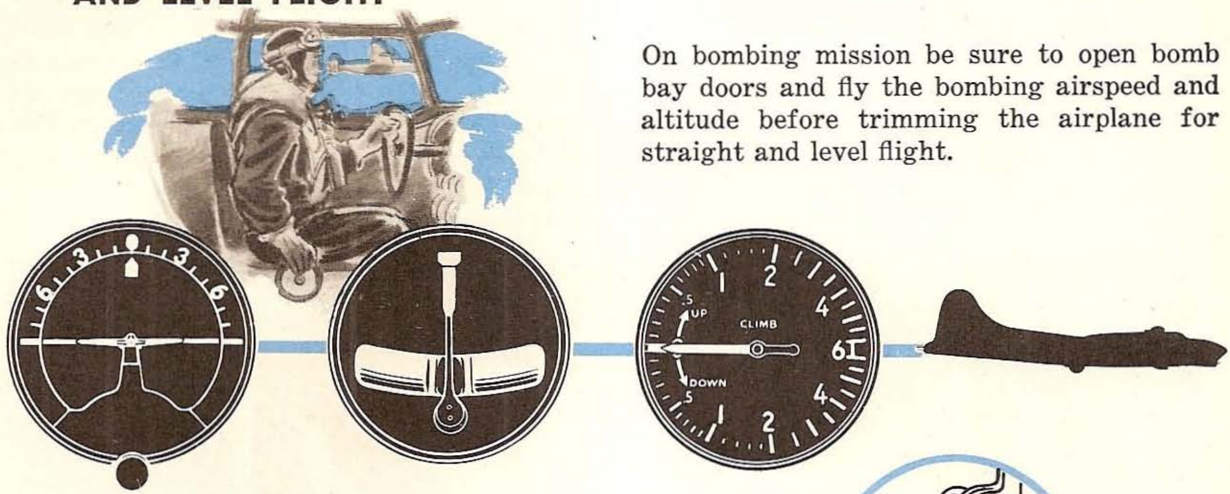
4. TURN AUTOPILOT MASTER SWITCH *ON*

(**Wait 10 minutes** before turning other switches ON.) This delay is required to allow the stabilizer gyro and vertical flight gyro to come up to speed.



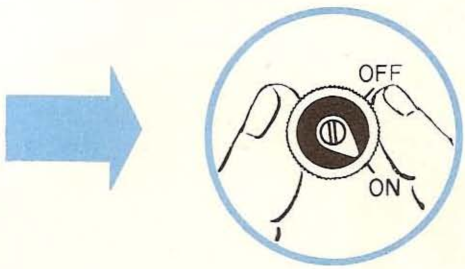
5. MANUALLY TRIM AIRPLANE FOR STRAIGHT AND LEVEL FLIGHT

On bombing mission be sure to open bomb bay doors and fly the bombing airspeed and altitude before trimming the airplane for straight and level flight.



6. TURN SERVO-PDI SWITCH *ON*

7. TURN TELL-TALE LIGHTS SWITCH *ON*

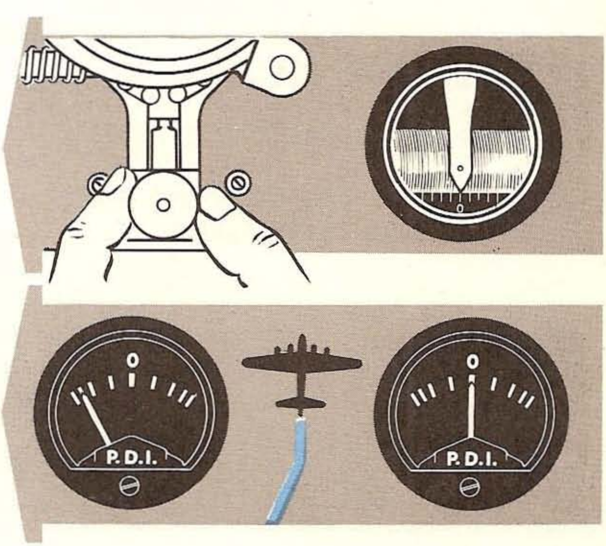


8. CENTER PDI

This may be done by either of the following methods:

A. Bombardier disengages autopilot clutch and centers PDI by moving autopilot clutch arm to its center position. Hold PDI centered until autopilot is engaged; then re-engage autopilot clutch.

B. Alternate method—Pilot centers PDI by turning airplane in direction of PDI needle. Then resume straight and level flight, keeping PDI centered until autopilot is engaged.

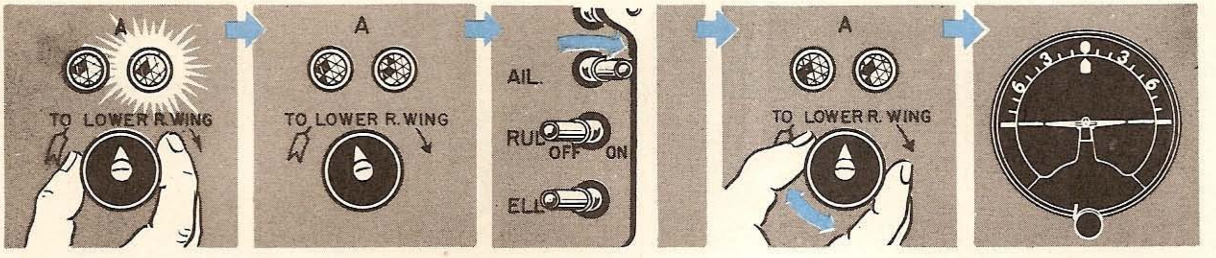


9. ADJUST AILERON CENTERING KNOB UNTIL BOTH AILERON TELL-TALE LIGHTS ARE OUT

TURN AILERON SWITCH ON.

READJUST AILERON CENTERING KNOB TO LEVEL WINGS.

Before similarly engaging the rudder servo you check the gyro horizon, and readjust aileron centering to make sure the wings are level. If the wings are not level when rudder is centered and engaged, cross-control may result, as the autopilot will apply rudder to hold the airplane on a straight course.

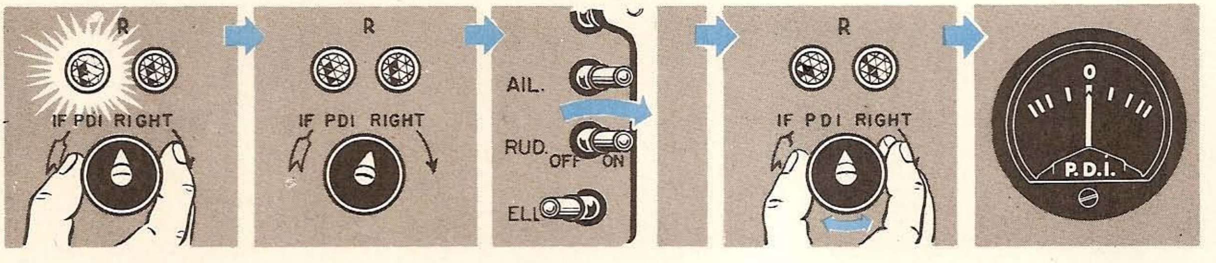


10. ADJUST RUDDER CENTERING KNOB UNTIL BOTH RUDDER TELL-TALE LIGHTS ARE OUT

TURN RUDDER SWITCH ON.

READJUST RUDDER CENTERING KNOB TO CENTER PDI.

This prevents the erecting cutout from being energized from the directional panel. The erecting cutout is energized if the PDI is off center $1\frac{1}{2}°$ or more.

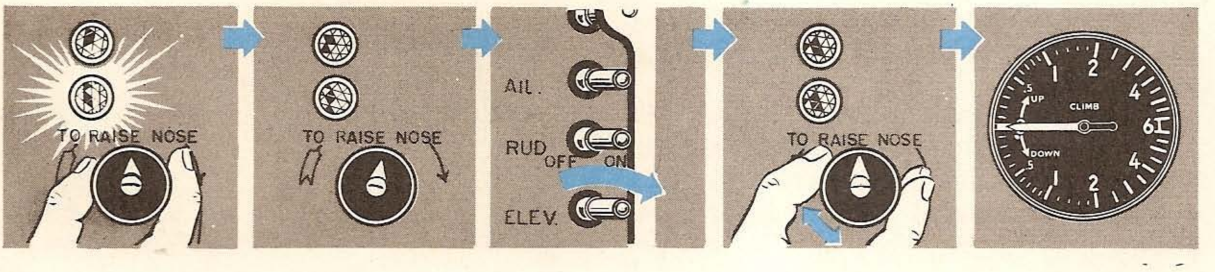


11. ADJUST ELEVATOR CENTERING KNOB UNTIL BOTH ELEVATOR TELL-TALE LIGHTS ARE OUT

TURN ELEVATOR SWITCH ON.

READJUST ELEVATOR CENTERING KNOB FOR LEVEL FLIGHT

The elevator centering is readjusted for level flight to prevent the gaining or losing of altitude while flight adjustments are being made.



Flight Adjustments

GENERAL

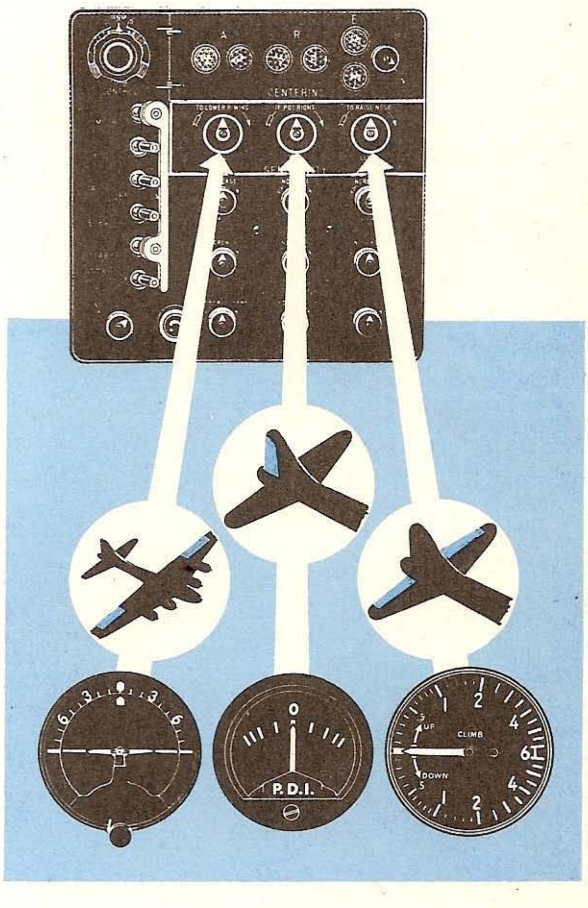
Control knobs on the autopilot control panel permit precise adjustment of the autopilot for maximum efficiency under any flight or load-carrying condition. Once these adjustments have been set for a particular airplane only slight readjustments will be required each time the autopilot is used—unless, of course, flight or load conditions change considerably.

1. CENTERING

The centering controls on the ACP are comparable to the trim tabs of the airplane. They control the normal attitude of the airplane while the autopilot is in operation. Adjustment of the centering knobs aligns the electric center of the servo unit balance pot with the pot wiper when the control surfaces are in trim.

When flying under autopilot control, use centering knobs in place of the mechanical trim tabs to compensate for **slight** changes in airspeed, center of gravity, or gross weight.

When large changes of airspeed, center of gravity, or gross weight occur, it is necessary to disengage the autopilot, re-trim mechanically, and re-engage the autopilot.



Caution

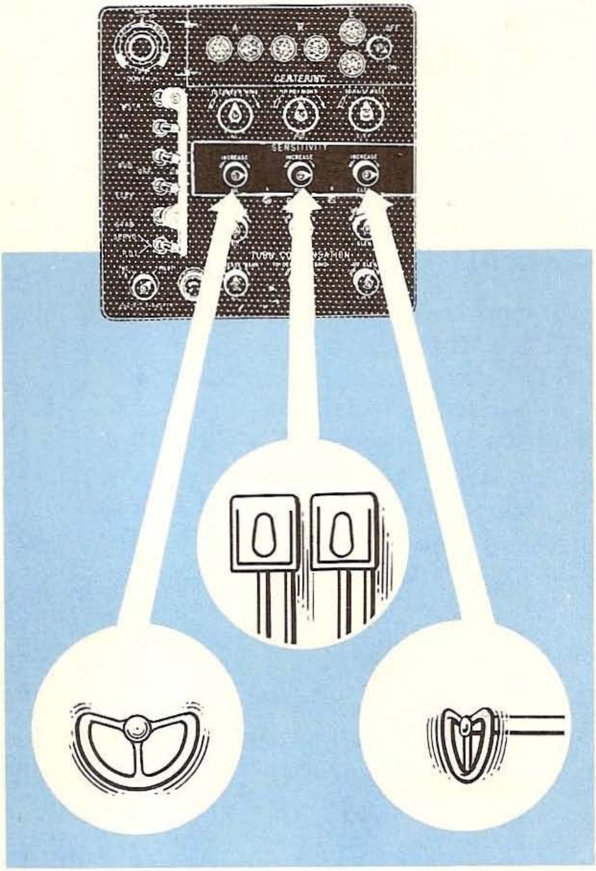
Never trim the controls manually with the mechanical trim tabs while the autopilot is in operation. Use of the trim tabs will not change airplane's attitude because the autopilot will counteract the effect of the trim tabs. Then, when autopilot is disengaged, trim tabs will suddenly become effective and produce a violent reaction.

2. SENSITIVITY

The sensitivity knobs regulate the amount of airplane deviation allowed by the autopilot before it applies correction. This alertness of the autopilot is comparable to a human pilot's reaction time.

A human pilot may apply a correction for even the slightest deviation (high sensitivity) or he may wait for a larger deviation before applying the correction (low sensitivity).

High sensitivity provides maximum flight stability, but it is possible to adjust sensitivity so high that the controls vibrate or "chatter."



TO ADJUST SENSITIVITY, TURN KNOBS CLOCKWISE UNTIL CONTROLS CHATTER; THEN BACK OFF UNTIL CONTINUOUS CHATTER STOPS

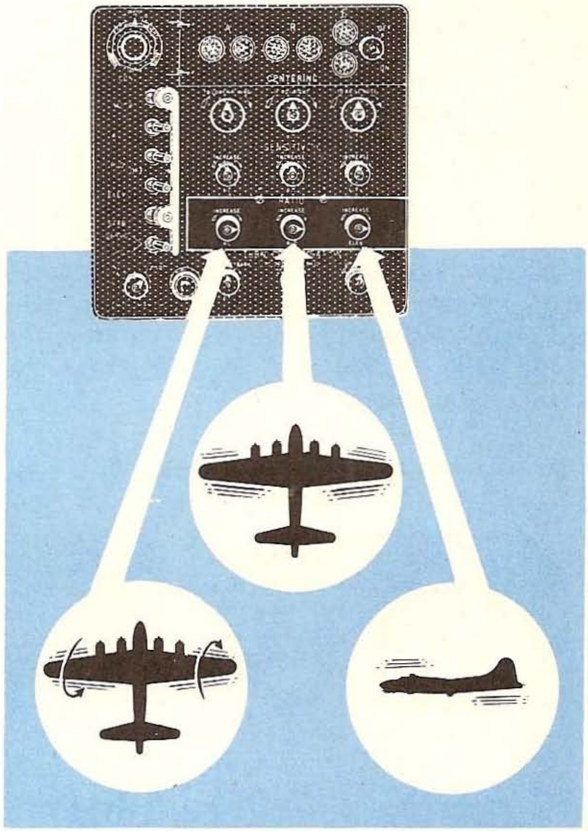
LOW SENSITIVITY

HIGH SENSITIVITY

3. RATIO

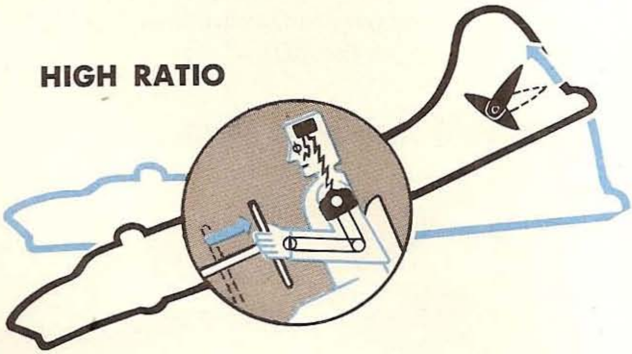
The ratio knobs regulate the amount of control surface movement resulting from a given deviation of the airplane. Thus, with a high ratio setting, the autopilot may apply too much control surface in correcting a given deviation, giving fast recovery, which may cause over-control. On the other hand, if ratio is set too low, the autopilot will apply too little control in correcting a deviation, producing smooth recovery which may be too slow for correct flight.

Ratio will require slight readjustment with any appreciable change of indicated airspeed. Following any change of ratio, re-check centering.



TO ADJUST RATIO, TURN KNOBS CLOCKWISE TO GIVE OVER-CONTROL; THEN REDUCE RATIO TO RETAIN QUICK RECOVERY WITHOUT OVER-CONTROL. OBSERVE WING TIPS, HORIZON AND PDI FOR EVIDENCE OF OVER-CONTROL.

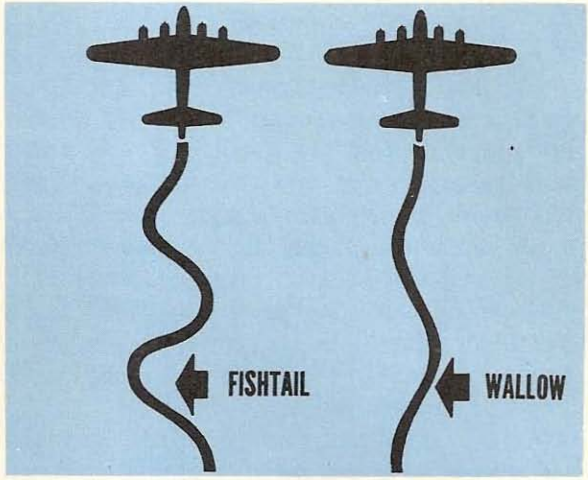
HIGH RATIO



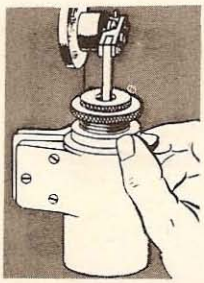
LOW RATIO

4. DASHPOT ADJUSTMENTS

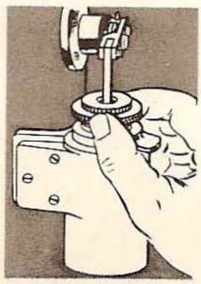
The dashpot is linked to the rudder pickup pot wiper in the directional panel in such a way that it produces an extra initial rudder correction signal proportional to the speed of turn axis deviation. Incorrect dashpot adjustment produces a tendency for the airplane either to "fishtail," as a result of over-control of the rudder, or to "rudder hunt," as a result of under-control. This may happen even with sensitivity, ratio, and turn compensation properly adjusted.



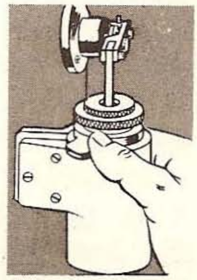
To Correct Dashpot Adjustment, Do This:



1. Unlock dashpot by turning lock nut lever counter-clockwise.



2. Turn knurled nut up or down until hunting ceases, or "fishtailing" ceases.



3. Lock adjustment by turning lock nut lever clockwise.

5. TURN COMPENSATION

Immediately after engaging the system and making sure sensitivity and ratio are well adjusted, check the turn compensation adjustments as follows, **first making sure the airplane is flying straight and level:**

1. Bombardier disengages autopilot clutch and moves the clutch arm slowly to extreme right or extreme left.

2. Adjust aileron compensation knob to produce an 18° bank, as indicated by the artificial horizon.

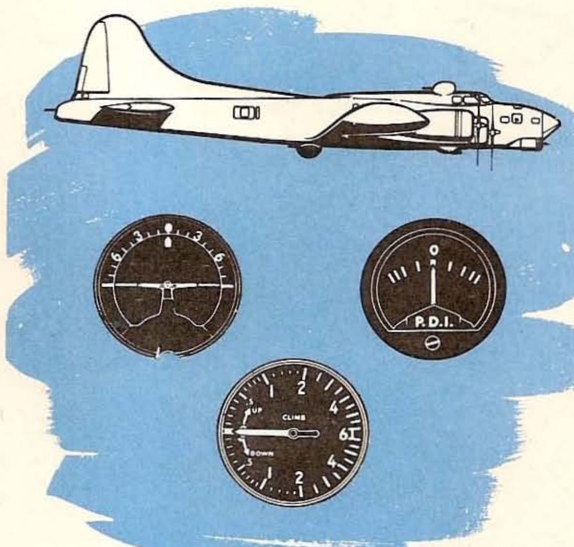
3. Adjust rudder compensation knob to produce a perfectly coordinated turn, as indicated by the ball-bank inclinometer. Ball must be in **exact** center.

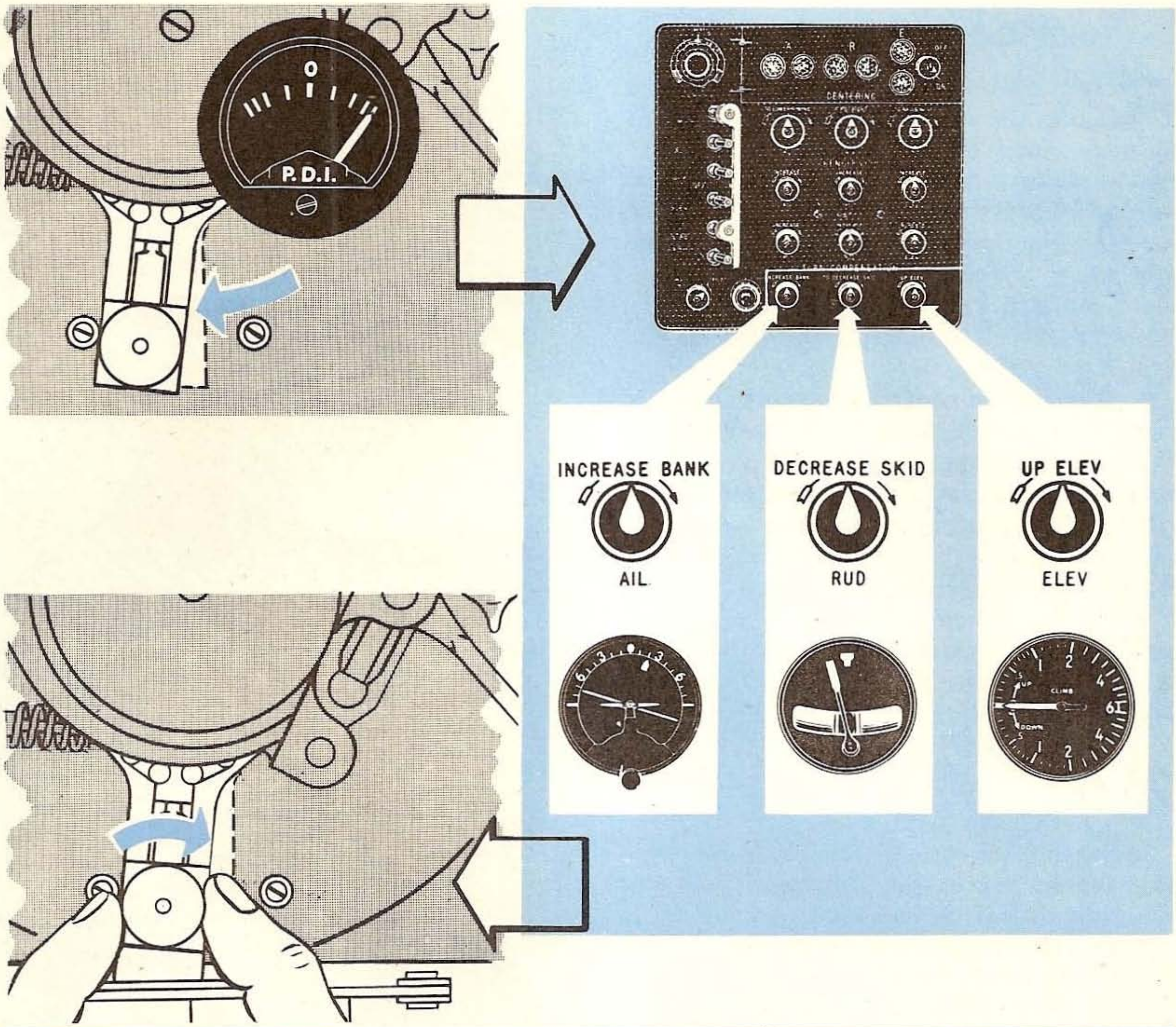
4. Make final adjustments with both knobs to obtain a perfectly coordinated turn with 18° bank.

5. Adjust elevator compensation knob to apply sufficient up-elevator to maintain altitude during the turn. Changes in load or airspeed may require readjustment of the up-elevator trimmer.

6. Bombardier re-engages autopilot clutch at its extreme position, and allows the stabilizer to re-center the PDI.

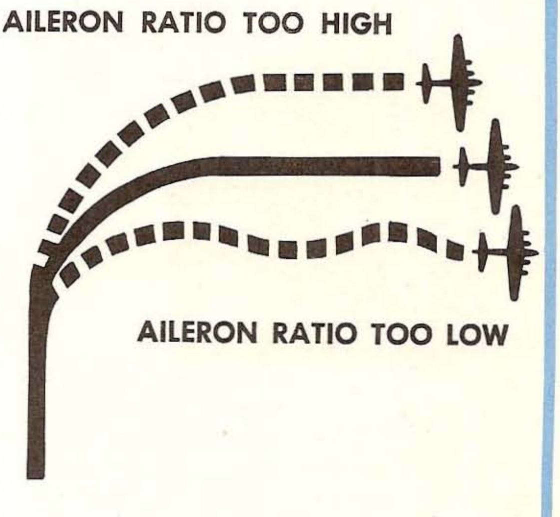
STRAIGHT AND LEVEL FLIGHT





Note:

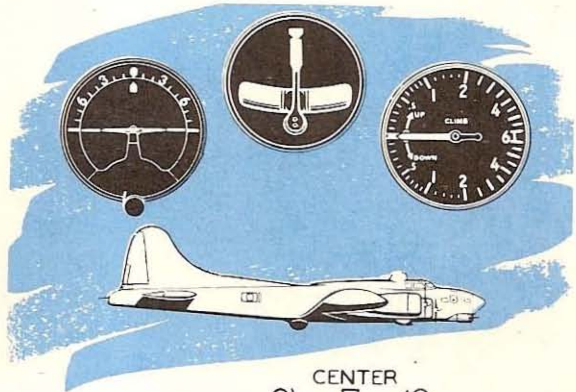
Allowing the directional gyro in the stabilizer to recenter PDI gives a check on aileron **ratio**. After the autopilot clutch is engaged, the airplane must turn 5¼° to center PDI from the extreme position. If aileron ratio is too high, the wings will quickly level off before the airplane has turned the necessary 5¼°. Then, with only rudder in effect, the airplane will skid and turn more slowly to center PDI. If aileron ratio is too low, the airplane will quickly turn the necessary 5¼° to center PDI, but the wings will not level off fast enough and the airplane will continue to turn, causing the PDI to overshoot center. The result will be a **fishtail** action as the airplane straightens out.

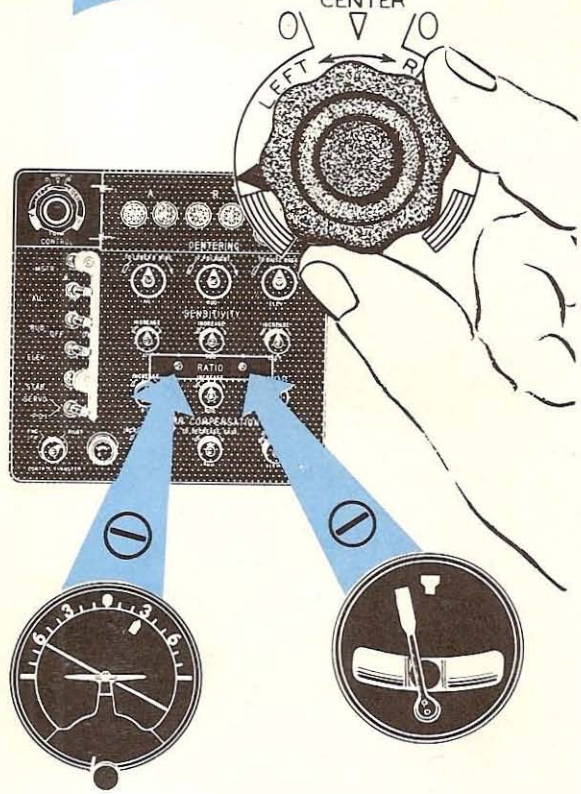


6. TURN CONTROL

The turn control offers a convenient means of changing the airplane's heading while flying under autopilot control. The turn control seldom requires readjustment unless there is reason to believe that a previous adjustment has been changed. This adjustment is made only after the turn compensation adjustments outlined have been completed.

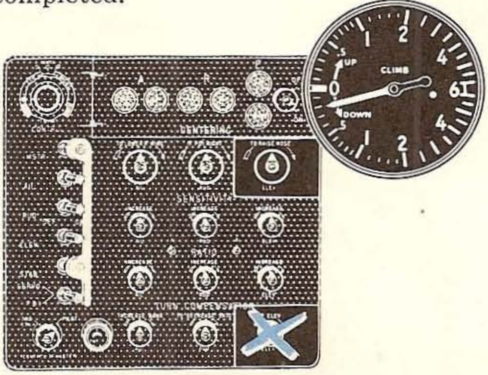
1. Be sure airplane is flying straight and level.
2. Rotate turn control knob slowly, either to right or to left, until pointer reaches the lined region of the dial, or until you feel a distinct resistance to further rotation.
3. At that setting, adjust the aileron trimmer on the ACP to produce a 30° bank as indicated by the artificial horizon.
4. Adjust rudder trimmer to produce a perfectly coordinated turn, as indicated by the inclinometer. Make final adjustments with both trimmers.





Note:

If the elevator compensation knob has been adjusted for bombardier's turns, it will also maintain altitude in turn-control banks up to 18°, provided airspeed is maintained. If loss of altitude occurs in a turn-control turn, it can be corrected by adjusting elevator centering and then readjusting centering for straight and level flight after the turn has been completed.



5. Slowly return pointer to **zero** and **hold it there** while airplane resumes level flight.
6. When airplane has leveled off, re-center turn control pointer.

Caution

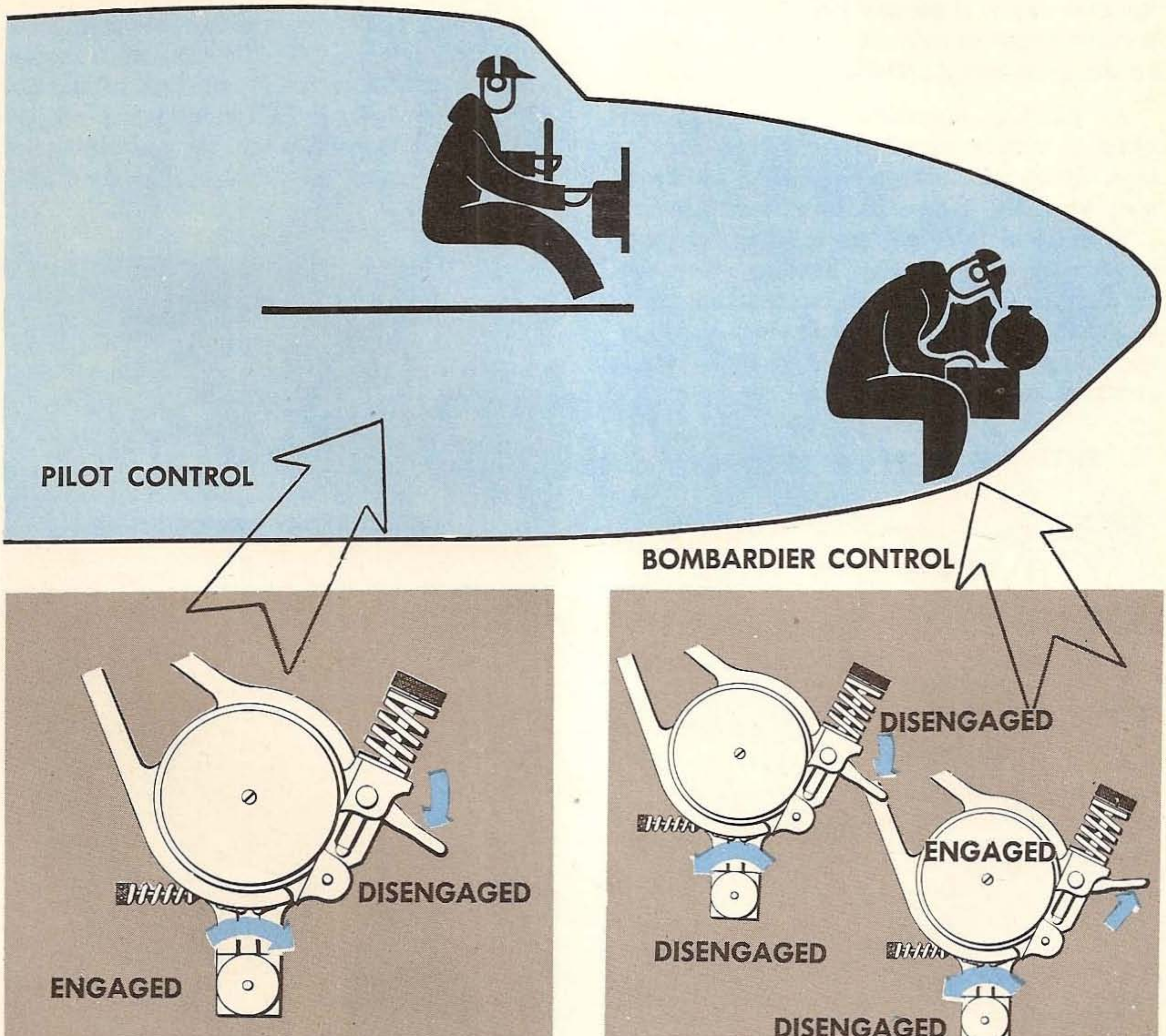
Never operate turn control without first making sure PDI is centered and bombardier is not making a turn with the autopilot clutch.

OPERATION OF AUTOPILOT AND BOMBSIGHT CLUTCHES

When the bombardier manually directs the airplane both clutches are disengaged. At all other times one and only one clutch is engaged. When changing from one clutch to the other always engage the second before disengaging the first.

When you direct the airplane through the bombsight, the bombsight clutch is engaged and the autopilot clutch is disengaged.

When the pilot has full control the autopilot clutch is engaged and the bombsight clutch is disengaged.



TURN CONTROL OPERATION

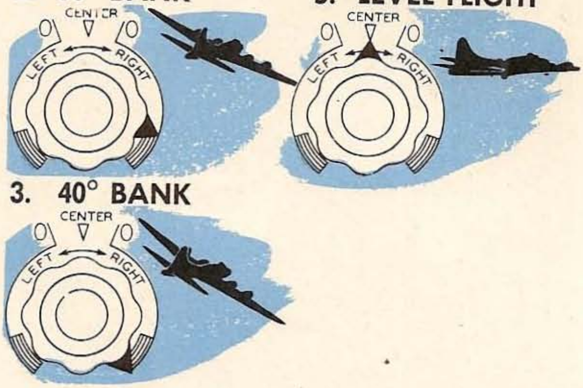
Whenever it is desired to turn the airplane to a new heading while flying on autopilot control, rotate turn control slowly in the direction of turn desired. As the pointer passes the zero mark, you will feel a "click" as the cam switch closes, energizing the erecting cutout and directional arm lock.

Stop rotation of knob when artificial horizon indicates airplane has reached desired degree of bank.

NOTE: A warning stop causes the knob to turn with increased difficulty after the signal for a 30° bank has been applied. This is to warn you to "take it easy" as you are approaching the maximum degree of bank obtainable (40°). A steeper bank may cause the vertical flight gyro to strike against its stop on the gyro cover, resulting in precession.

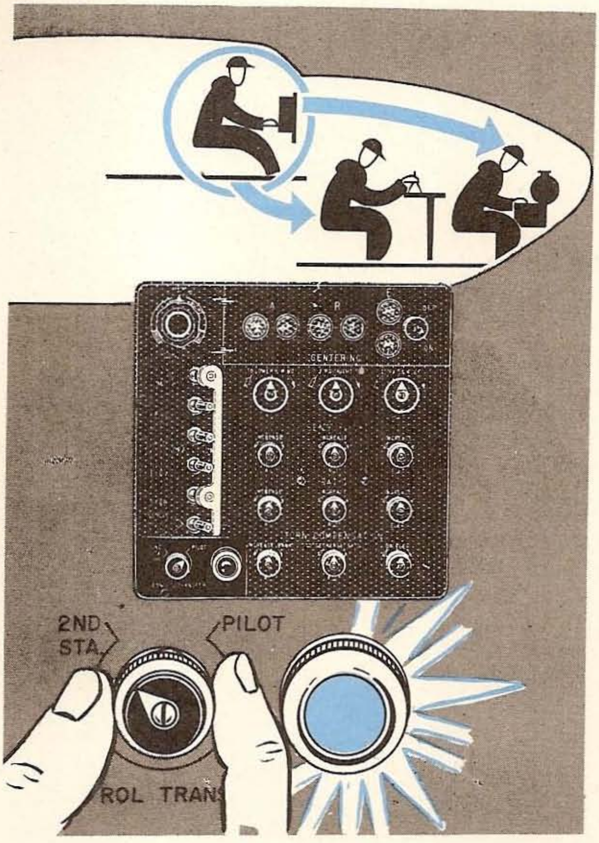
As airplane approaches the desired new heading, slowly rotate control knob back to **zero,** timing this return so pointer will reach zero when the desired heading is attained.

Hold the pointer at zero until the airplane has leveled off on its new heading; then center the pointer to engage the erecting roller and release the directional arm lock. (No signal is applied by turn control when pointer is at either zero mark.)



Operation of the Control Transfer

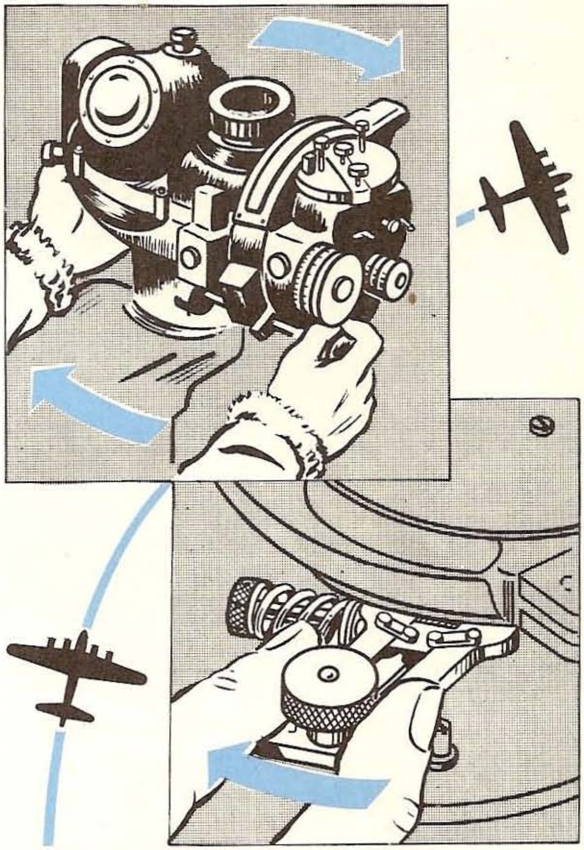
If the autopilot system includes a second turn control at a remote station (as in the bombardier's or navigator's compartment), the ACP will be provided with a control transfer in the lower left-hand corner. This control enables the pilot to transfer control of the airplane smoothly and gradually from the turn control in the ACP to the remote turn control, which is operated in an identical manner by the bombardier or navigator. When the pilot wishes to transfer control of the airplane to the remote turn control, he rotates the control transfer knob to its extreme clockwise position. This is done slowly to prevent the sudden introduction of a strong signal in case the remote turn control is not centered at the time of transfer. (Never leave transfer knob at an intermediate position.) An indicator light adjacent to the control transfer knob informs the pilot when the remote turn control is in control of the airplane.



DIRECTIONAL PANEL TURNS

Manual Turns

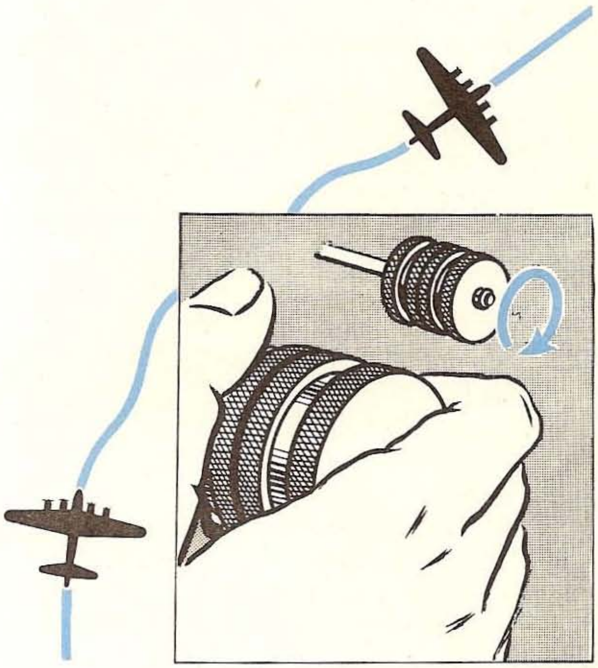
When you desire to turn the airplane, you can disengage both clutches and manually displace the autopilot clutch either by the autopilot clutch arm or by turning the bombsight. To make your turns smooth, you displace the autopilot clutch arm slowly. When the arm is against either stop, the airplane banks 18° in a coordinated turn. Moving the arm to the left turns the airplane to the right, and vice versa. As the airplane comes on the desired heading, move the autopilot clutch arm to center and engage whichever clutch is desired. If you are starting a bombing run, engage the bombsight clutch. The autopilot will maintain the new heading until the autopilot clutch is again displaced.



Turns Through the Bombsight

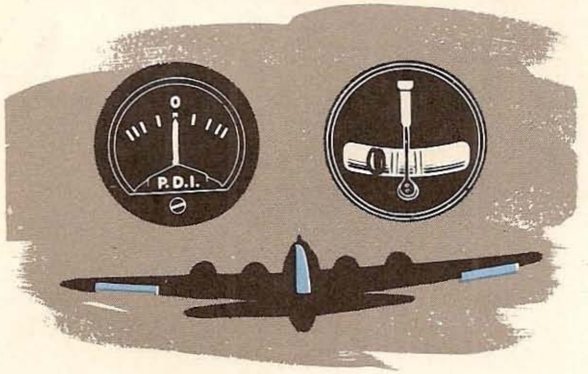
In bombing with the autopilot, you direct the airplane by use of the bombsight course knobs. The bombsight clutch is engaged; thus the stabilizer holds the sight on a fixed heading. The autopilot clutch must be disengaged so that the bombsight can control the airplane.

Turning both or either of the course knobs clockwise will turn the airplane to the right. The degree of bank and turn is determined by the rapidity at which you turn the course knob or knobs. By continuously turning the knobs, you can keep the airplane in a turn. As the airplane comes on the desired heading, you stop turning the knobs, and the directional gyro through the bombsight will maintain the new heading.



MALADJUSTMENTS AND THEIR CORRECTION

1. PDI CENTERED, BALL NOT CENTERED, IN STRAIGHT FLIGHT

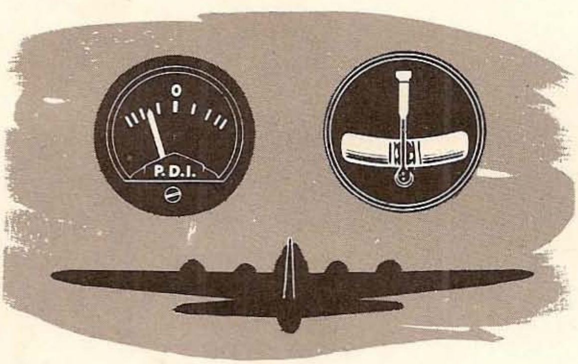


This condition is caused by improper trimming or centering with one wing low and opposite rudder applied to keep the airplane from turning. To correct:

1. Readjust aileron and rudder centering, **or**

2. Disengage both rudder and aileron switches and re-center PDI; adjust centering and re-engage rudder and aileron switches.

2. BALL CENTERED, BUT PDI OFF

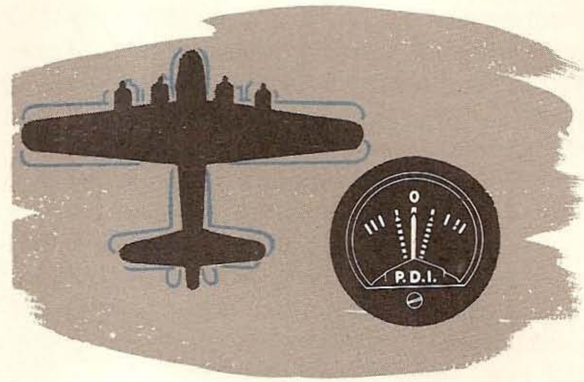


To correct:

1. Readjust rudder centering, **or**

2. Disengage both rudder and aileron switches and re-center PDI; adjust centering and re-engage rudder and aileron switches.

3. OVER-CONTROL IN RUDDER AXIS



This is caused by improper setting of ratio or dashpot. To correct:

1. Loosen locking collar and unscrew dashpot slowly. Stop at the point where over-control ceases, and re-lock.

2. If loosening the dashpot does not eliminate over-control, reduce rudder ratio. After changing the ratio, check rudder centering and the rudder compensation adjustments; then tighten dashpot to a setting just below that which produces over-control.

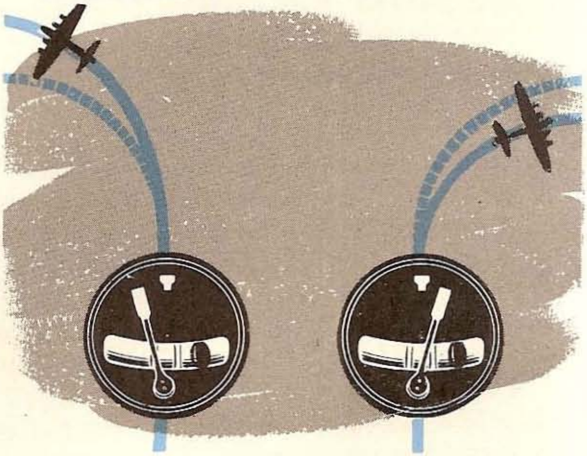
4. TURNS COORDINATED IN ONLY ONE DIRECTION

Plane not properly trimmed before starting turns. To correct:

1. Return to level flight and readjust aileron and rudder centering, **or**

2. Disengage rudder and aileron switches and retrim manually before re-engaging.

5. AIRPLANE SKIDS WHEN TURNING ONE DIRECTION AND SLIPS WHEN TURNING THE OTHER DIRECTION



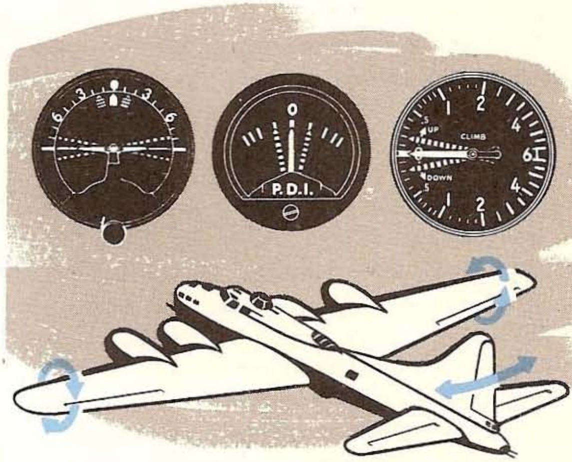
To correct:

1. Disengage autopilot and check manual trim of airplane; re-center and re-engage autopilot.

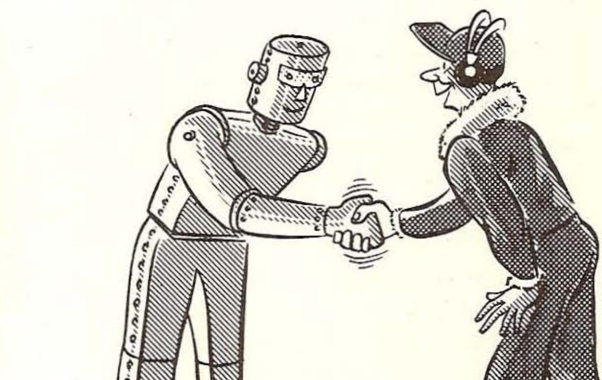
6. LOSS OR GAIN OF ALTITUDE

1. In straight and level flight, correct by using the elevator centering knob.
2. In bombardier's turn, adjust elevator compensation and increase elevator ratio. On a bombing run, maintain altitude by use of elevator centering knob.

7. AIRPLANE WALLOWS OR LACKS STABILITY



To correct: For a condition of general lack of stability, increase sensitivity adjustments. Also inspect cable tensions, as loose control cables are a common cause of sloppy aileron action. Since the rudder and elevator servos are close to the surfaces which they control, very little cable trouble is encountered on these two axes.



BE A BETTER BOMBARDIER!!

KNOW YOUR AUTOPILOT

C-1 AUTOPILOT NOMENCLATURE

Aileron engaging switch—Located on the ACP and marked "Ail." It is used to engage the aileron control of the autopilot.

Aileron trimming screw—Located on ACP between sensitivity and ratio knobs. Marked with an "A." Regulates intensity of aileron signal from the turn control.

Amplifier—Used to amplify, analyse, and relay signals to the proper servo units.

Autopilot clutch—Located on the top of the stabilizer. It transmits the stability of the directional gyro to the directional panel.

Autopilot clutch engaging knob—Located on autopilot clutch and is used to engage autopilot clutch to the directional gyro.

Autopilot connecting rod—It connects the autopilot clutch to the drift gear clutch, allowing turns to be made from the bombsight through the directional panel.

Autopilot control panel (ACP)—Located in pilot's compartment. It is an assembly of switches and knobs used for engaging and adjusting C-1 autopilot for proper flight.

Autopilot master switch—Located on the ACP and marked "MSTR." It completes or breaks the circuits to the servo motors, flight gyro, rotary inverter, and amplifier.

Centering knobs—The first lateral row of knobs located on the ACP. They are used to trim the autopilot electrically.

Compensation knobs—Last lateral row of knobs located on ACP. They are used to coordinate turns made from directional panel.

Control transfer knob—Located at lower left hand corner of ACP. Transfers control of the airplane from turn control in the ACP to remote turn control.

Dashpot—Located on rear left side of the stabilizer, used to accelerate initial rudder correction from directional panel.

Directional panel—Located on left side of stabilizer. It provides a means by which you can maneuver the airplane to make properly banked turns with bombsight while flying under autopilot control.

Directional panel arm—It connects the autopilot clutch to the operating parts of the directional panel.

Directional arm lock—Located on rear of stabilizer. It locks autopilot clutch arm during turns made from turn control.

Elevator engaging switch—Located on ACP and marked "ELEV"; used to engage elevator control of the autopilot.

ECO switch—Located in directional panel. Energizes erecting cutout mechanism when PDI is moved $1\frac{1}{2}°$ off center.

Erecting cutout mechanism — Located on flight gyro. It releases the lateral erecting mechanism whenever airplane is in a turn.

Erecting mechanism—Located on flight gyro. It is used to keep gyro in the vertical.

Flight gyro—Located near airplane's center of gravity. It provides stability about pitch and roll axes of the airplane.

Junction box—Used to connect electrical wiring of the various units of autopilot.

Ratio knobs—The third lateral row of knobs located on ACP. Regulates amount of control applied for any given deviation.

Rotary inverter—A motor generator that changes direct current supplied by batteries of the airplane into alternating current for use in amplifiers and bridge circuits.

Rudder engaging switch—Located on the ACP and marked "RUD". It is used to engage the rudder control of the autopilot.

Rudder trimmer screw — Located between sensitivity and ratio knobs on ACP. It is marked with an "R". It regulates intensity of rudder signal from turn control.

Sensitivity knobs—The second lateral row of knobs located on ACP. They are used to regulate how far airplane can deviate before a correction is put in by autopilot.

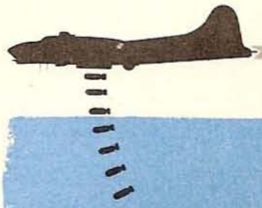
Servo—(Aileron, Rudder, Elevator)—These three units supply the force to move the three control surfaces of the airplane.

Servo-PDI switch—Located on ACP and marked "SERVO-PDI". It completes the circuit to the torque unit and the PDI.

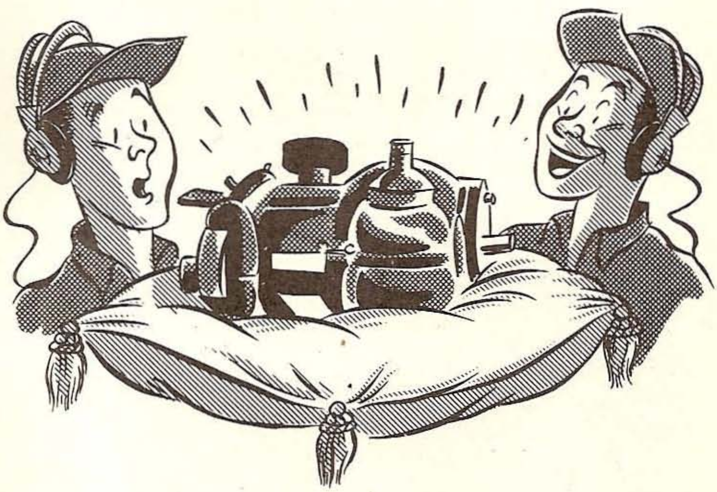
Tell-tale lights—Located on upper part of ACP. They indicate an unbalanced or balanced electrical circuit.

Turn control—Located on upper left corner of ACP. It provides a means for changing airplane's heading while flying under autopilot control.

SECTION 4



M-Series Bombsight



INTRODUCTION

The Norden or M-Series bombsight is a synchronizing, precision instrument. Synchronization means adjustment of flight path and travel of the optical system so that the bomb will be released at the proper point.

The Norden sight is of American design and construction. There are several models in use, among them the M-4, M-6, M-7, and M-9. The even-numbered models use 12 volts direct current; the odd-numbered models use 24 volts. The reason for the voltage difference is that the newer bombers have 24-volt circuits.

These four models are very much alike in principle and operation. If you learn to use any one of them, you can use all of them.

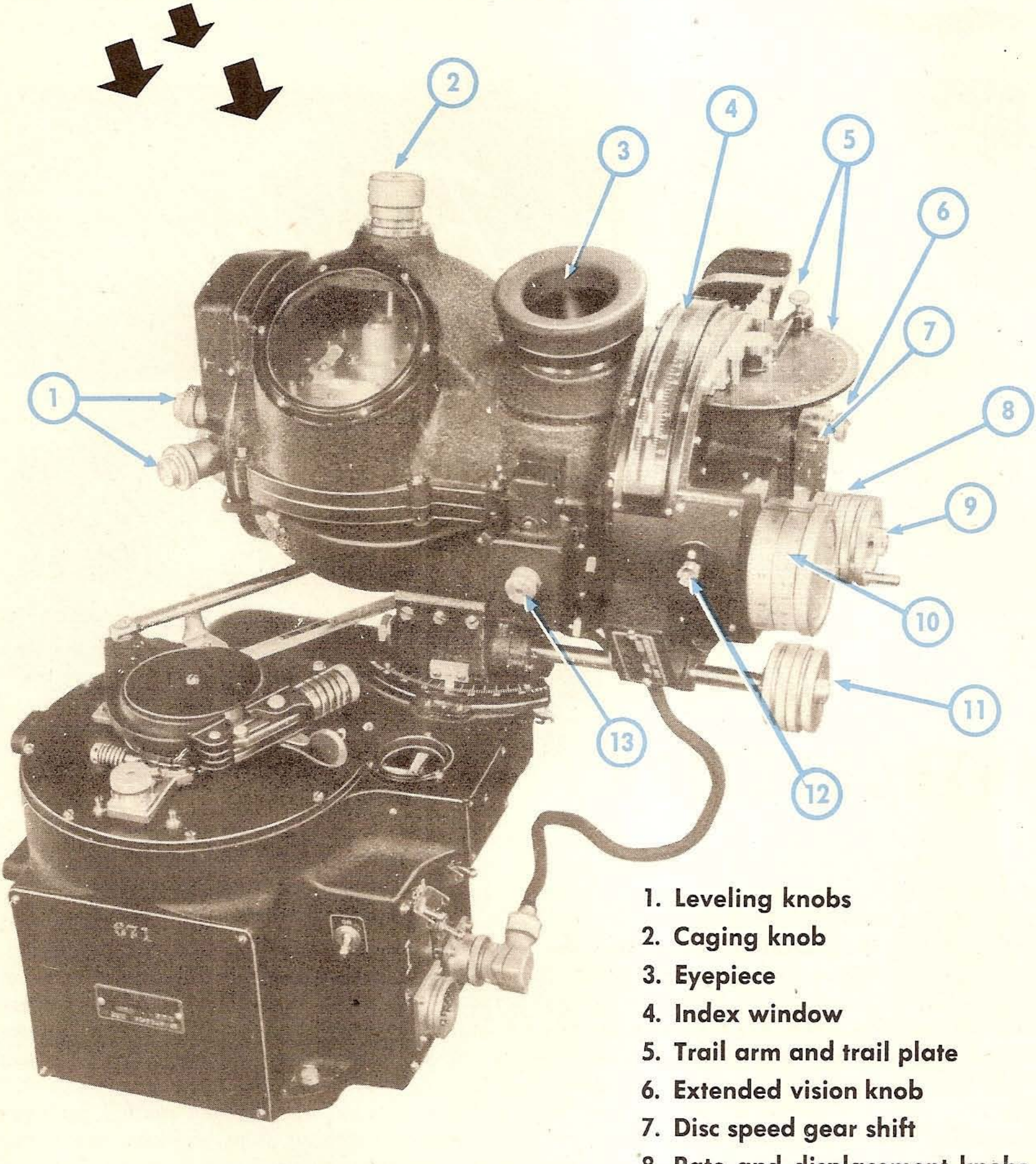
The Norden sight will seem complex to you at first. Don't expect to learn it in one day. You will master it, as hundreds have before you, by taking it up step by step, part by part.

These parts and steps are inter-dependent, so you should learn each of them thoroughly. The better you understand the construction of this instrument, the better you will understand how to operate it. Frequent reviews will help you remember the material you have covered.

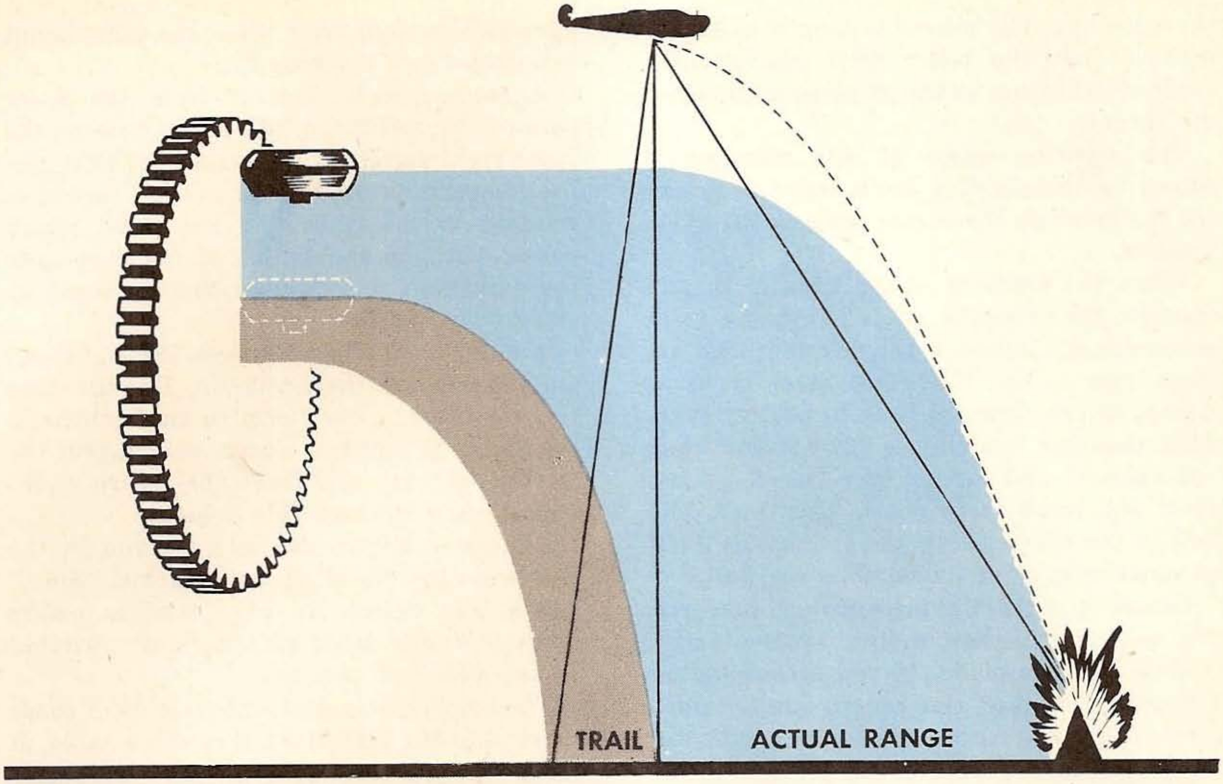
You will use the Norden mainly for synchronous bombing. You will also use it for fixed angle bombing.

From your study of the bombing problem you know what the bombsight must do. Always keep the bombing problem in mind. Remember that the sight solves the bombing problem for you ONLY IF YOU SET IN THE CORRECT DATA AND OPERATE THE SIGHT PROPERLY.

M-SERIES BOMBSIGHT



1. Leveling knobs
2. Caging knob
3. Eyepiece
4. Index window
5. Trail arm and trail plate
6. Extended vision knob
7. Disc speed gear shift
8. Rate and displacement knobs
9. Mirror drive clutch
10. Disc speed drum
11. Turn and drift knobs
12. Tachometer adapter
13. Crosshair rheostat



Solving the Range Problem

The bombsight has two main units — the sighthead and the stabilizer. The sighthead is attached to the stabilizer by a pivoting connection and two locking pins.

The sighthead's principal function, solving for range, is carried out by three main parts.

1. The rate end, which computes the exact release point for the bomb.

2. The optical system, through which you observe the target.

3. The vertical gyro, which stabilizes the optics so that roll and pitch of the airplane will not move the line of sight from target.

The rate end combines the values of ATF, groundspeed, and trail to compute the dropping angle. From the bombing tables, you get the values of ATF and trail and set them into the sight. Then groundspeed remains the only unknown factor. You use the rate knob, on the rate end, to solve for it.

By turning on the rate motor switch, you start a motor which turns a disc in the rate end. The speed at which the disc turns represents ATF. You set in the desired speed by positioning the disc speed drum. To find the correct disc speed setting, you divide ATF into the bombsight constant, 5,300.

The disc drives a roller which can be moved from the center of the disc to its upper edge. When the roller is in the center of the rotating disc, it does not turn; when it is just off center, it turns very slowly. The farther you move the roller from the center of the disc, the more rapidly the roller turns. You control the position of the roller on the disc with the rate knob and the trail arm.

You set in trail by moving the trail arm to the desired position on the trail plate. This moves the roller out from the center of the disc a distance proportional to trail. Then looking through the optics, you turn the rate knob until the lateral crosshair appears to stay on the target. By doing this, you have moved the roller an additional distance on the disc. This additional distance is proportional to actual range. The distance from the center of the disc to the roller is then proportional to whole range and the roller's speed of rotation is proportional to groundspeed.

At the same time that the rate knob positions the roller on the disc, it positions the dropping angle index on the tangent scale, thus setting up the correct dropping angle.

The roller drive is transmitted to a mirror which reflects the image of the target into the telescope. The mirror is hinged in such a manner that the roller drive changes the angle of reflection as the airplane approaches the target.

The sighting angle at any moment is shown by the sighting angle index. You can see the index on the degree scale in the index window.

When the sighting angle index is exactly opposite the dropping angle index, the sight automatically releases the bomb if the release lever is up. There are three types of release levers. One you have to hold up manually. Another locks in the ON position when you raise it and has to be released by you after the bomb is released. The third, you lock in the ON position and it releases itself automatically after the bomb is released.

Before you start synchronizing, however, you must get the line of sight on the target. You do this manually. If you are at higher altitudes, you use the search knob, which gives rapid displacement of the mirror for sighting angles from 70° to 0°. When you pick up the target, you engage the mirror drive clutch to connect the drive of the roller to the mirror.

At lower altitudes, when you need more than 70° forward vision, you use the extended vision knob, which permits vision up to 90°. When using the extended vision knob, the mirror drive clutch is not engaged until a sighting angle of 70° is reached.

If you desire to move the crosshair while the mirror drive clutch is engaged, use the displacement knob. This changes the position of the crosshair without changing the speed at which the roller drives.

The vertical gyro stabilizes the optics in roll and pitch. The gyro and optics ride on pivots which have the same effect as a universal joint, making it possible for the gyro and optics to stand upright and hold their own horizontal plane regardless of pitching and rolling of the airplane.

The fore and aft bubble and the lateral bubble (spirit levels) are on top of the gyro. You level the gyro with the fore and aft leveling knob and the lateral leveling knob, which are on the left end of the sight case. The caging knob is on the sighthead directly over the gyro. You use this knob to lock the gyro to the sight case when the gyro is not being used on a bombing run.

A stem, which projects from the lower part of the sighthead, fits into a hole on the front right corner of the stabilizer. This connection permits the sighthead to be turned in relation to the stabilizer. The shaft which passes through the center of the stem into the sighthead is locked to the stabilizer by the dovetail locking pin.

Another connection between the sighthead and stabilizer is the clevis pin. This attaches the bombsight clutch arm to the sighthead. When the bombsight clutch is engaged, the directional gyro stabilizes the entire sighthead in yaw through this linkage.

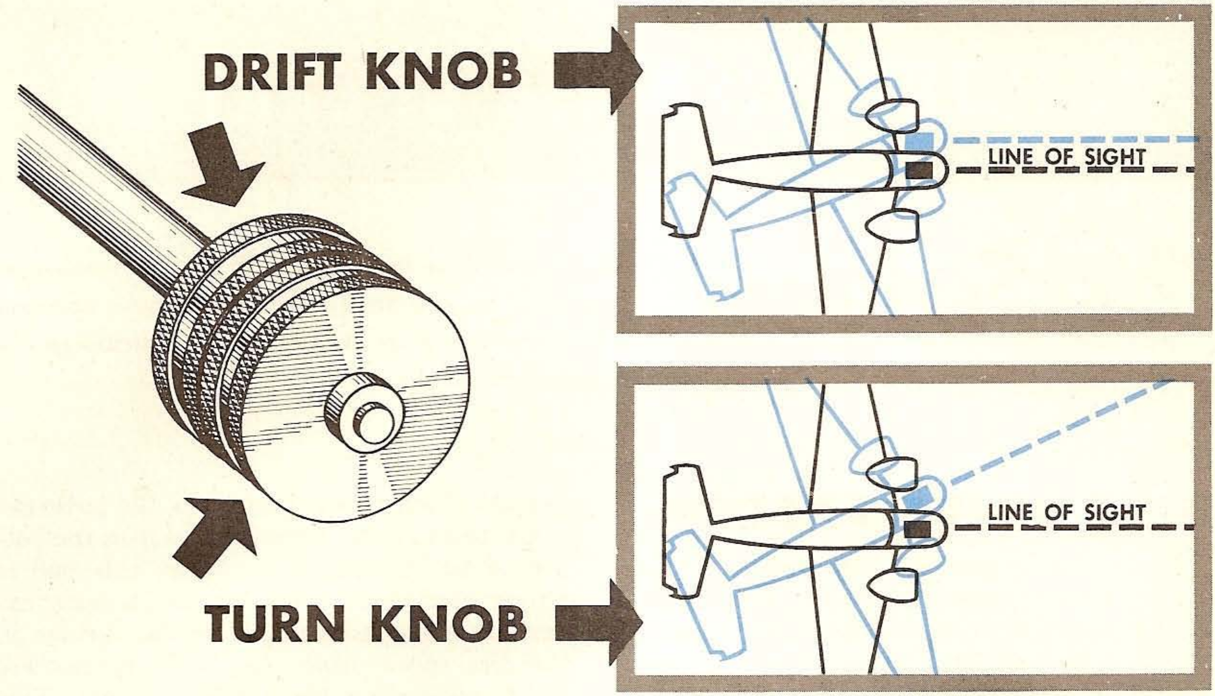
To turn on the directional gyro, you flip the switch on the stabilizer case marked "Stab." Leave this switch on three minutes before turning on any other switch. Other switches on the stabilizer case are:

The bombsight switch, marked "BS," sends current to the sighthead through a cable. It turns on the vertical gyro and the bubble light.

The switch, marked "PDI," energizes the PDI circuit to the Pilot Director Indicator.

The torque unit switch, marked "Servo," energizes the torque unit.

The directional gyro does not have enough power to maintain stability without some aid. This aid comes from the torque unit, which holds the spin axis of the gyro horizontal in relation to the stabilizer case.



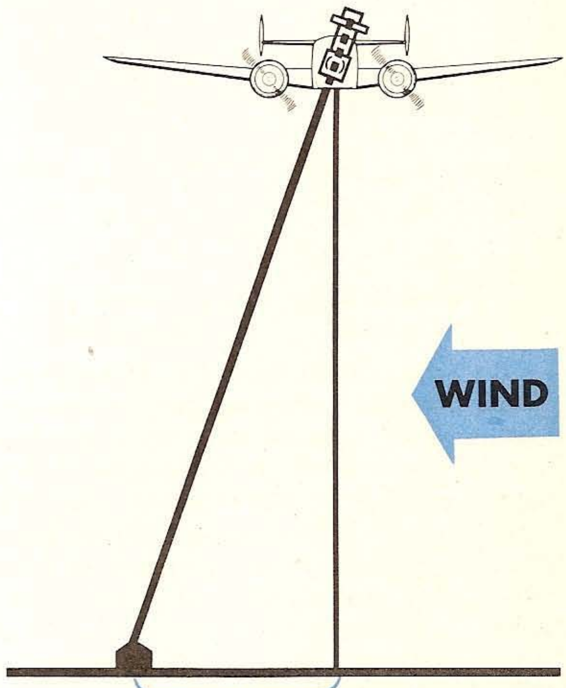
Solving the Course Problem

You use the course knobs to make drift and course corrections. These knobs, concentrically mounted, are on the lower right side of the sighthead. The turn knob, the outer of the two, changes the line of sight and the airplane the same amount. The inner knob is the drift knob, which changes the heading of the airplane without changing the line of sight. Therefore, you establish drift angle by use of the drift knob. Although it is correct to use the turn knob alone, you never single-grip the drift knob. You always use it in conjunction with the turn knob (double grip), in order to establish the drift angle and displace the line of sight toward the target in one operation. You can read the drift angle from the drift scale, which is on the stabilizer.

The PDI, an electrical device, signals to the pilot the corrections to make in the heading of the airplane when you use the course knobs.

Solving for Crosstrail

When drift and trail are combined, the result is crosstrail. The crosstrail mechanism, in the sighthead, **automatically** combines the two factors and gives crosstrail. In doing this, the mechanism tilts the telescope laterally so that the angle between the line of sight and vertical subtends crosstrail distance on the ground.



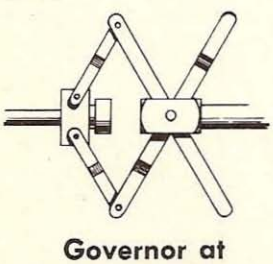
CONSTRUCTION and OPERATION

The Sighthead

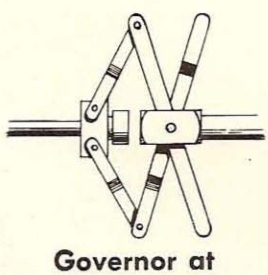
The sighthead is the upper unit of the bombsight assembly. As you have learned, its main purpose is to solve the range problem and to stabilize the optics in roll and pitch.

DISC DRIVE SYSTEM

When you turn on the rate motor switch, you start a shuntwound motor, which furnishes power to drive the disc. This type of motor is used because its speed can be controlled for any actual time of fall. One of the devices for controlling the motor's speed is the governor, which is on the armature shaft of the motor. The governor has two metal arms, which are pivoted at their center to the shaft in such a way that they form an X-shape. As the motor speed increases, centrifugal force causes the metal arms of the X to close toward an I-shape, like a pair of scissors.



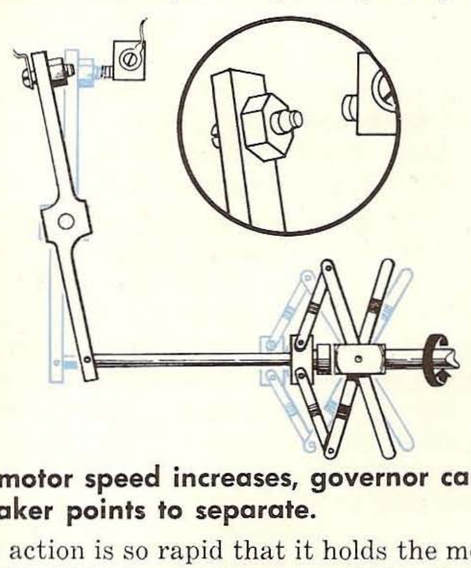
Governor at low speed.



Governor at high speed.

Connecting links from the governor are attached to the bottom of the breaker arm, which has as its pivot point the shaft from the disc speed drum. A breaker point is on the upper end of the breaker arm. The springs in the disc speed drum, acting through the shaft of the drum, tend to rotate the breaker arm so as to keep its breaker point against the fixed point on the case. Current will flow to the rate motor as long as these points are closed, with the rate motor switch on.

As the motor speed increases, the governor arms tend to close, exerting a pull on the bottom of the breaker arm. When this pull is strong enough to overcome the tension exerted on the breaker arm by the springs in the disc speed drum, the breaker arm will pivot, separating the breaker points. This cuts off current to the motor. As the motor slows down, the governor's force lessens, allowing the disc speed drum springs to close the breaker points. This sends current back to the rate motor, causing it to pick up rpm.

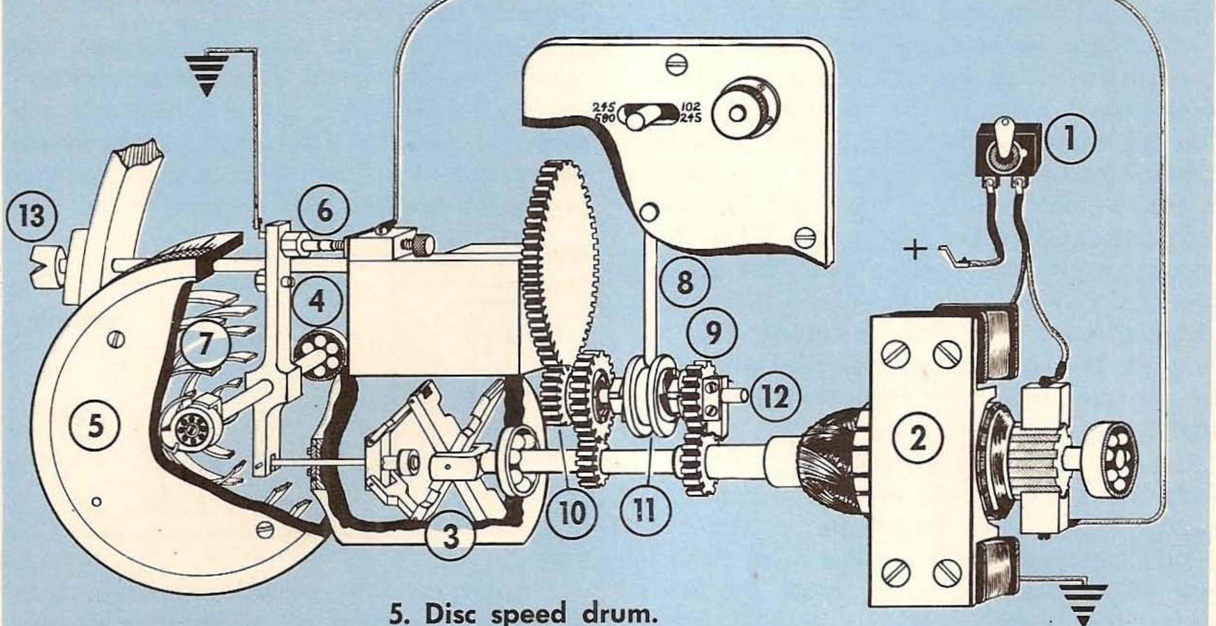


As motor speed increases, governor causes breaker points to separate.

This action is so rapid that it holds the motor speed within one-tenth rpm of the desired constant speed.

You set the desired constant speed on the disc speed drum. This drum contains two flat coil springs, one of which is in operation throughout the entire range of the drum. The other spring operates only through the last half of the range. On the disc speed drum

DISC DRIVE SYSTEM

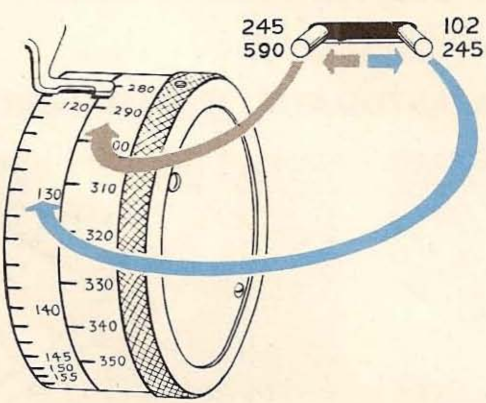


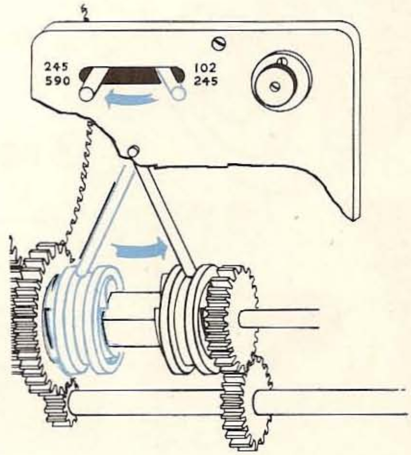
1. Rate motor switch.
2. Rate motor.
3. Governor.
4. Breaker arm.
5. Disc speed drum.
6. Breaker points.
7. Disc speed drum springs.
8. Disc speed gear shift.
9. Idling gears.
10. Pinion gear.
11. Clutch.
12. Idling gear shaft.
13. Tachometer adapter.

there are two scales. The inner scale, in black figures, gives disc speeds from 102 to 245 rpm. The outer scale, in red figures, gives disc speeds from 245 to 590 rpm.

In using either scale, you must set the disc speed gear shift to the proper disc speed range. The disc speed gear shift is a lever on the outside of the rate end, above the rate knobs. The range at which you set the lever is shown by numbers engraved in a plate on the rate end.

Two gears are mounted on the rate motor shaft so that they rotate whenever the motor is running. One gear is larger than the other. When they rotate, they turn two other gears which idle (turn freely) on another shaft. That is, they turn without turning the shaft. The ratio between these two idling gears is such that one turns faster than the other.





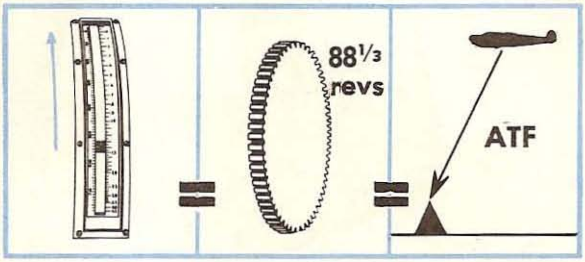
A pinion gear which drives the disc is attached to the same shaft on which the idling gears turn, and this shaft must turn in order to drive the disc. The shaft is turned by a clutch which fits on a squared portion of the shaft between the two idling gears. The turning of either idling gear can be transmitted to the clutch through gear teeth on the two outer faces of the clutch and the inner faces of the two idling gears. When the clutch engages the smaller gear, the idling gear shaft which drives the disc will turn at a higher speed than when the larger gear is engaged. The clutch is positioned to either of the two disc speeds by the disc speed gear shift.

The shaft on which the disc is mounted extends through the sight ease. A tachometer may be connected to the adapter on the end of this shaft, making it possible to check the exact disc speed. A spring holds the disc against the roller.

The sight is constructed so that the disc must make $88\frac{1}{3}$ revolutions during actual time of fall. That is, with no trail set in the sight, it requires $88\frac{1}{3}$ revolutions of the disc to drive the sighting angle index from the dropping angle index to zero.

Actual time of fall is given in **seconds.** You can find the disc speed, in **revolutions per second,** by dividing $88\frac{1}{3}$ by the ATF. It is much easier to read the disc speed in **revolutions per minute,** which can be obtained by multiplying the **revolutions per second by 60.**

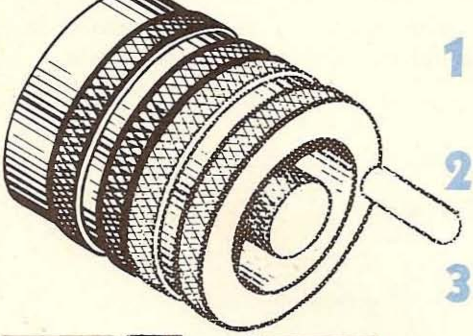
Without trail set in sight.



The disc speed in revolutions per minute to be set into the sight can be found in one calculation by dividing ($88\frac{1}{3} \times 60$) or 5,300 by ATF. The number 5,300 is called the sight constant.

RATE SYSTEM

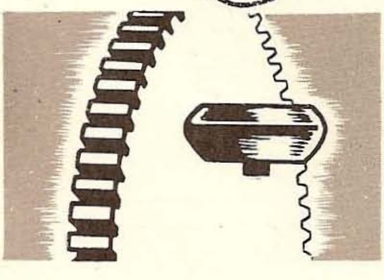
WHEN YOU TURN THE RATE KNOB, YOU DO THREE THINGS:

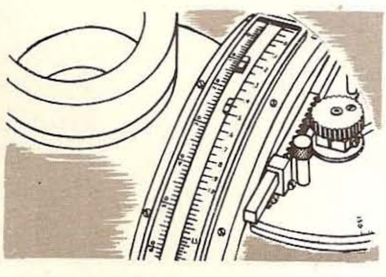


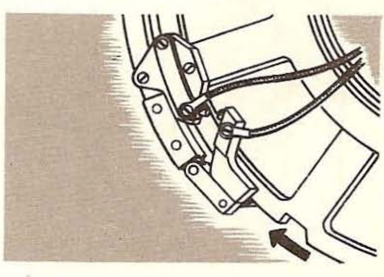
1 POSITION THE ROLLER ON THE DISC,

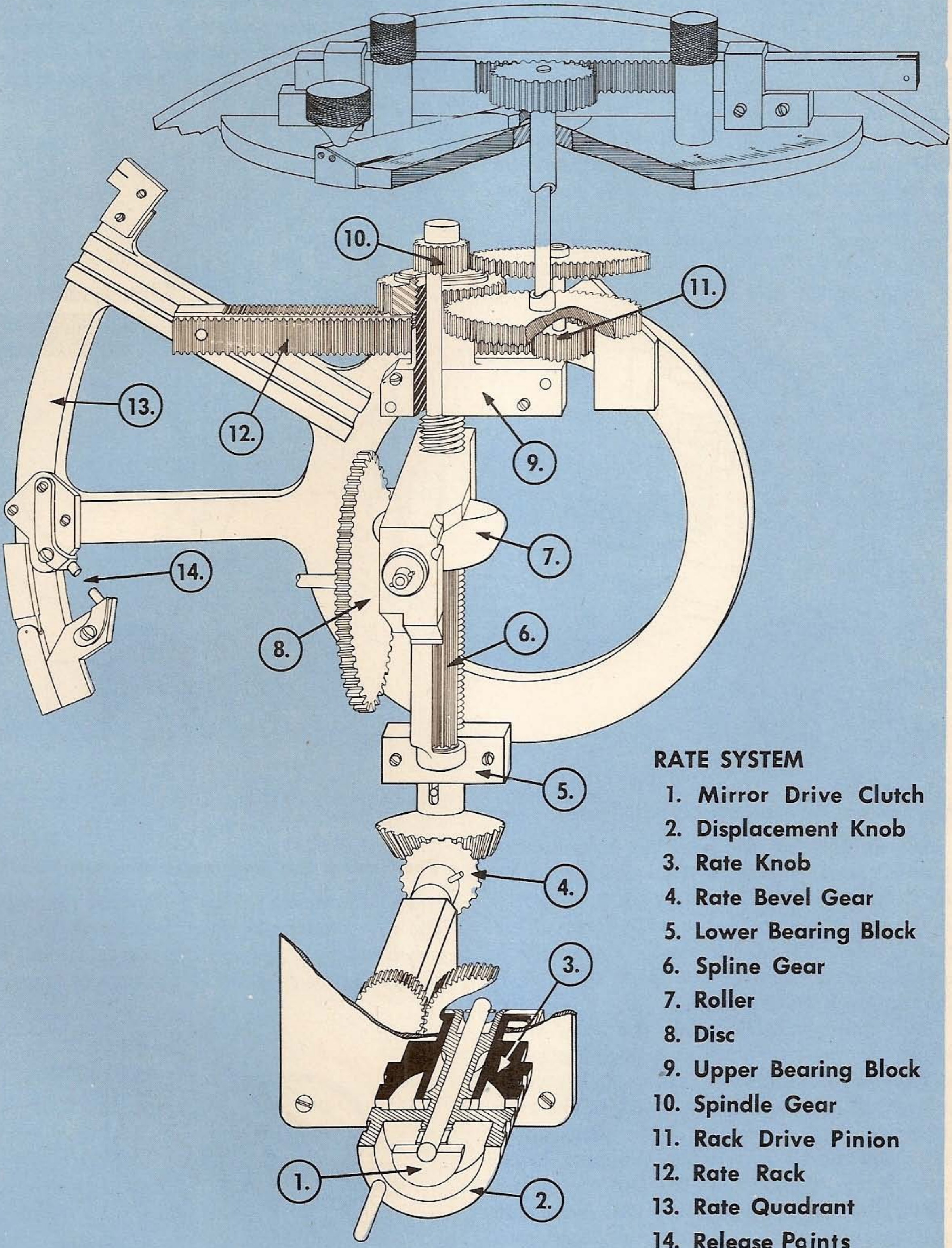
2 POSITION THE DROPPING ANGLE INDEX,

3 POSITION THE AUTOMATIC RELEASE POINTS







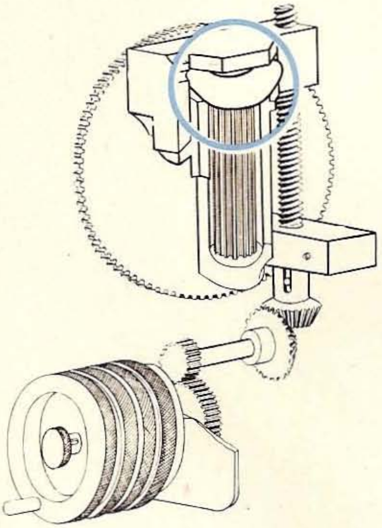


RATE SYSTEM

1. Mirror Drive Clutch
2. Displacement Knob
3. Rate Knob
4. Rate Bevel Gear
5. Lower Bearing Block
6. Spline Gear
7. Roller
8. Disc
9. Upper Bearing Block
10. Spindle Gear
11. Rack Drive Pinion
12. Rate Rack
13. Rate Quadrant
14. Release Points

Positioning the Roller on the Disc

The rate knob, through intermediate and bevel gears, turns the spindle screw. This screw is threaded through the roller carriage, in which the roller turns on a vertical axis. To understand how this operates, visualize the spindle screw as a bolt and the carriage as a nut on the bolt. The spindle screw (or bolt) cannot move, except to rotate; and the carriage (or nut) can move up or down on the threads but cannot rotate. Thus when the spindle screw is turned, the carriage moves up or down on its threads, thus positioning the roller on the disc.

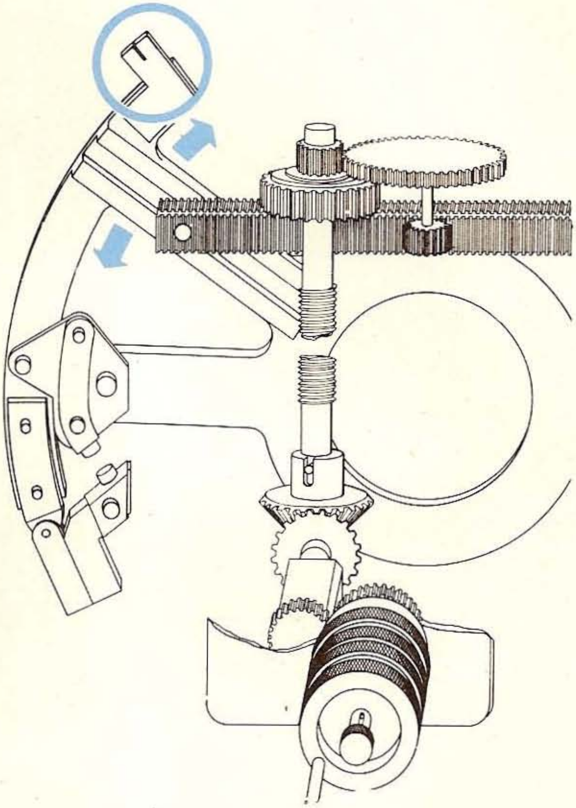


Positioning the Dropping Angle Index

As you position the roller by turning the spindle screw, you turn the spindle gear at the same time. The spindle gear is fastened to the upper end of the spindle screw. This gear is meshed to an intermediate gear which is on the upper end of the same shaft with the rate rack drive pinion.

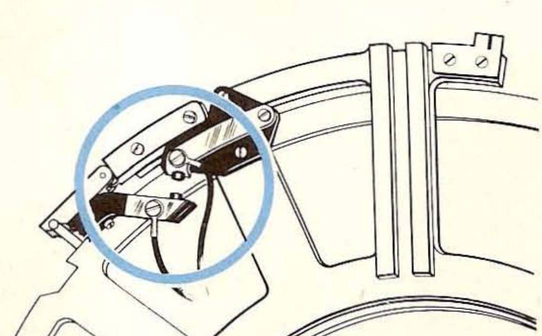
The pinion meshes with the rate rack, which changes the rotary motion of the gears to a linear motion of the rate rack. A stud in one end of the rack fits in a slot in the rate quadrant. Any movement of the stud causes the quadrant to move. The dropping angle index is mounted on the quadrant so you can see it through the index window. Thus you can see that by turning the rate knob you move the quadrant and position the index.

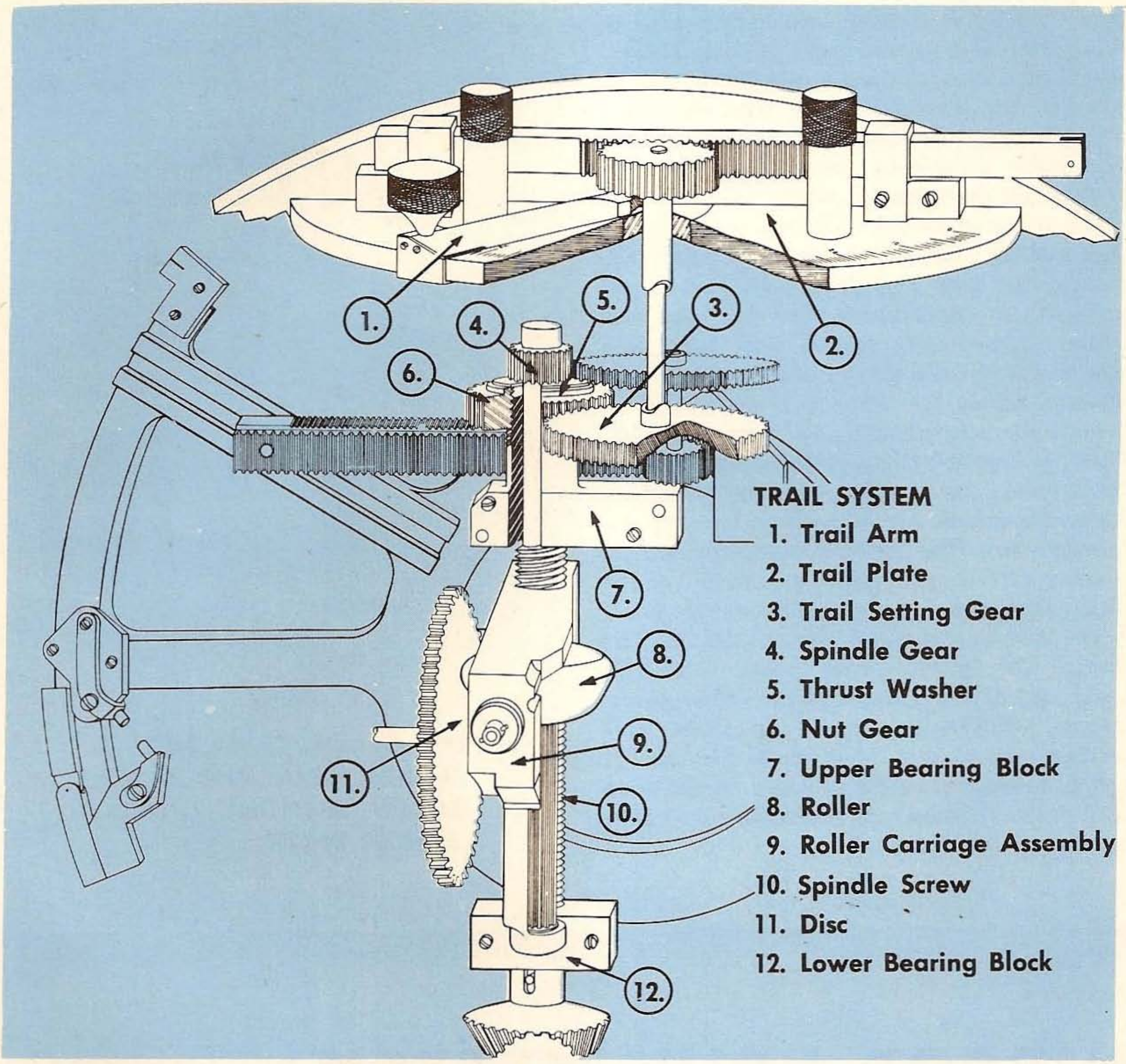
The tangent scale is calibrated in tangent values. Therefore, when you position the roller from the center of the disc to a distance proportional to whole range, you position the dropping angle index at the tangent of the angle that will subtend whole range. (This is true only when there is no trail in the sight.)



Positioning the Automatic Release Points

The automatic release points are located on the rate quadrant. When you move the rate quadrant, you position the points so that the bombs can be released at the correct moment.





TRAIL SYSTEM

You know from your study of the bombing problem that it is necessary to subtract trail from whole range to get actual range. You also know that when you have synchronized, the distance from the center of the disc to the roller is proportional to whole range.

To subtract trail, you must have some way to move the roller trail distance on the disc, without moving the dropping angle index. After this is done you use the rate knob to synchronize for the remaining distance, which is proportional to actual range. The position of the dropping angle index will then show you the tangent of the dropping angle that will subtend the actual range.

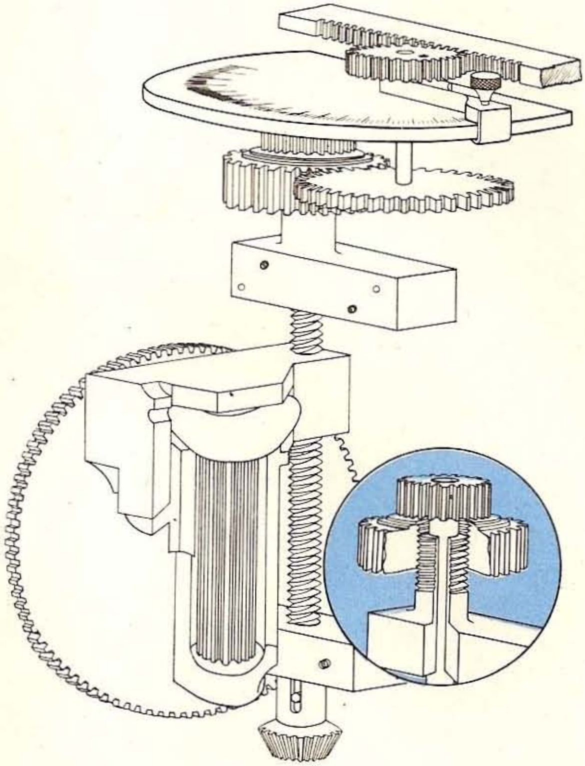
Moving the trail arm lifts the entire spindle screw and roller carriage assembly. This movement positions the roller on the disc without turning the spindle screw, without moving the dropping angle index, and without positioning the automatic release points. The amount of trail you set in is shown by the position of the trail arm on the trail plate. This plate is calibrated from 0 to 150 mils.

The spindle screw is supported in fixed

upper and lower bearing blocks. It is free to rotate and slide up and down in these blocks. The threaded part of the upper bearing block is called the threaded screw. The nut gear, which has gear teeth on the outside and regular screw threads on the inside, screws up or down on the threaded screw.

When you move the trail arm, you turn the trail setting gear, which turns the nut gear. Moving the trail arm from zero causes the nut gear **to climb upward on the threaded screw**. Immediately above the nut gear, around the spindle screw shaft, is the thrust washer. Above the washer, fixed solidly to the spindle screw shaft, is the spindle gear. Thus the upward climb of the nut gear lifts the washer, the spindle gear, **and therefore the whole spindle screw, without turning the spindle screw**. The thrust washer, acting as a bearing surface, prevents transmission of rotation from the nut gear to the spindle gear.

The spindle screw is raised against the tension of the thrust spring, which is on the lower end of the spindle screw. This spring insures positive, smooth action of the trail setting system and it returns the spindle screw, roller carriage and roller to the zero trail position when you return the trail arm to zero.



NUT GEAR LIFTS WASHER, SPINDLE GEAR AND SPINDLE SCREW WITHOUT TURNING SPINDLE SCREW.

MIRROR DRIVE SYSTEM

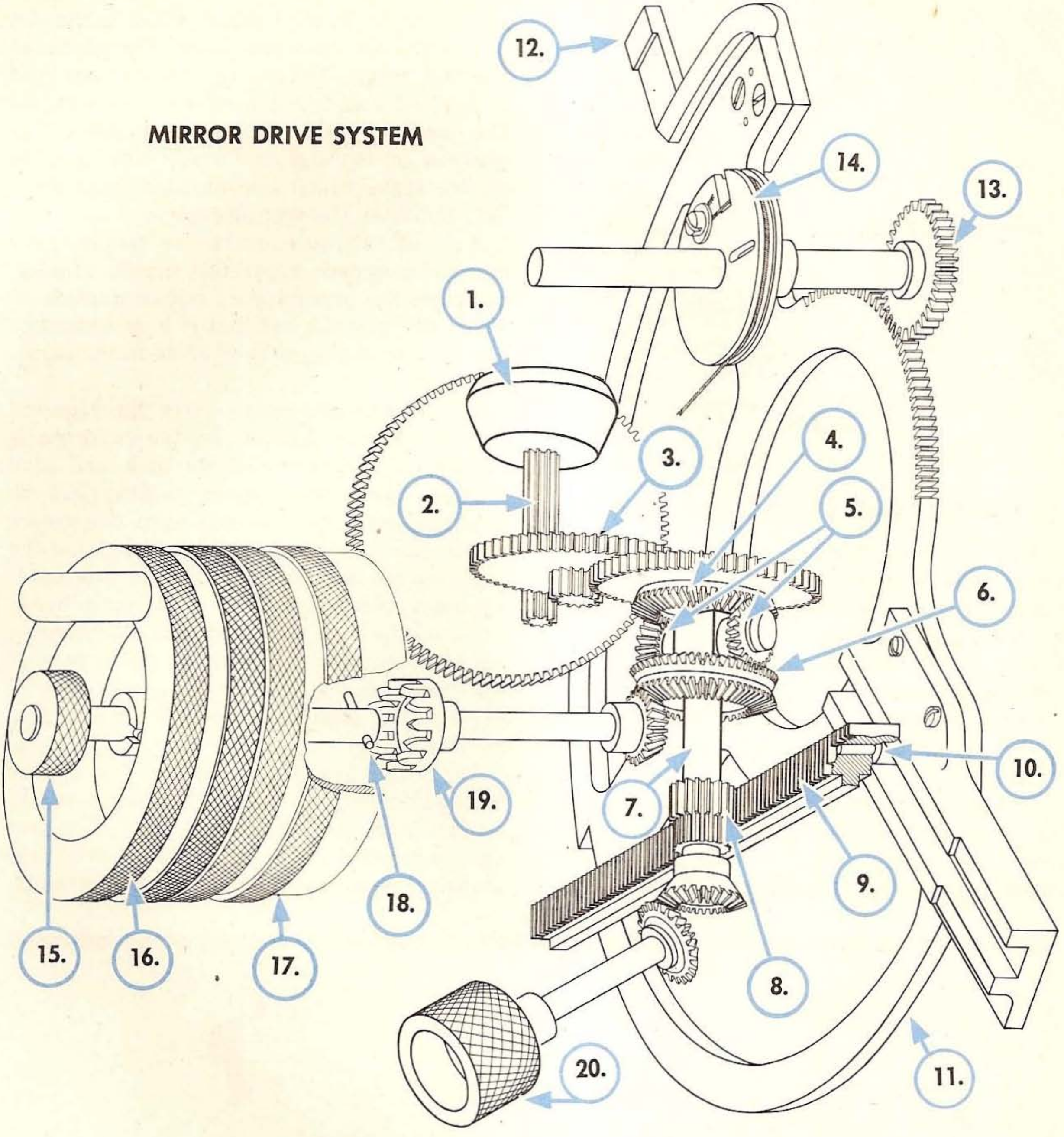
The mirror drive system is the mechanism by which the roller drives the mirror of the optical system. As the roller turns, it turns its shaft, which has gear teeth cut in it. This geared section of the shaft is the roller spline gear. This gear, through an intermediate gear, drives the upper traction gear, which is part of the T-head assembly.

The T-head assembly consists of the upper traction gear, the T-head gears, the lower traction gear, and T-head shaft. For a constant rate setting (constant roller position) the upper traction gear rotates at a constant speed or, when synchronized, at a speed proportional to groundspeed (or speed of closure in case of a moving target).

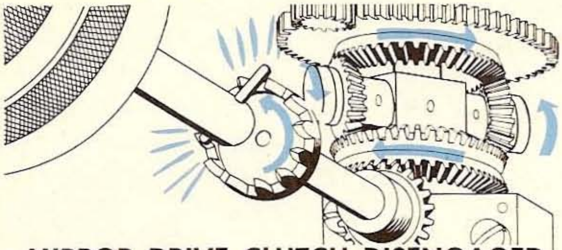
The upper traction gear and lower traction gear are mounted so that they are free to rotate on the T-head shaft. Between these gears and meshed to them are the T-head gears, which can revolve freely on a cross member of the T-head shaft.

As the upper traction gear turns, it turns the T-head gears. As the T-head gears turn, they must do one of two things: walk around the lower traction gear, thus rotating the T-head shaft, or cause the lower traction gear to rotate without rotating the T-head shaft.

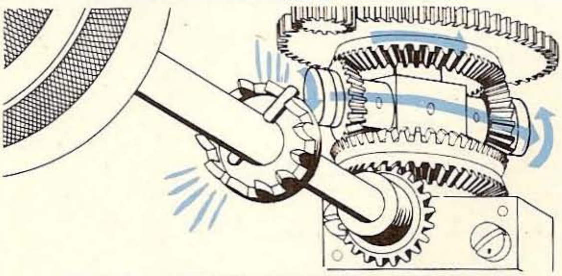
MIRROR DRIVE SYSTEM



1. Roller
2. Roller Spline Gear
3. Intermediate Gear
4. Upper Traction Gear
5. T-Head Gears
6. Lower Traction Gear
7. T-Head Shaft
8. Mirror Drive Rack Pinion
9. Mirror Drive Rack
10. Stud
11. Mirror Drive Quadrant
12. Sighting Angle Index
13. First Sheave Gear
14. #1 Sheave
15. Mirror Drive Clutch
16. Displacement Knob
17. Rate Knob
18. Male Part of Mirror Drive Clutch
19. Female Part of Mirror Drive Clutch
20. Search Knob



MIRROR DRIVE CLUTCH DISENGAGED



MIRROR DRIVE CLUTCH ENGAGED

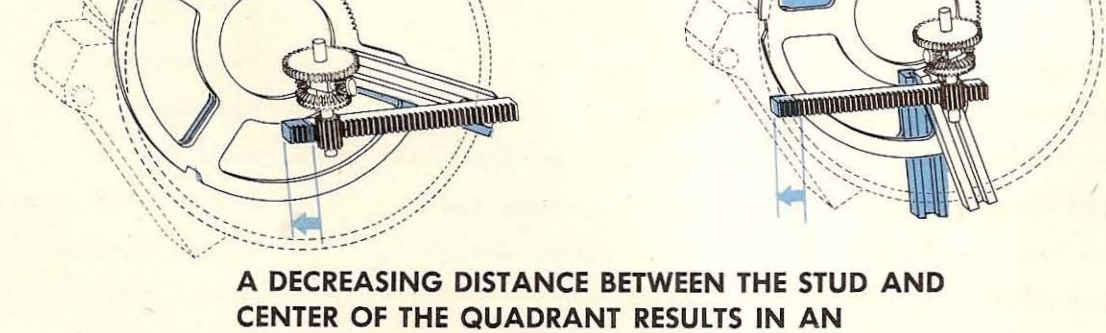
Whether the T-head gears walk around the lower traction gear or the lower traction gear rotates, depends on whether or not the lower traction gear is locked by the mirror drive clutch. If the mirror drive clutch is locked, the T-head gears will walk around the lower traction gear, thus rotating the T-head shaft. If it is not locked, the lower traction gear will rotate.

The mirror drive rack pinion is mounted on the T-head shaft, below the lower traction gear. The pinion meshes with the mirror drive rack. On the forward end of the mirror drive rack is the stud, which slides in the slot of the mirror drive quadrant. Therefore, as the rack moves, the sliding action of the stud in the slot causes the quadrant to move. On the quadrant is the sighting angle index. The position of the sighting angle index on the degree scale, which is calibrated from 0° to 70°, indicates the sighting angle.

As your airplane nears the target, your speed of approach apparently becomes faster, although the groundspeed remains constant. From this you can see that it is necessary to have an increasing rate of drive to the sighting angle.

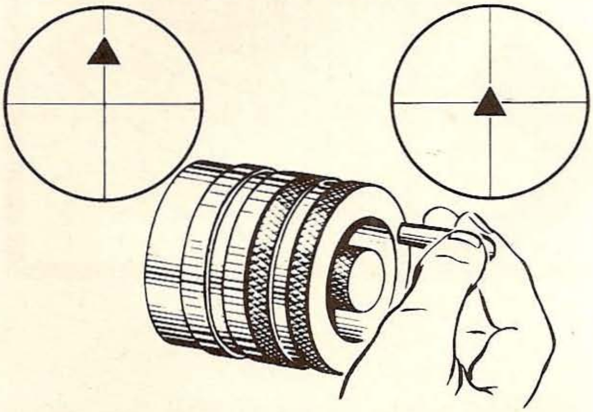
The stud-in-slot action gives the required increasing rate of drive. As the quadrant is driven by the mirror drive rack and stud (which move at a speed proportional to groundspeed), the distance from the center of the quadrant to the stud decreases, as the sighting angle index and the sighting angle approach zero. Therefore, a constant linear drive of the rack and stud and a decreasing distance between the stud and the center of the quadrant result in an increasing rate of drive to the quadrant. This is known as tangential speed.

Part of an arc of the quadrant has geared teeth. This part, known as the geared sector, meshes with the first sheave gear. The first sheave gear is attached by a shaft to the first sheave. The mirror drive cable, which trans-



A DECREASING DISTANCE BETWEEN THE STUD AND CENTER OF THE QUADRANT RESULTS IN AN INCREASING RATE OF DRIVE TO THE QUADRANT fers motion from the quadrant to the mirror is attached to the first sheave. As the sheave turns, it winds the cable on it, thus pulling the mirror at a speed proportional to the speed of the mirror drive quadrant.

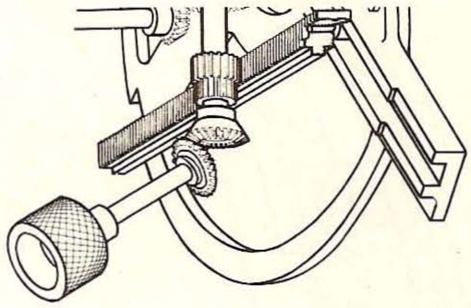
For any given groundspeed and bombing altitude, there is only one speed at which the mirror can be driven to keep the crosshairs on the target. To get this speed, you must put the roller in one certain position on the disc. You may get the roller to this position without having the crosshair on the target. Therefore, you need some method of positioning the crosshair, without changing the position of the roller on the disc. You do this with the displacement knob, which is attached to the shaft of the mirror drive clutch.



If the mirror drive clutch is engaged and you turn the displacement knob, you turn the clutch shaft which, through a bevel gear, turns the lower traction gear. By turning the lower traction gear, you may momentarily speed up or slow down the drive of the T-head shaft without changing the position of the roller on the disc.

The mirror drive clutch shaft is divided into two parts. On one is the male part of the mirror drive clutch. On the other is the female part. When you engage the mirror drive clutch, the two parts lock. Thus, the lower traction gear is locked to the displacement knob. If the two parts are not locked, you cannot change the position of the lateral crosshair by turning the displacement knob.

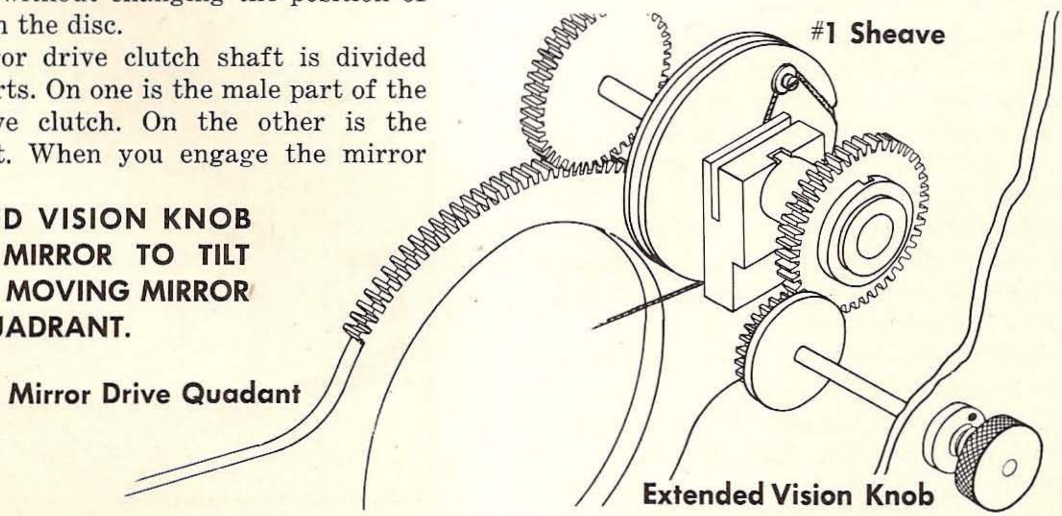
When you desire rapid displacement of the mirror to pick up the target or to roll the sighting angle index back to the 70° position, you use the search knob. This knob is connected by bevel gears to the T-head shaft. When you turn the search knob you rotate the T-head shaft manually. You cannot use the search knob when the mirror drive clutch is engaged.

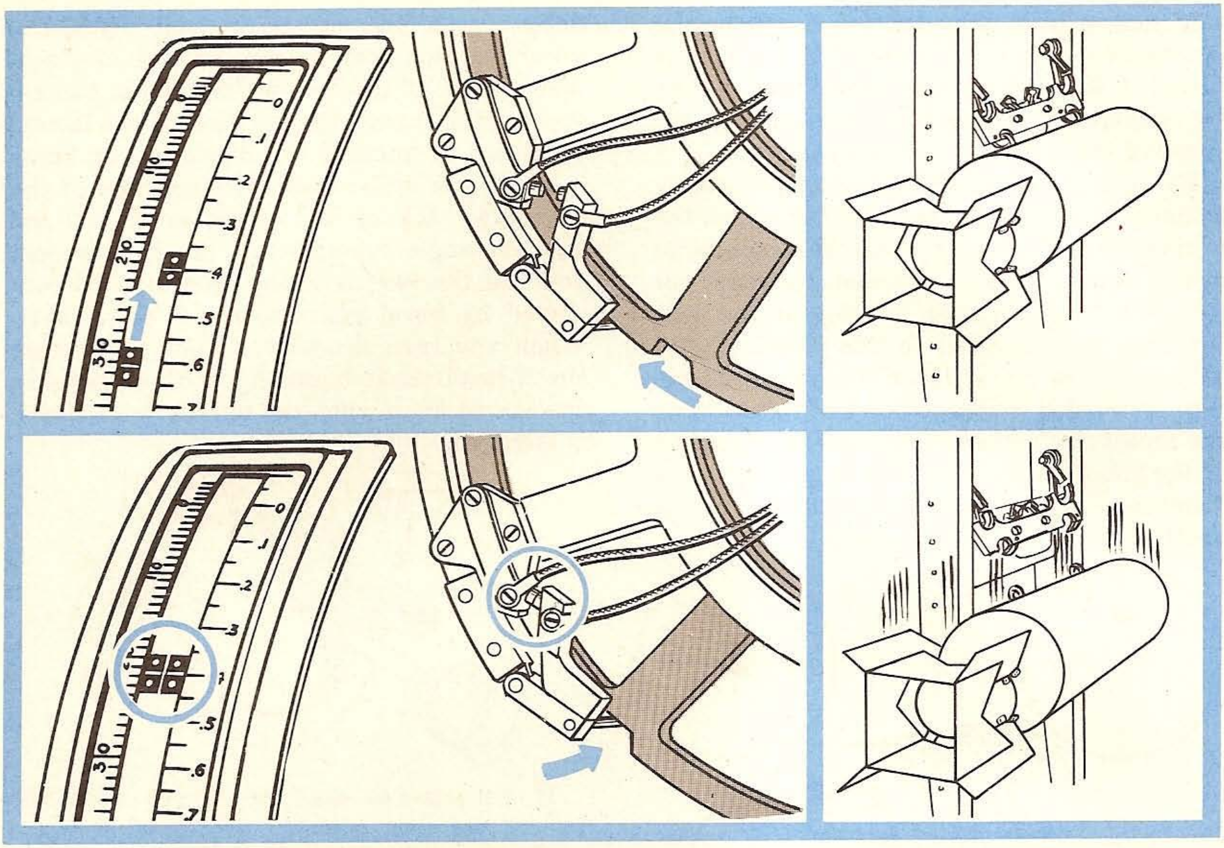


If you cannot see the target with 70° vision, you can get 20° additional forward vision by using the extended vision knob. This knob unlocks the first sheave from its shaft and turns the sheave to allow the mirror to tilt for the extra vision without moving the sighting angle index.

CAUTION: You cannot synchronize for rate while using extended vision. If you forget to return the extended vision knob to its normal position, your bomb will not be released at the proper point.

EXTENDED VISION KNOB ALLOWS MIRROR TO TILT WITHOUT MOVING MIRROR DRIVE QUADRANT.



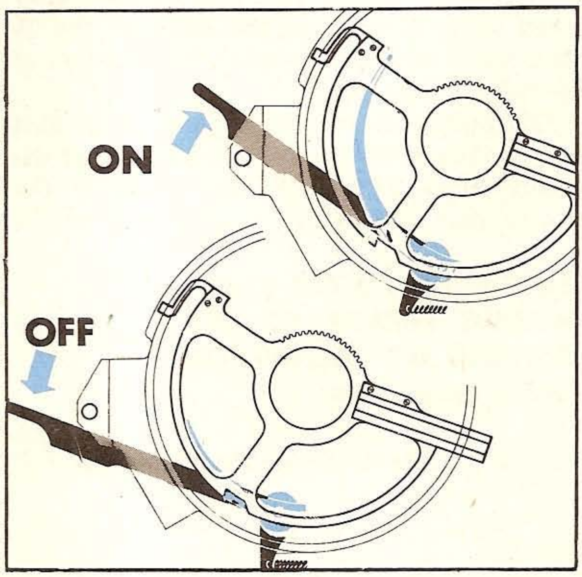


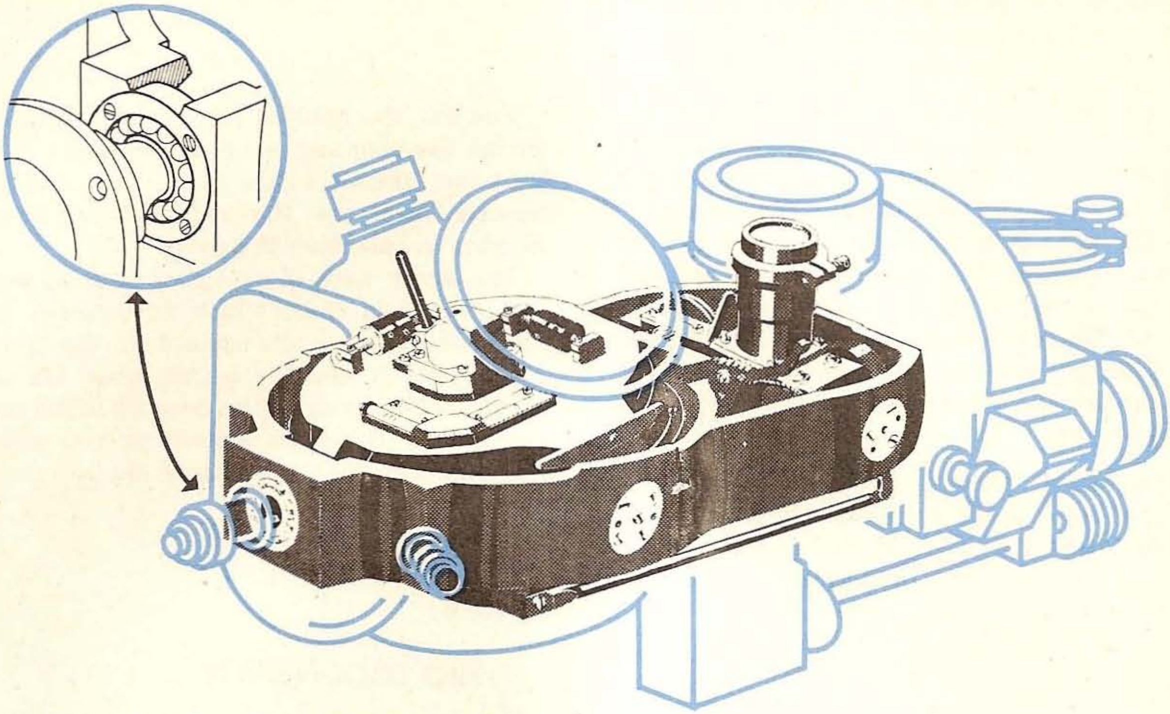
AUTOMATIC RELEASE MECHANISM

To make it unnecessary for you to release the bombs by manual controls, the sight has an automatic release mechanism. The main parts are the automatic release notch, automatic release points, and the release lever.

The automatic release notch is on the mirror drive quadrant. The automatic release points are on the rate quadrant and are placed so that a stud which extends from the pivoted release point rides on the edge of the mirror drive quadrant. When the sighting angle and dropping angle coincide, the stud drops into the notch, closing the points. This completes an electrical circuit to the bomb racks and releases the bomb.

The release lever is a safety device. When the release lever is in the OFF position a cam rides flush with the edge of the mirror drive quadrant, covering the automatic release notch. This keeps the stud from dropping into the notch. However, with the release lever in the ON position the cam is moved away from the notch and thus permits the automatic release points to close at the proper time.





CARDAN ASSEMBLY

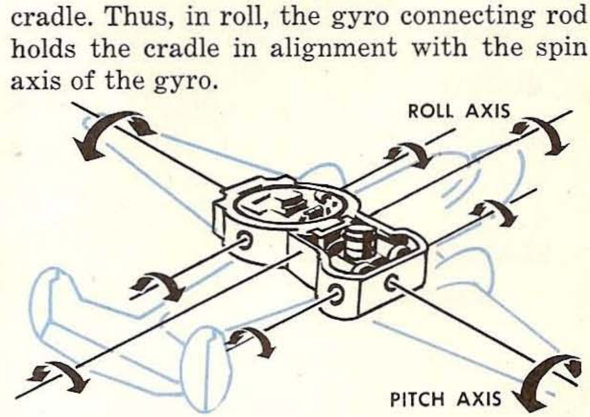
To understand how the mirror drive cable is connected to the mirror, you must first understand how the telescope cradle is stabilized by the cardan assembly. The assembly stabilizes the cradle both in pitch and roll. The main parts of the assembly are the cardan, the vertical gyro and the telescope cradle.

The cardan is a pear-shaped metal ring which is pivoted at both ends in the sighthead. From your position at the rear of the sight, when you are operating the sight, one of the pivots is at the left end of the sighthead and the other at the right end in the plate between the rate end and cardan assembly. The pivots are known as gudgeon bearings.

You can see from the position of the pivots that the cardan is free to turn in the pitch axis. In the right end of the cardan is the telescope cradle, which is mounted in fore and aft gudgeon bearings, so that the cradle is free to move in the roll axis. It moves with the cardan when the cardan turns in the pitch axis.

In the left part of the cardan is the vertical gyro, which also is mounted on fore and aft gudgeon bearings. The movement of the gyro in its fore and aft bearings is the same as that of the telescope cradle in the telescope cradle's bearings. Thus the stabilizing effect of the gyro is carried through its bearings to the cardan and to the telescope cradle, because both the telescope cradle and gyro are supported in the cardan by fore and aft bearings.

The telescope cradle is stabilized in roll by the gyro connecting rod. The rod extends from the bottom of the gyro housing to the bottom of the differential lever, which is attached to the lower part of the telescope cradle. Thus, in roll, the gyro connecting rod holds the cradle in alignment with the spin axis of the gyro.



THE VERTICAL GYRO

To stabilize the optics in roll and pitch, the axis of the gyro must be in the vertical. The housing which holds the gyro, so that its spin axis is vertical, is attached to the cardan.

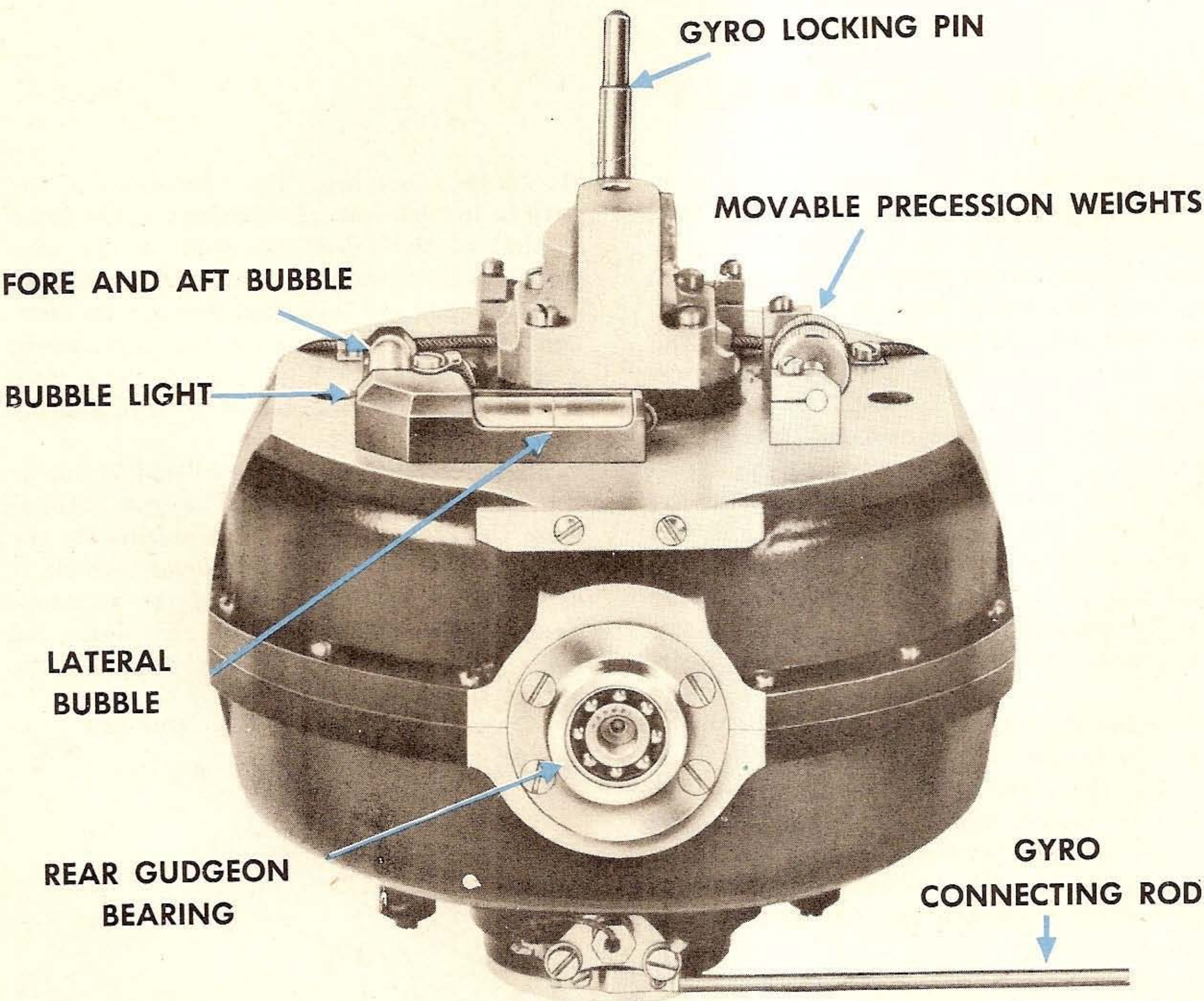
The gyro is a series-wound motor run by direct current. The current passes through carbon brushes to the commutator of the rotor. The rotor is driven at about 7,800 rpm.

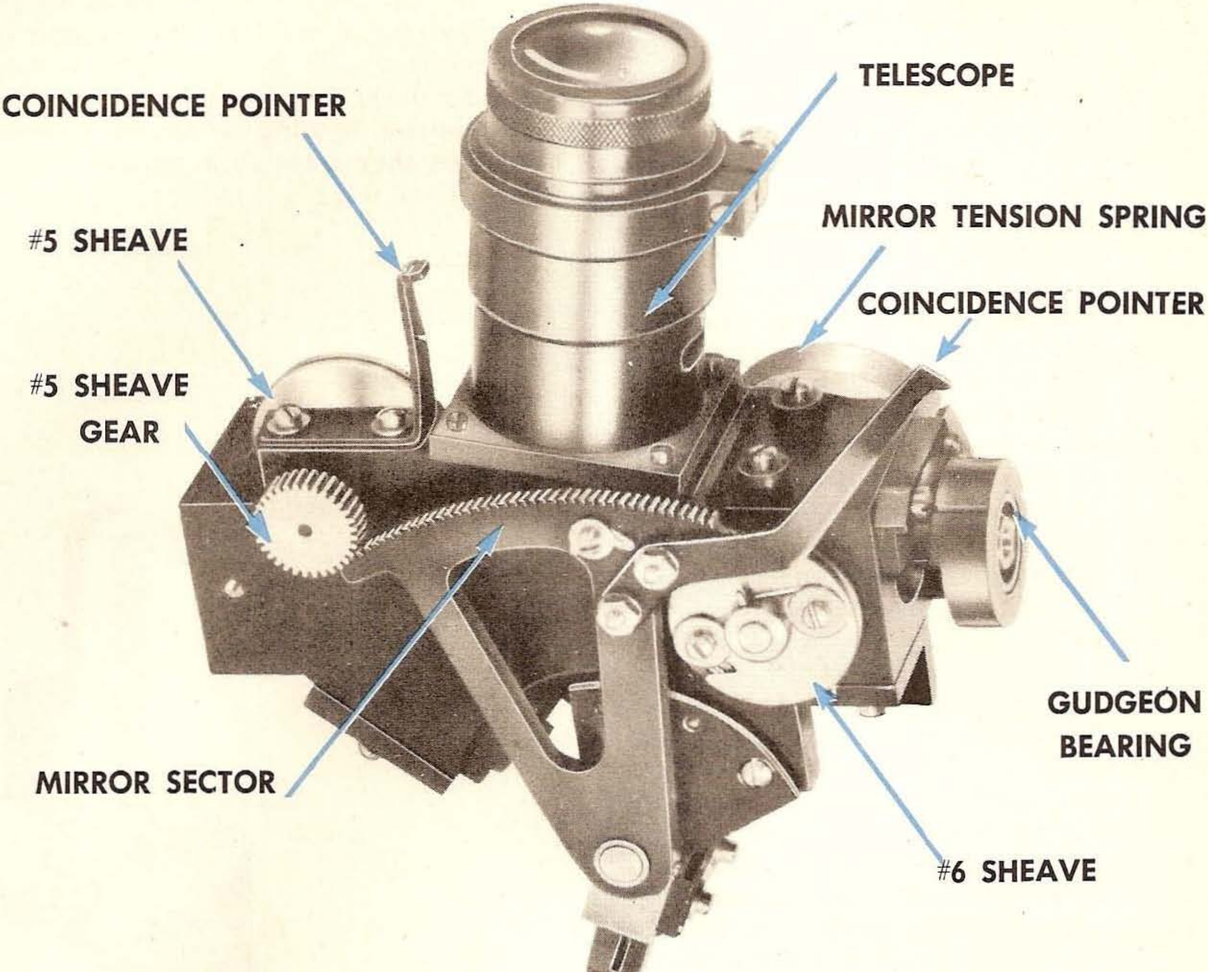
The gyro housing is divided into two parts, the upper and lower. On the upper part of the housing are:

Gyro locking pin	Fore and aft bubble
Upper rotor bearing	Lateral bubble
Bubble light	Movable precession weights

You use the bubbles for leveling the gyro during the bombing run and the bubble light is at the junction of the bubble tubes. Maintenance men use the movable precession weights in balancing the gyro.

The lower half of the gyro housing contains the field coils, which fit between the rotor and the motor armature; the lower rotor bearing, and the brush tubes. On the bottom and outside of the housing is the connection for the gyro connecting rod which links the gyro to the telescope cradle.

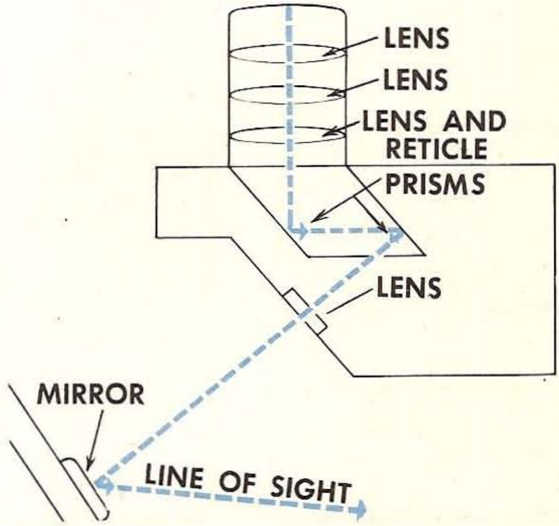




THE TELESCOPE CRADLE

The telescope cradle contains the optical system and the mirror return system. The optical system consists of a one-piece refracting telescope, which is a fixed part of the cradle. The telescope has an 18° field of vision and 2.2 magnifying power, and the crosshairs are etched on one of the lenses. Beneath the telescope is a mirror which rotates on lateral bearings. The target you see through the telescope is reflected into it by the mirror.

The angle of the mirror is controlled by the very flexible mirror drive cable, which consists of seven strands of bronze wire. From the first sheave, which was discussed in the section on mirror drive, the mirror drive cable passes over the second sheave which is in the rate end. From the second sheave, it



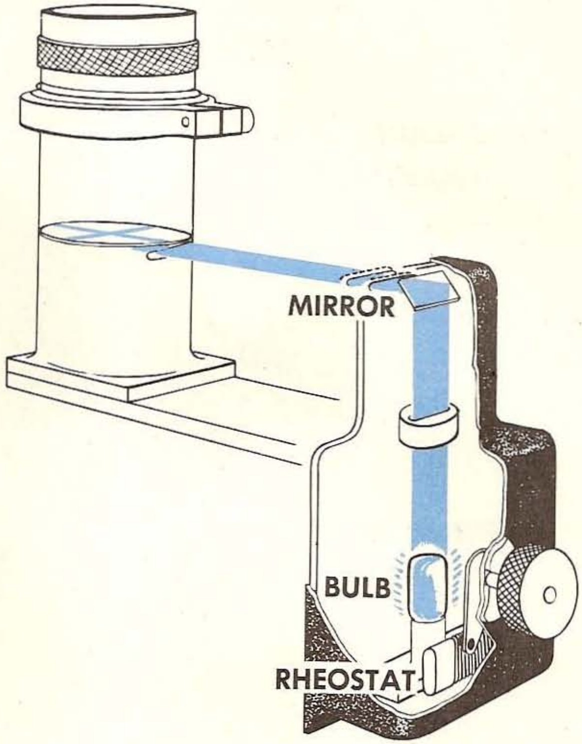
passes through a channel in the exact center of the cardan gudgeon bearing to the third sheave, which is mounted on the cardan.

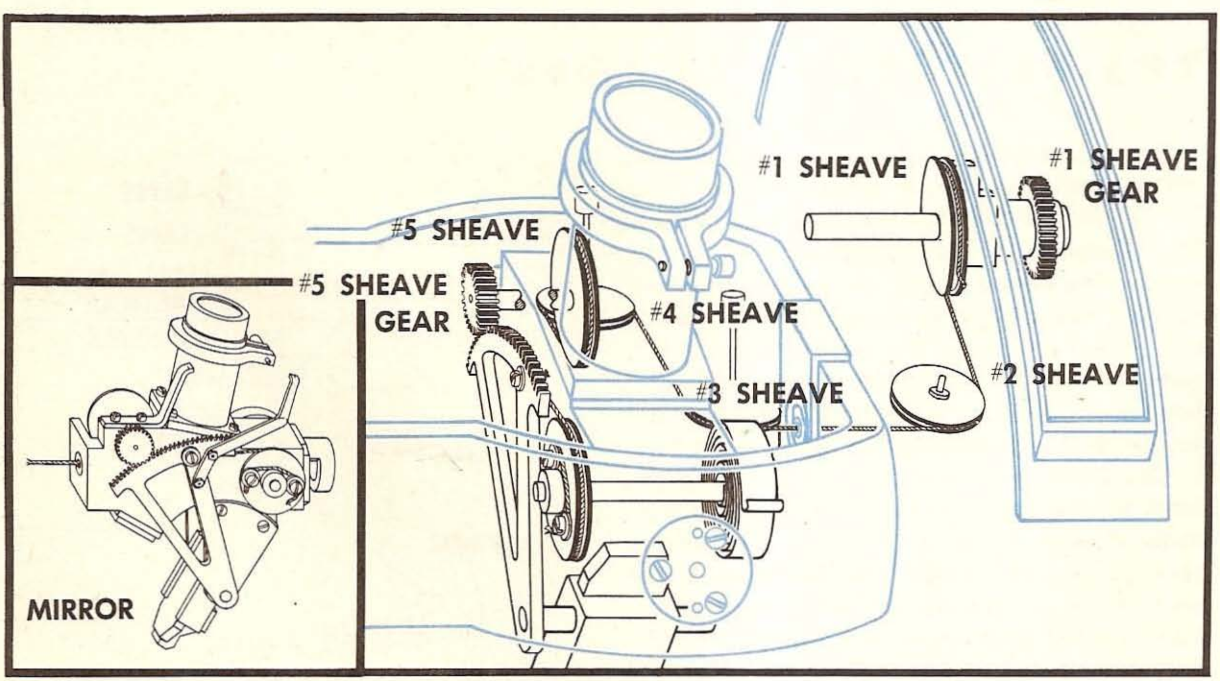
From the third sheave, the cable goes to the fourth sheave, which guides the cable through the exact center of the cradle gudgeon bearing to the fifth sheave. The cradle is fastened to the fifth sheave, which is mounted on a shaft on the cradle.

The fifth sheave gear is fastened to the shaft turned by the fifth sheave. The gear meshes with the geared portion of the mirror sector. The sector's axis of rotation is the lateral axis on which the mirror turns. Thus, when the fifth sheave gear turns, it turns the sector, and the sector turns the mirror.

A double cable connects the sector to the sixth sheave, which is mounted on the cradle. As the sector moves the mirror toward zero, the cable turns the sheave. As the sheave rotates, it turns the shaft on which it is mounted. On the other end of the shaft is a flat coil spring, which tightens as the shaft turns. Thus you can see there is always spring tension against the sector.

The crosshairs are lighted indirectly for night bombing. The lighting system consists of a rheostat, a small bulb, and a small mirror which reflects light from the bulb onto the crosshairs through a narrow slit. You use the crosshair rheostat which is on the rear of the sight just below the eyepiece to control the brightness of the bulb. The amount of light reflected onto the crosshairs is controlled by the angle of the mirror. The angle of the mirror is adjusted by maintenance men when they make their regular inspections.

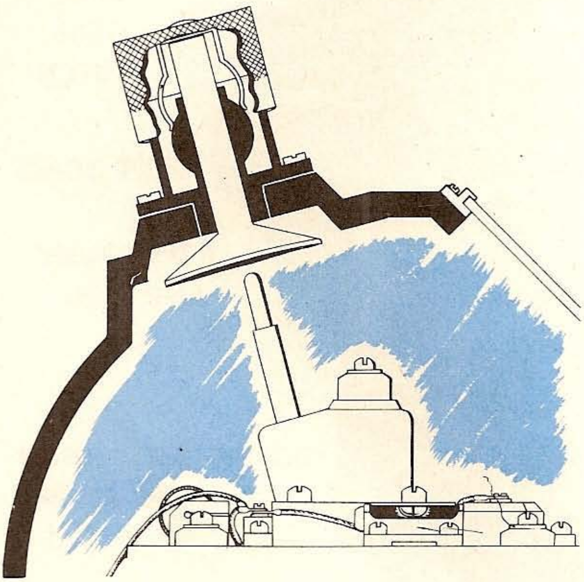




GYRO CAGING AND LEVELING

When you are not actually on a bombing run, it is necessary to keep the gyro caged; that is, held stationary in relation to the rest of the sight. Caging the gyro keeps it from tumbling and being damaged. You do this with the caging knob, which is the knurled knob on top of the sighthead and directly above the vertical gyro. This knob is fastened to the top end of a shaft which has an inverted funnel or cone on its lower end.

When you push down on the caging knob, the cone catches the gyro locking pin, which projects upward from the gyro housing. This downward pressure moves the locking pin into alignment with the center of the cone. When the cone holds the locking pin in this fixed position, the gyro then is "caged" and cannot swing free to stabilize the telescope cradle against pitch and roll.

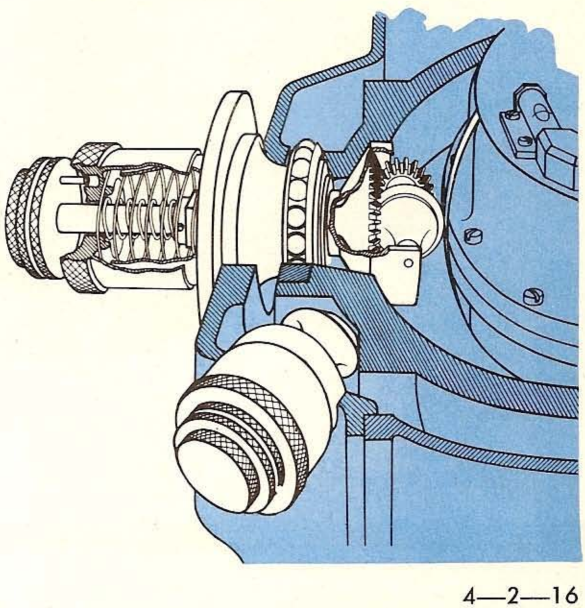


You use the leveling knobs on the left side of the sight case to level the bubbles on the gyro. When you adjust the level so the bubbles are centered then the gyro's spin axis is vertical. There are two leveling knobs, the fore and aft, and the lateral. When you use the fore and aft leveling knob, you apply pressure and torque directly to the gyro housing along the lateral axis, which tends to move it in roll. From the law of precession, you know the reaction occurs 90° from the point of applied force. Therefore the gyro is moved in pitch, leveling the fore and aft bubble.

Pressure and torque on the lateral leveling knob applies torque to the cardan. But as the cardan is attached to the gyro, it tends to move the gyro in the pitch axis. The 90° reaction causes it to move in the roll axis, thereby leveling the lateral bubble.

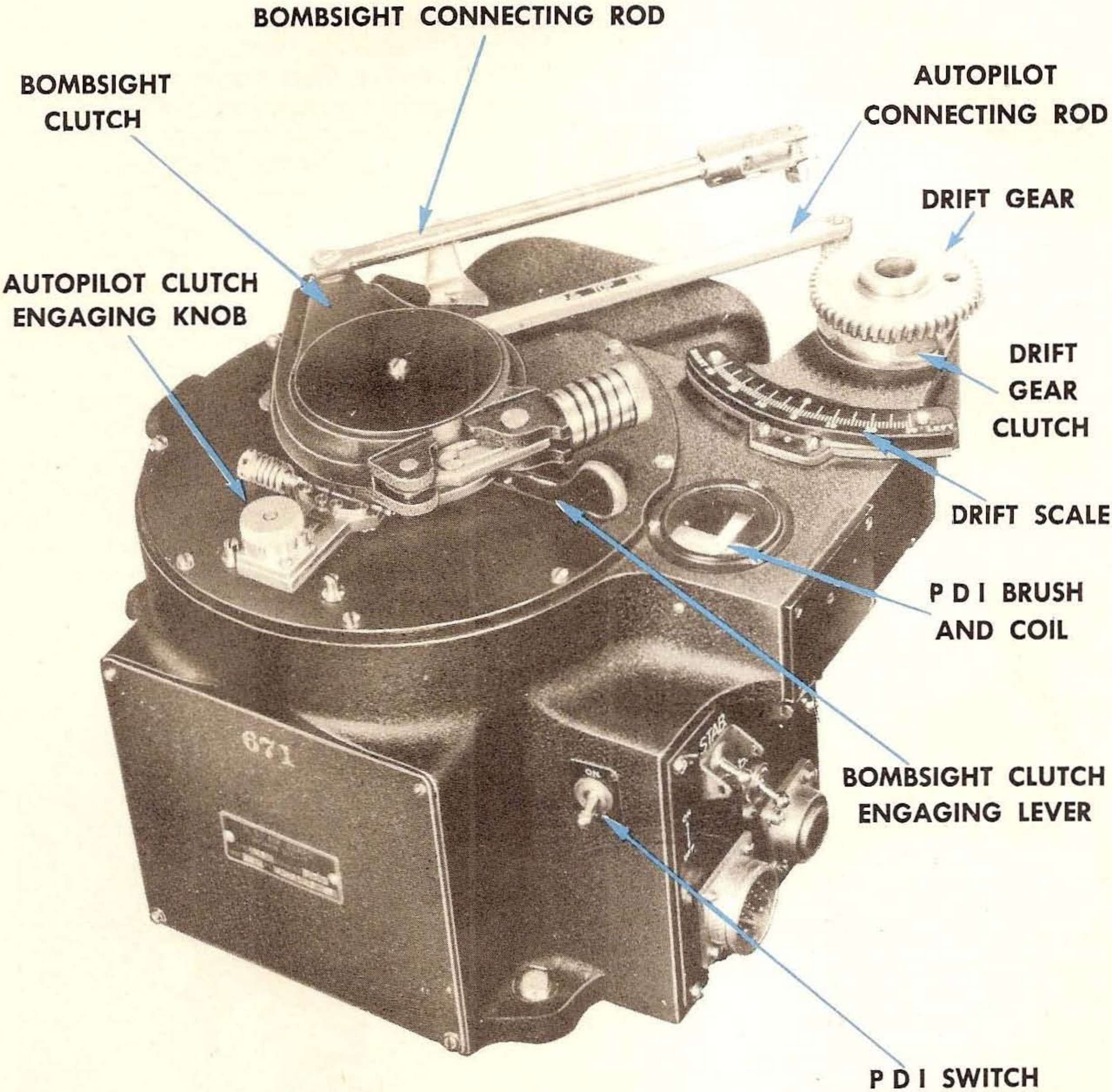
Each leveling knob has two knurled sections, mounted on the same shaft. You use the small outer knob for large corrections. This knob gives the full, direct force of applied pressure and torque to the gyro. The larger knob—the inner one—gives small corrections. You use it after bringing the gyro approximately to its level position with the outer knob.

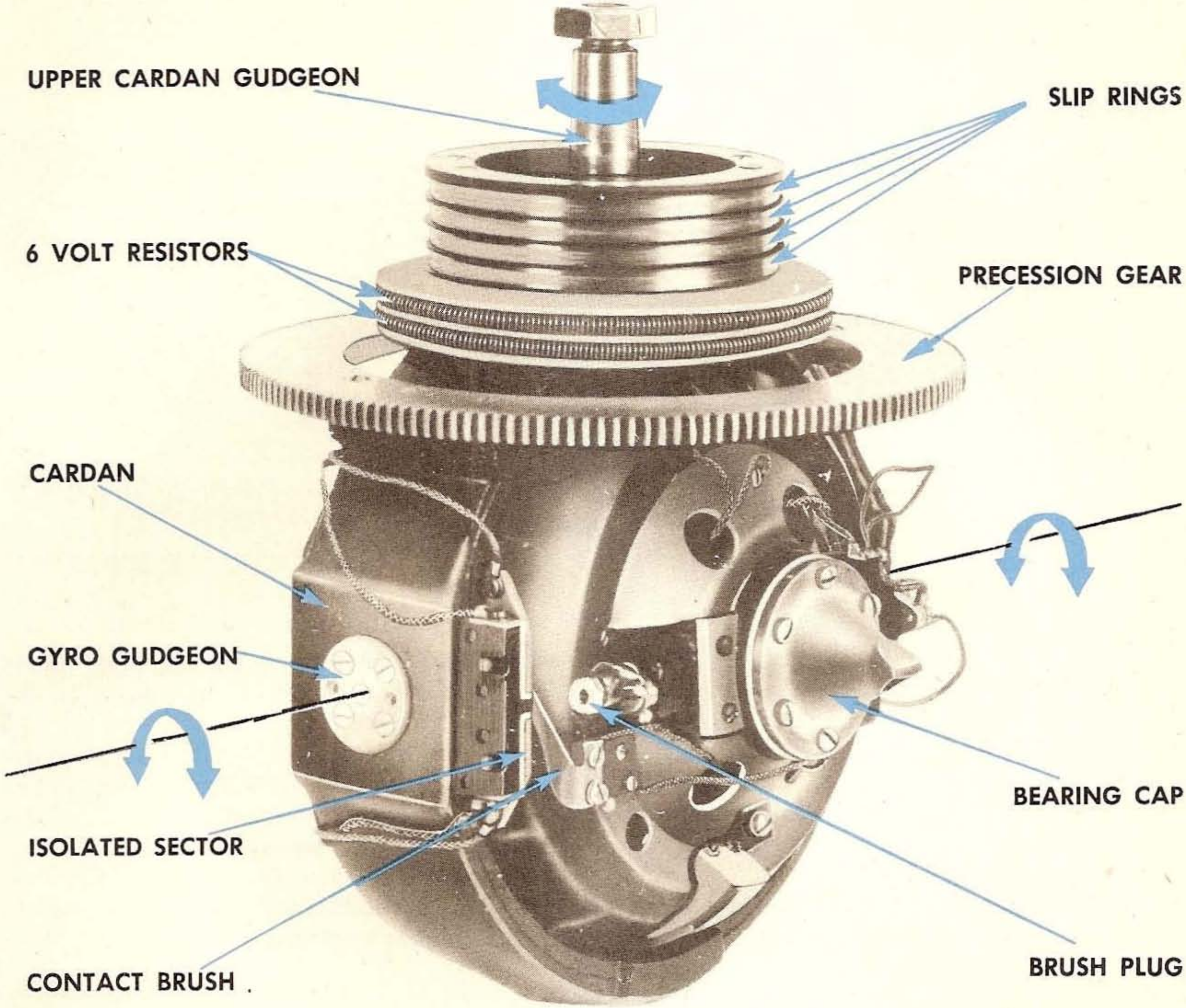
The amount of force you can apply with the larger inner knob is limited by the tension of a coil spring. This spring, known as the inner spring, is coiled around the shaft within the large knob and between the knob and a collar on the shaft. When you push in this knob, the only pressure applied to the gyro is that of the spring tension against the collar on the shaft. Also in the large inner knob is a large coil spring, known as the outer spring, which holds the knobs free when they are not in use.



The Stabilizer

The stabilizer is the lower unit of the bombsight assembly. As you have already learned, its purpose is to stabilize the sighthead in yaw and to help in solving the course problem.





DIRECTIONAL GYRO

In order for the directional gyro to stabilize the sighthead in yaw, its spin axis must be horizontal. Although this gyro is slightly larger than the vertical gyro and rotates at about 7,800 rpm, its construction is essentially the same.

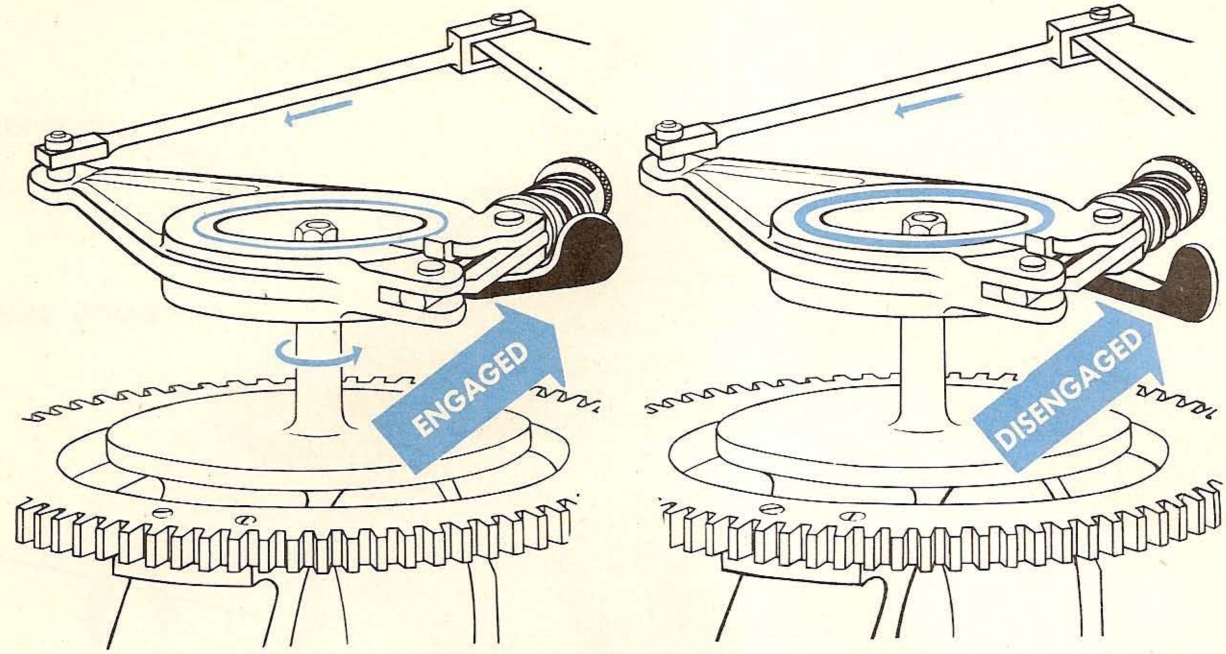
However, the directional gyro cannot be caged; and, since it has a system which counteracts precession, there are no bubbles on the gyro for you to level.

The gyro is mounted in its housing. This housing is mounted in a cardan—a metal ring —by **horizontal** gudgeon bearings. The cardan is mounted in the stabilizer case by **vertical** gudgeon bearings. Thus, the cardan can rotate in the stabilizer case, but as it is mounted vertically in the case, you can see that it must always remain vertical in relation to the case.

Since the directional gyro is a horizontal one, it resists any attempt to move it in yaw.

The horizontal gudgeon bearings transmit this stability from the gyro to the cardan.

The upper cardan gudgeon extends up through the stabilizer case. The clutch drums fit on this extension. The bombsight clutch collar fits around the clutch drum. When the clutch is engaged, the collar is locked to the drum. The bombsight clutch arm is a part of and extends out from the clutch collar.



Therefore, with the bombsight clutch engaged, there is a mechanical linkage from the directional gyro to the bombsight clutch arm. As the clutch arm is connected to the sighthead through the bombsight connecting rod the sighthead is stabilized by the gyro.

Current is transmitted to the gyro through a slip ring on top of the cardan. This ring, with three others, is mounted on the cardan inside the stabilizer case, directly below the clutch drum. Another of the slip rings serves as a ground to complete the circuit to the gyro.

Directly below the slip rings are two resistance coils. These coils limit the amount of current flowing to the torque unit. The precession gear is beneath these coils and mounted solidly on the cardan. As it is mounted to the cardan, any force applied to this gear precesses the gyro.

THE TORQUE UNIT

The torque unit applies force to the precession gear when the directional gyro tilts out of horizontal. Since the gyro is necessarily small, its strength is not sufficient to stabilize the sighthead without tending to precess. The torque unit counteracts this precession.

As you learned when you studied its construction, the cardan can move only in two directions — clockwise or counter-clockwise through 360°. Remember that the clutch drum is attached to the cardan and the bombsight head is attached through a linkage to the clutch drum. Thus you can see that any attempt to move the sighthead must result in a twisting action on the drum. This twisting force is transmitted to the cardan and thus precesses the gyro. This twisting motion can be either clockwise or counter-clockwise. Therefore, the torque unit must be able to apply a counter-force either clockwise or counter-clockwise.

The torque motor rotates only in one direction. Through a gear train, the motor drives one of the two clutch drive gears. The second clutch drive gear is meshed with the first and is driven by the first, but in the opposite direction. Therefore, one clutch drive gear rotates clockwise; the other rotates counterclockwise. The bottom surfaces of both clutch drive gears are faced with cork.

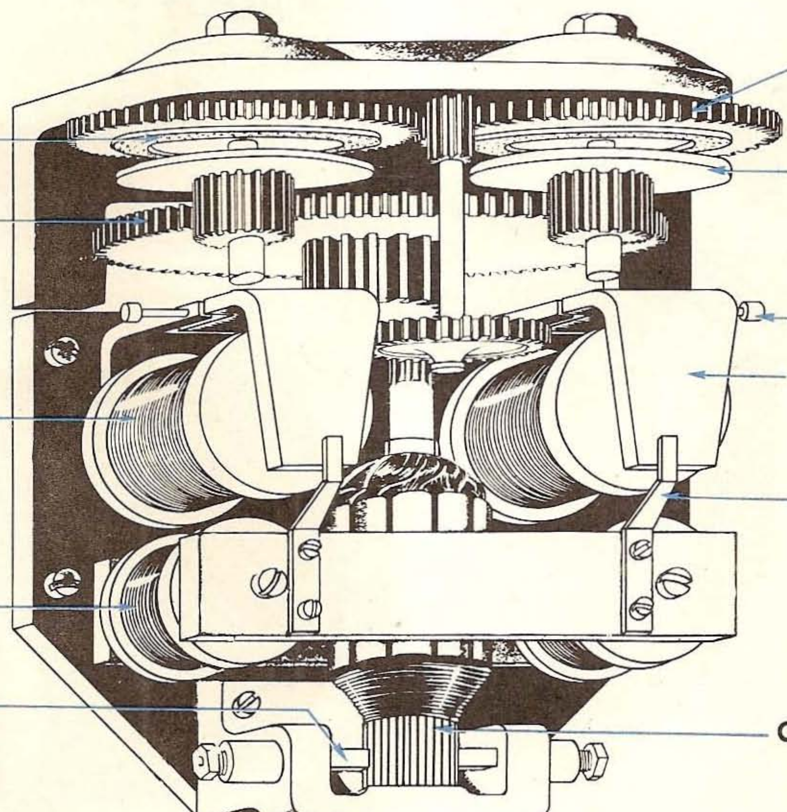
Directly beneath the cork facings of the clutch drive gears but not touching them are the clutch discs. These discs, flat metal plates, are supported by extensions of clapper arms which are operated by the clapper magnets. The clapper arms, made of soft iron, are L-shaped and pivoted at their elbows.

Whenever one of the clapper magnets is energized, it pulls in one end of its clapper arm. The lever action of the pivoted "L" pushes the clutch disc up against the cork facing of the drive gear. The rotation of the drive gear is thus transmitted to the clutch disc through the clutching action between the cork facing and the clutch disc.

On the shaft of the clutch disc is a gear. This gear meshes with an intermediate gear, which, through a small gear on its shaft, transfers the motion to the precession gear.

This gives the desired correction in one direction. When correction in the opposite direction is necessary, the other clapper magnet is energized and the power of the opposite turning clutch drive gear is transferred through its clutch disc and the intermediate gear to the precession gear. As only one clapper magnet can be energized at a time, both clutch discs can be connected to the same intermediate gear without the action of one clutch drive interfering with the action of the other.

Which magnet is energized depends on which way the gyro tilts. The contact sector, mounted on the cardan, is a bar carrying two



pairs of electric contacts separated by a strip of nonconductive material. A contact brush, mounted on the gyro housing, rides on the contact sector. When the gyro's axis moves out of horizontal, the brush moves from the dead center strip of the sector to one of the electric contacts. This completes an electric circuit to the proper clapper magnet.

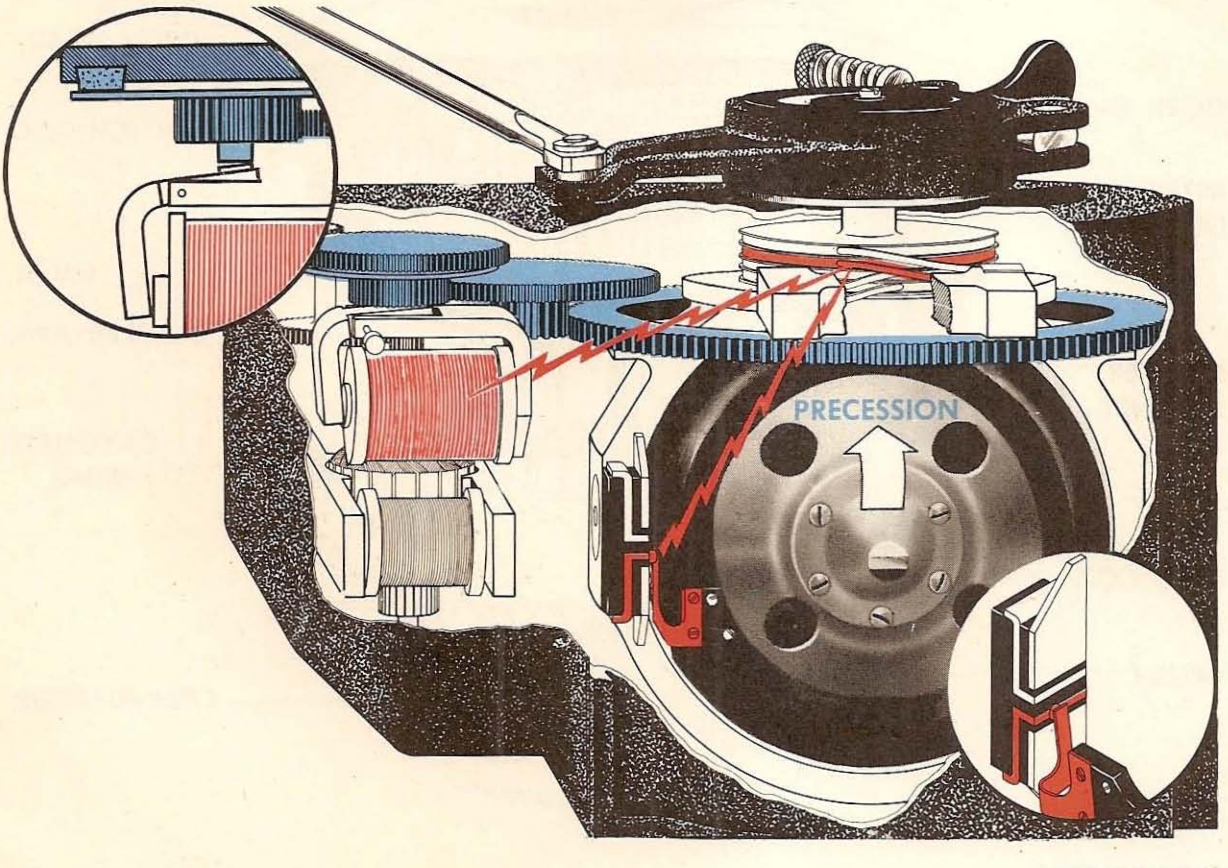
The first contact above the center strip sends one half the operating voltage of the sight to the proper magnet. The voltage is reduced by the upper resistance coil, which is wired into the circuit between the contact and the top slip ring. The top slip ring carries the current from the magnet to the contact. The circuit is completed when the contact brush, which is the "ground," touches the contact, thus energizing the magnet, precessing the gyro, and moving the brush back to the dead center strip.

If the gyro has precessed a greater amount in the same direction, the brush will ride up to the second contact above the center strip. This circuit bypasses the resistance coil and therefore sends the full operating voltage of the sight to the magnet through the same slip ring.

The contacts below the center strip are connected to the opposite clapper magnet through the lower resistance coil and the second slip ring. Thus their reactions are identical to those of the upper contacts, but in the opposite direction.

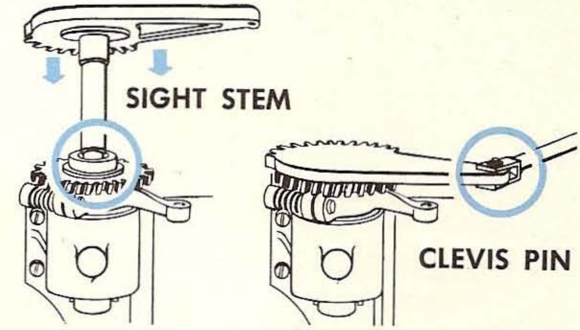
The torque unit counteracts precession of the directional gyro. Therefore, the gyro stabilizes the sighthead in yaw, through the bombsight clutch, bombsight connecting rod, and the course knob mechanism.

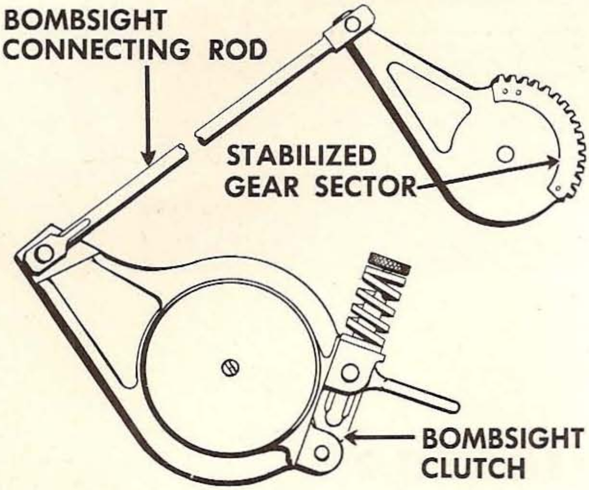
WHEN CONTACT BRUSH IS OFF CENTER, AN ELECTRIC SIGNAL IS SENT TO PROPER CLAPPER MAGNET



THE COURSE KNOBS

When you engage the bombsight clutch, the stability of the directional gyro is transmitted to the bombsight connecting rod. This arm is connected to the stabilized gear sector. The stabilized gear sector is mounted on the sight stem, which extends from the bottom of the sighthead into the sleeve on the stabilizer.





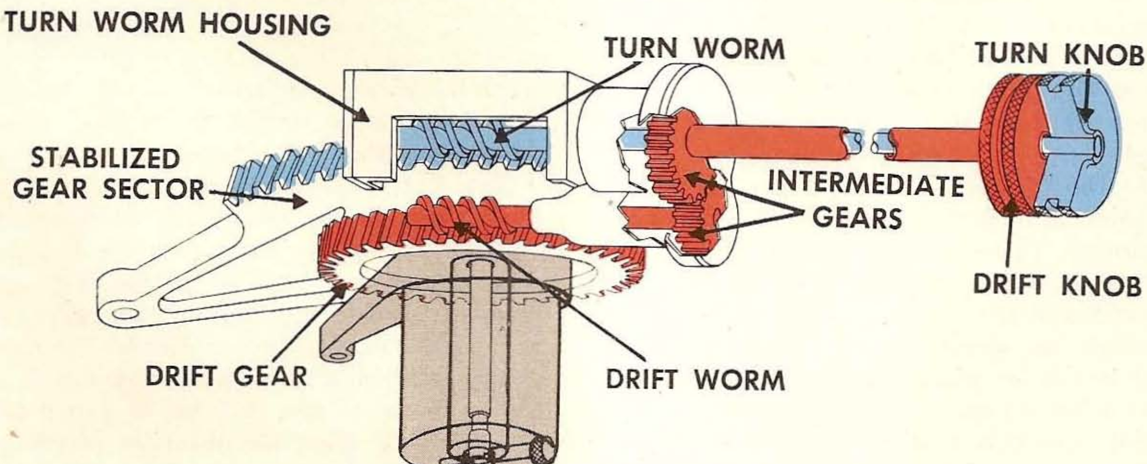
Two connections between the sighthead and stabilizer are the sight stem, on which the sighthead rests and is free to turn, and the clevis pin, which locks the bombsight connecting rod to the stabilized gear sector. The stabilized gear sector is mounted on the stem so that the stem is free to turn in it. The turn worm, which meshes with the geared part of the stabilized gear sector, is mounted on the sighthead. The turn worm is on the shaft from the turn knob.

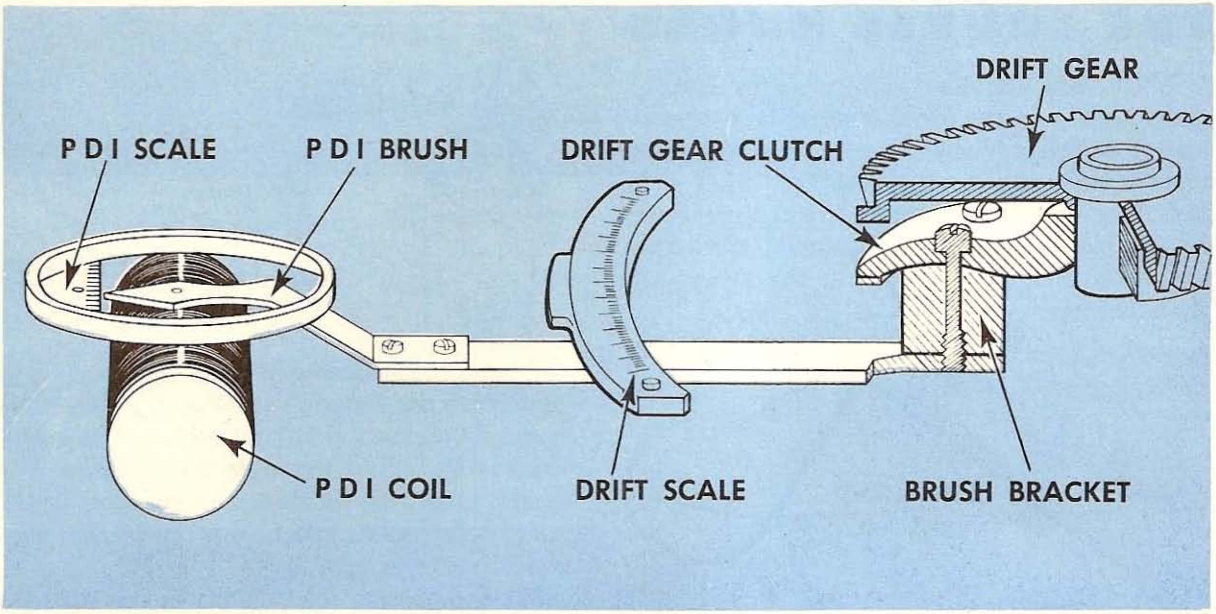
The stabilized gear sector is locked to the bombsight connecting rod by the clevis pin. Therefore the sector is stabilized. As the turn worm is meshed with the sector, the sighthead is stabilized through this linkage. You cannot turn the sighthead in relation to the stabilized sector unless you turn the turn worm with the turn knob.

When you turn the turn knob, you turn the turn worm. The turn worm forces itself around the stabilized gear sector, thus forcing the sighthead around with it.

The drift worm is in the same housing with the turn worm, and you can rotate it only with the drift knob. The drift worm meshes with the drift gear, which is mounted on the stabilizer around the sleeve in which the sighthead stem fits. Therefore, when you turn the sighthead with the turn knob, the drift worm will drag the drift gear around the same amount the sighthead is turned.

However, when the drift knob is turned, the turn worm holds the sighthead stabilized and the drift gear is turned independently of the sighthead. Any time the drift gear is turned, by the displacement of the sighthead or drift knob, the pilot will get a signal from the PDI (Pilot Director Indicator).





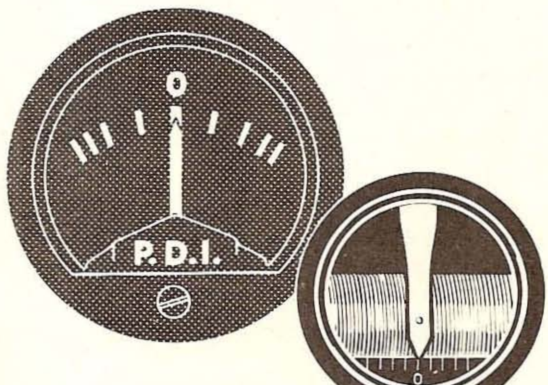
THE PDI SYSTEM (PILOT DIRECTOR INDICATOR)

The drift gear clutch collar is mounted around the hub of the drift gear, below this gear. Any time the drift gear turns, the drift gear clutch collar turns. The clutch collar gets its name from the fact that the friction with which it grips the drift gear hub may be adjusted.

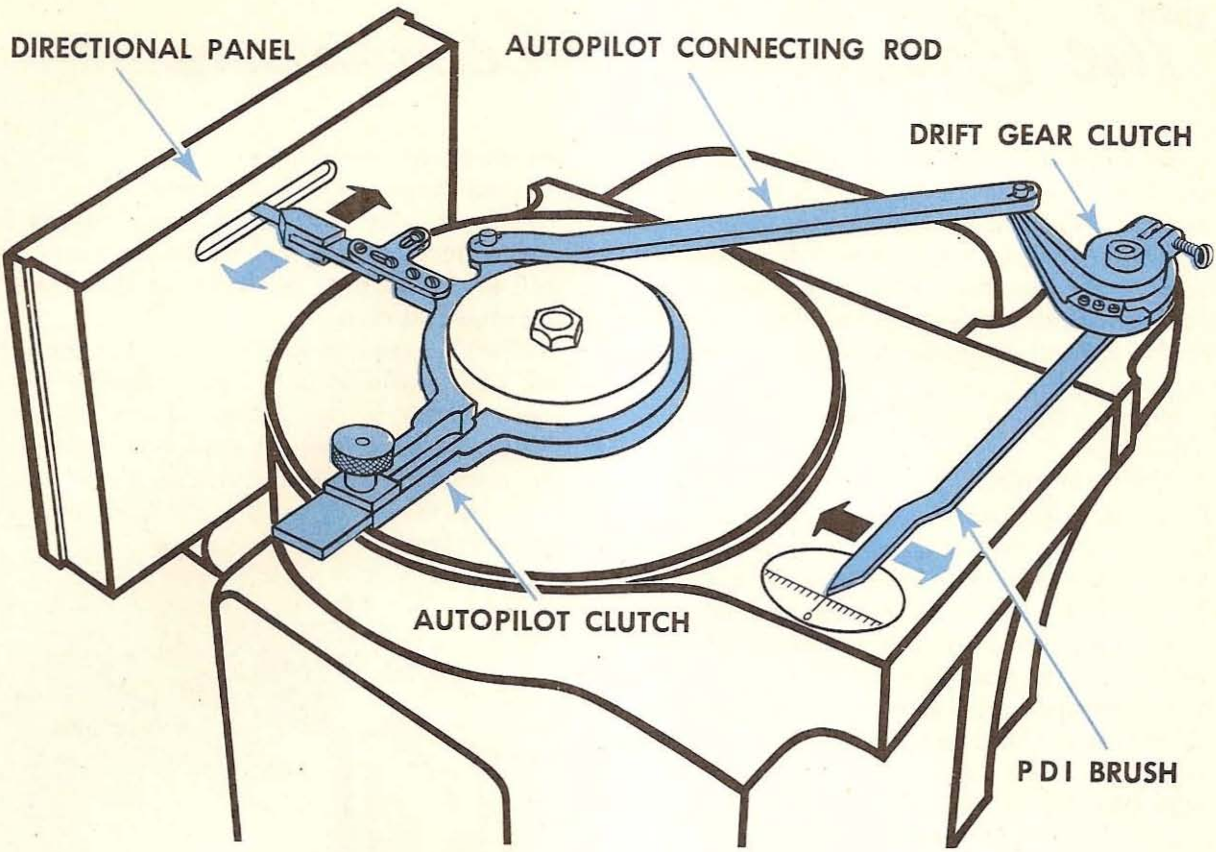
Attached to the clutch collar inside the stabilizer case is the PDI brush, which rides on a resistance coil. You can see this coil and the brush through a window on the stabilizer. The brush can operate only within a certain range. When it reaches the limits of this range, the clutch collar slips on the drift gear hub so that the mechanism will not be damaged.

As the PDI brush moves from the center of the coil, it sends a signal to the pilot's instrument. This instrument is a double-acting voltmeter which measures two values: the amount and the direction of current flowing through its circuit. These two values are determined by the position of the brush on the resistance coil.

You use this system to signal the pilot when the airplane is flown manually. An additional system is necessary to send signals while using the C-1 automatic pilot.



The drift gear clutch arm is part of the drift gear clutch. Therefore, whenever the clutch is moved, the arm is moved. The autopilot connecting rod links the drift gear clutch arm to the autopilot clutch collar. The autopilot clutch collar fits around the clutch drum just below the bombsight clutch. An arm, known as the directional panel drive arm, extends from the autopilot clutch into



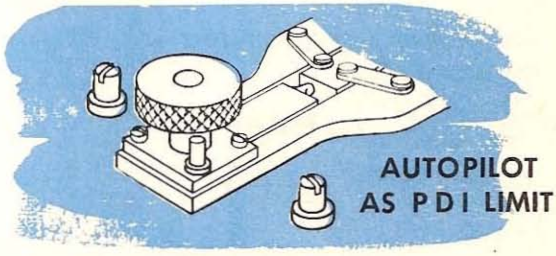
the directional panel, which is fastened to the left side of the stabilizer case.

As the drift gear clutch collar is moved, it moves the PDI brush over the coil. At the same time, it moves the autopilot clutch so that the directional panel drive arm moves, sending the signal to the autopilot.

THE AUTOPILOT CLUTCH

The autopilot clutch has three functions:

1. It serves as a PDI limit. On the stabilizer case there are two studs, one on each side of the engaging knob of the autopilot clutch. These studs limit the movement of the autopilot clutch. Therefore, through mechanical linkage, they limit the movement of the PDI brush.



2. It serves as a PDI lock. When you engage the autopilot clutch, you connect the PDI brush to the directional gyro through mechanical linkage, locking it to the gyro.

3. It proportions C-1 corrections with PDI displacement. The PDI brush and the directional panel drive arm are linked together mechanically. Therefore, for each movement of one, there will be a proportional movement of the other.

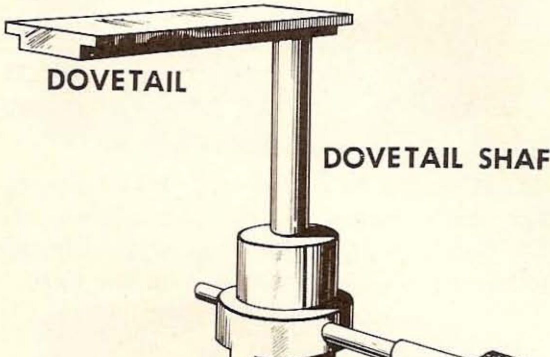
The Crosstrail Mechanism

To solve the crosstrail problem, the sight combines trail and drift. Drift is the angular relationship between the sighthead and stabilizer. When you set trail and drift into the sight, the crosstrail mechanism solves for the correct crosstrail and tilts the telescope cradle enough to subtend crosstrail distance on the ground.

Briefly, the crosstrail mechanism works this way:

The sight stem, by which the sighthead is mounted to the stabilizer, is hollow. A shaft, known as the dovetail shaft, passes through this hollow stem. The lower end of this shaft is locked to the stabilizer by the dovetail locking pin so that this shaft cannot rotate in relation to the stabilizer.

On the upper end of the dovetail shaft, inside the sighthead, is a flat metal bar known as the dovetail. One end of the dovetail is mounted on the shaft at a right angle to it. The other end of the dovetail extends back toward the rear of the sight. With zero drift, the dovetail lies in the fore and aft axis of the sighthead.

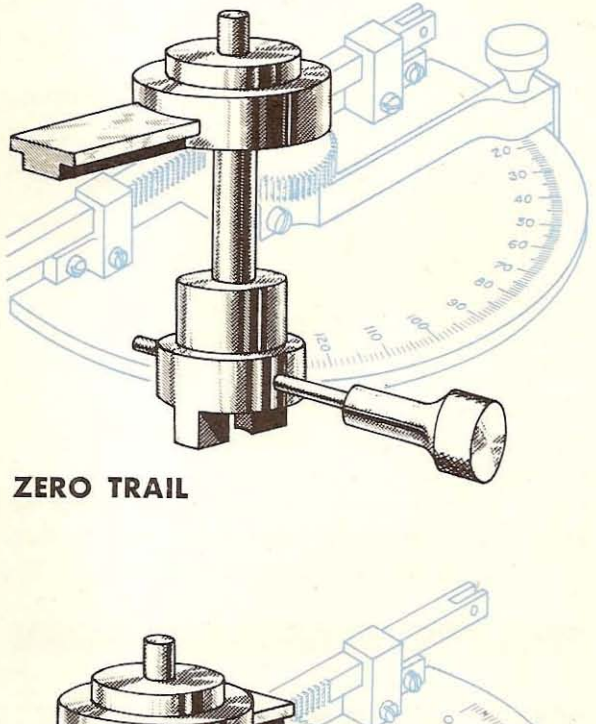


When you turn the course knobs to correct for drift, you crab the airplane into the wind. However, the sighthead remains pointed at the target. This forms an angle between the sighthead and stabilizer. As the dovetail is locked to the stabilizer, it remains in alignment with the stabilizer but moves out of alignment with the fore and aft axis of the sighthead. In this way you have set drift into the crosstrail mechanism.

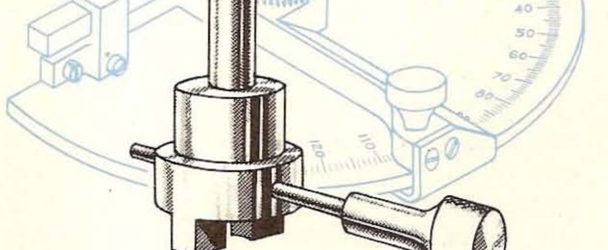
To add trail to the mechanism:

Fitted to the dovetail is a part which is moved along the dovetail by linkage from the trail arm. This part is known as the concentric stud and disc.

When no trail is in the sight, the concentric stud and disc is at the dovetail's pivot point, which is the center of the dovetail shaft. But when you set trail into the sight, the concentric stud and disc is moved back from the center of pivot a distance proportional to trail.



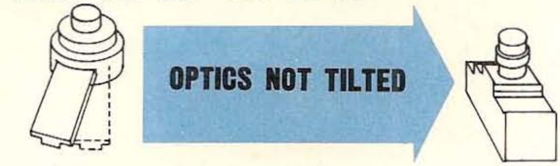
ZERO TRAIL



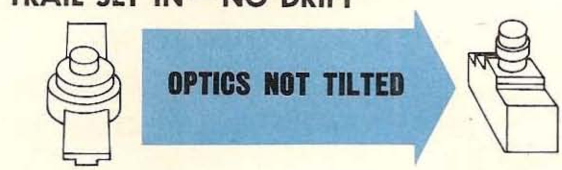
TRAIL SET IN

With drift and trail set into the crosstrail mechanism, the concentric stud will be moved to one side or the other of the zero drift position. The distance it is thus moved is proportional to crosstrail. This movement is transferred through linkage to tilt the telescope cradle the proper amount.

DRIFT SET IN — NO TRAIL



TRAIL SET IN — NO DRIFT



TRAIL AND DRIFT SET IN

Setting Trail in the Crosstrail Mechanism

When you move the trail arm to set trail in the rate end, this movement turns the trail arm pinion, which is on the trail arm. The pinion is meshed with the trail rack, which pushes the upper end of a lever known as the trail bell crank. The bell crank is pivoted on the sight case so that as its upper end is pushed away from the case, its lower end is pushed toward the case.

The lower end of the bell crank is attached to the push rod, which slides into the sight case through a sleeve. The sleeve is fitted into the case so that the push rod can move only fore and aft. The push rod is pivoted to the link rod, which in turn is pivoted to the link fork. The link fork is a collar-like device that fits around a shoulder on the concentric stud and disc.

Extending back from the collar are two prongs which ride on a guide stud. The stud anchors the end of the linkage without restricting the movement of the link fork.

Tilting the Optics

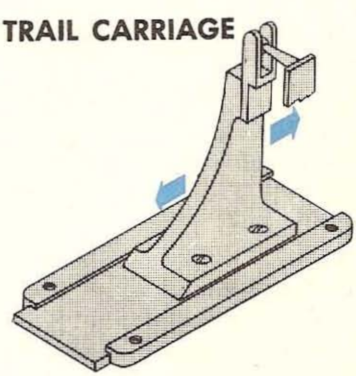
When the concentric stud and disc moves to the right or left of the dovetail's zero drift position, the stud moves the crosstrail carriage. The stud fits into the slot of a flat plate on the bottom of the crosstrail carriage. This plate is fitted into the sighthead on guide tracks so that the carriage can move only to the right or left.

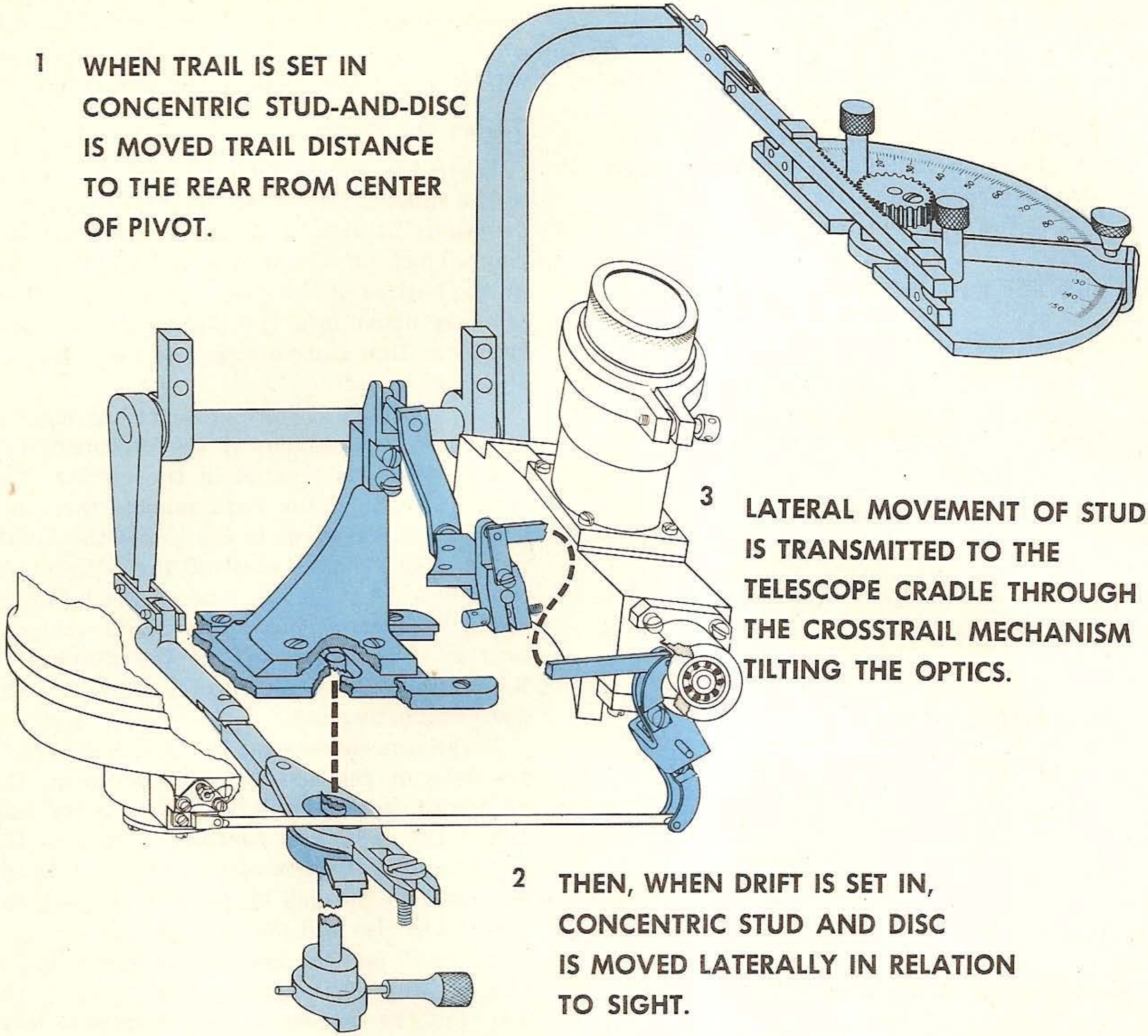
The upper part of the crosstrail carriage is connected to one arm of the crosstrail bell crank, which is pivoted in the cardan. The crosstrail connecting rod connects the other arm of the bell crank to the top of the differential lever. The center of the differential lever is pivoted on the rear of the telescope cradle at a point below the cradle gudgeon bearing. The other end of the differential lever is connected to the vertical gyro by the gyro connecting rod.

If the concentric stud and disc is moved to the left in relation to the sighthead, the crosstrail carriage will be moved to the left. When the crosstrail carriage moves to the left, it moves the arm of the bell crank to the left and, as the bell crank is U-shaped, the other arm also will move to the left.

This will pull the crosstrail connecting rod and the top of the differential lever to the left; but the bottom of the differential lever is held in place by the vertical gyro. Therefore, when the top of the differential lever moves, and the bottom is fixed, the pivot point of the differential lever must move. As this pivot point is below the cradle gudgeon bearing, it causes the cradle to tilt.

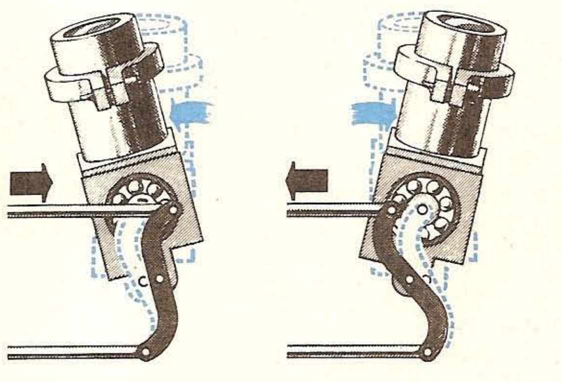
CROSS TRAIL CARRIAGE



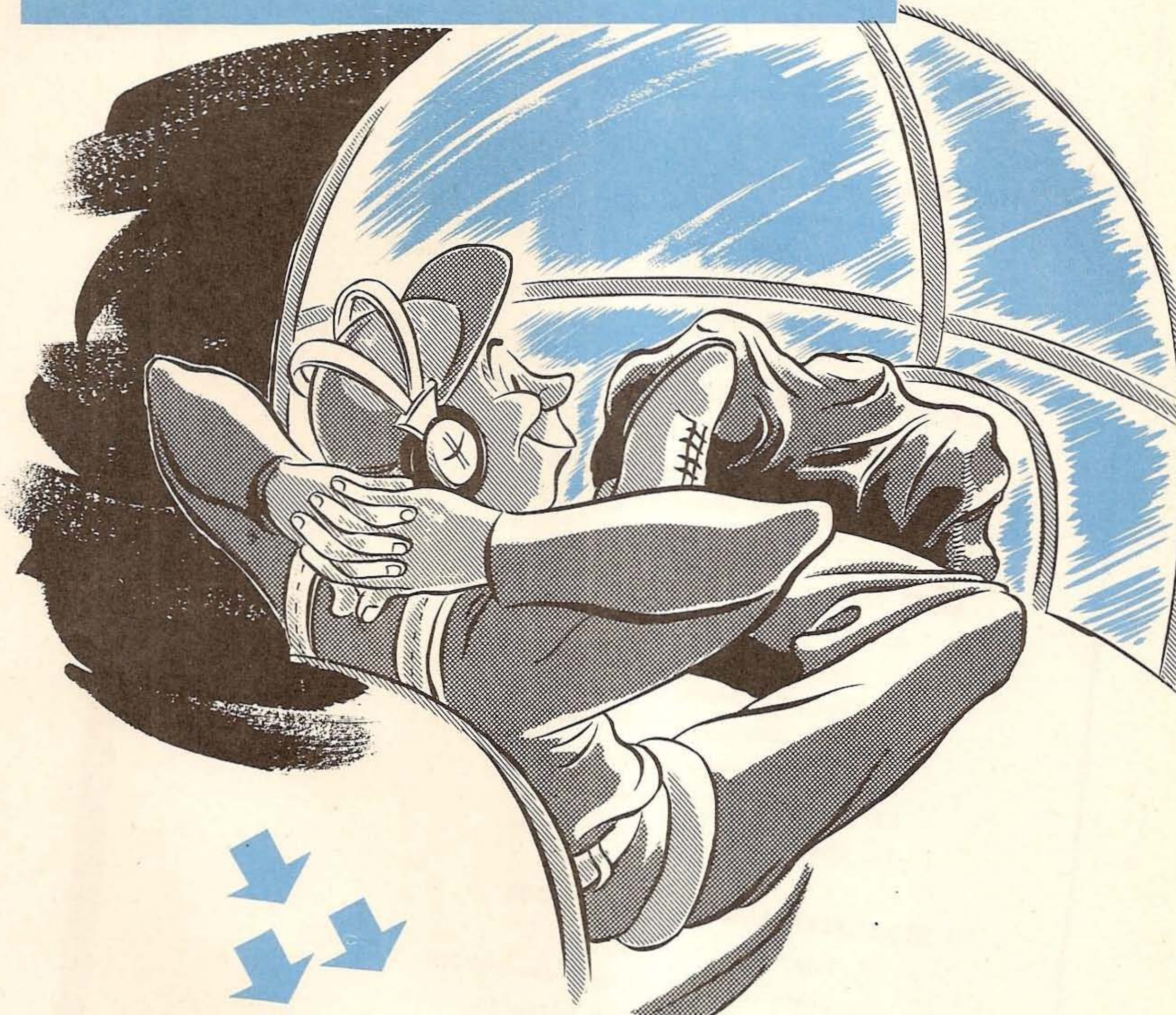


This puts your line of sight to the left of vertical. When the concentric stud and disc is moved to the right, the mechanical action is the same except that it is in the opposite direction. Then the line of sight is to the right of vertical.

When the optics are tilted for crosstrail, they are tilted independently of the gyro as the lower end of the differential lever is held fast by the gyro. When the gyro acts to stabilize the telescope cradle, the upper end of the differential lever is held fast by the crosstrail mechanism. The upper end of the differential lever is at the same height as the telescope cradle gudgeon bearing. Therefore, the vertical axis of the telescope cradle will move the same amount as the vertical axis of the gyro.



PREFLIGHT PROCEDURE



You must make a preflight inspection of your bombsight before every mission. Although the sight stands up well under normal conditions, malfunctions do occur—chiefly from misuse. A careful preflight check can make the difference between success and failure of a mission.

Every bomb you drop is scored on your training record, which is one basis of whether or not you will graduate as a bombardier. If your bombs drop "wild" on a training mission, as a result of a malfunction which would not show up in a careful preflight, you will be permitted to drop them again. But you will not get this second chance, if the malfunction is one that you should have found in your preflight.

IF YOU FIND A MALFUNCTION WHILE MAKING THE PREFLIGHT, CALL THE MAINTENANCE DEPARTMENT.

While you are learning preflight, you must also learn the reason for each step in the procedure. If you learn the reasons for each step, you will soon be able to make the preflight without a checklist.

PREFLIGHT CHECK LIST

INSTALLATION

1. Match sighthead and stabilizer.
2. Insert clevis pin and dovetail locking pin.
3. Check for security of cannon plugs on stabilizer.
4. Turn "STAB." switch ON.

CROSSTRAIL MECHANISM

5. Check for pre-set trail.
6. Check for dovetail misalignment.
7. Check for tilt of optics.

RATE END

8. Turn "BS" switch ON.
9. Check knobs on rate end.
10. Check rate motor and optic drive.
11. Check disc speed drum and gear shift.
12. Check for pre-set trail.
13. Check for roller slippage.
14. Check mirror drive cable length.

STABILIZER AND COURSE KNOBS

15. Turn "SERVO" switch ON.
16. Check action of course knobs and PDI.
17. Check torque unit and bombsight clutch.
18. Check autopilot clutch.
19. Check PDI with pilot.

SIGHT VERTICAL AND LIGHTING

20. Check vertical gyro.
21. Check leveling knobs.
22. Check bubble light.
23. Check crosshair light.

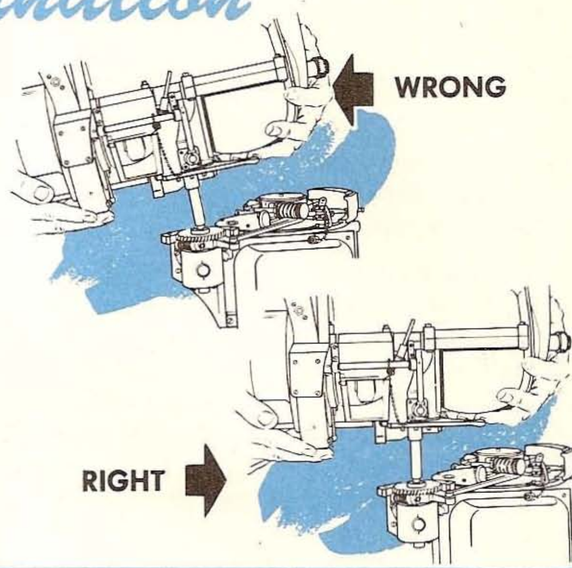
Preflight Explanation

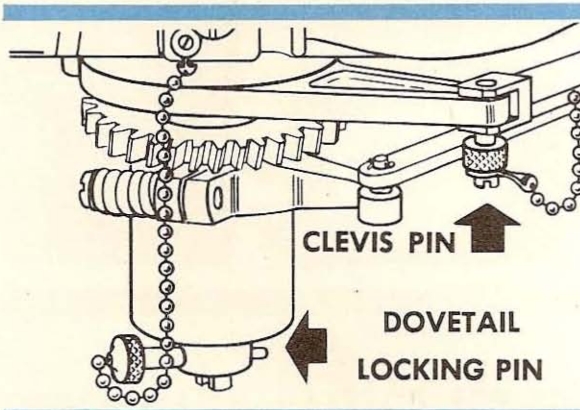
INSTALLATION

1. MATCH SIGHTHEAD AND STABILIZER BEFORE MOUNTING SIGHTHEAD

Although the sighthead and stabilizer do not always have the same serial number, they must use the same voltage. If the voltage differs, one unit will be damaged.

When mounting the sighthead, always lower the sight stem gently into the sleeve. Never force the sight stem into the sleeve or you will burr the drift worm and drift gear.



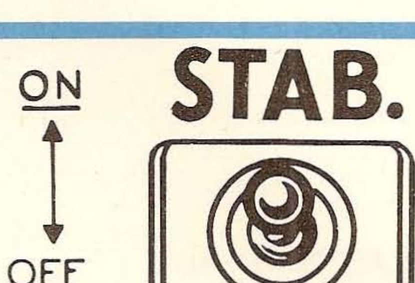


2. INSERT CLEVIS PIN AND DOVETAIL LOCKING PIN

Always be sure these pins are fitted securely. To assure stabilization of the sighthead, the bombsight connecting rod must be fastened to the stabilized gear sector with the clevis pin. The dovetail locking pin must be in place to give crosstrail corrections.

3. CHECK FOR SECURITY OF CANNON PLUGS ON STABILIZER

Although the cannon plugs may appear to be secure, always check to make sure. If the cannon plugs do not fit securely, the sight will not get the proper voltage.



4. TURN "STAB." SWITCH *ON*

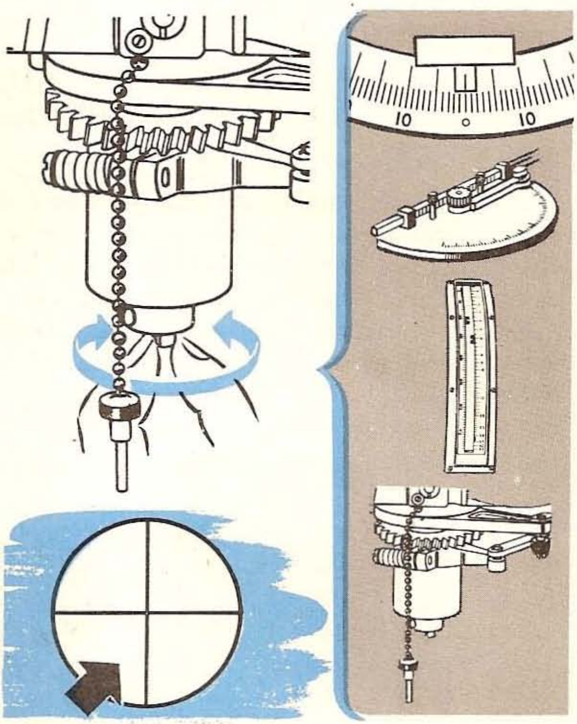
After turning this switch ON, wait three minutes before turning other switches ON. This allows the directional gyro enough time to gain running speed and prevents overloading of the circuit.

CROSSTRAIL MECHANISM

5. CHECK FOR PRE-SET TRAIL IN CROSSTRAIL MECHANISM

SETTINGS: *Zero drift, zero trail, and small sighting angle. Remove the dovetail locking pin. Rotate dovetail shaft. Fore and aft crosshair should not move.*

With the trail arm on zero, the concentric stud and disc should be on the dovetail center of pivot (zero trail position). If it is not, pre-set trail is present and the optics will be moved by the crosstrail mechanism when you rotate the dovetail shaft. Then, when you set in trail for the bombing mission, there will be incorrect trail in the crosstrail mechanism.

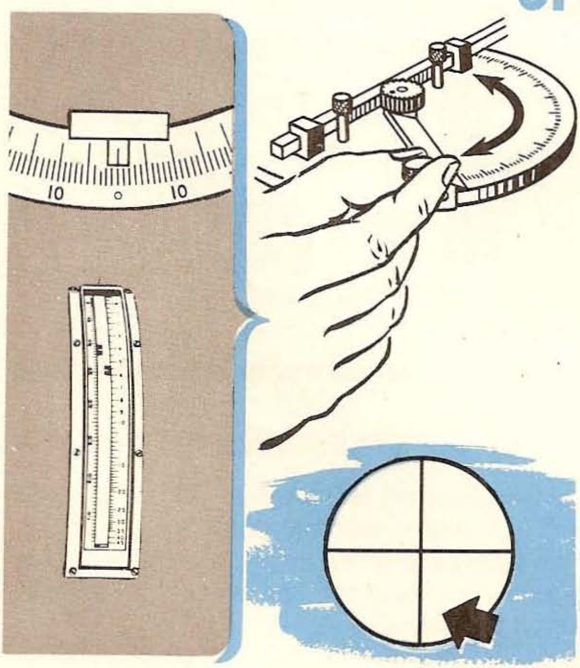


FORE AND AFT CROSSHAIR SHOULD NOT MOVE

6. CHECK FOR DOVETAIL MISALIGNMENT

SETTINGS: *Zero drift, small sighting angle, and small dropping angle. Swing trail arm through entire range. Fore and aft crosshair should not move.*

With zero drift, the dovetail should be in alignment with the longitudinal axis of the stabilizer. Therefore, when you move the trail arm, the fore and aft crosshair should not move. If it does move, the dovetail is misaligned.

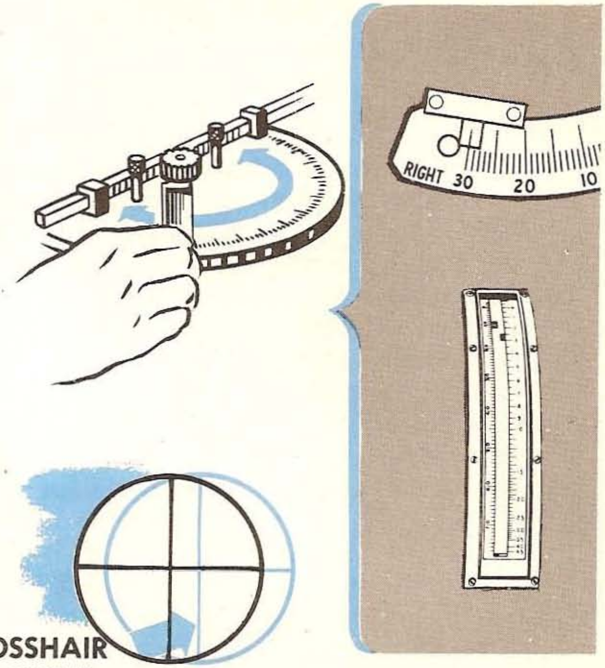


FORE AND AFT CROSSHAIR SHOULD NOT MOVE

7. CHECK TILT OF OPTICS

SETTINGS: *Maximum right drift, small sighting angle, and small dropping angle. Swing trail arm through entire range. Fore and aft crosshair should move to the right. Repeat this operation with maximum left drift; fore and aft crosshair should move to left.*

With maximum drift in the crosstrail mechanism, the optics should tilt when trail is added. This insures positive·action of the crosstrail mechanism.

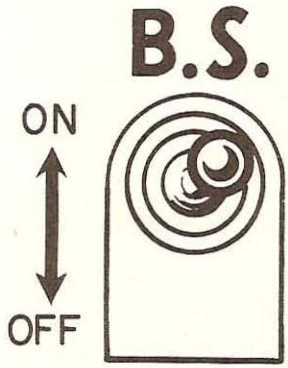


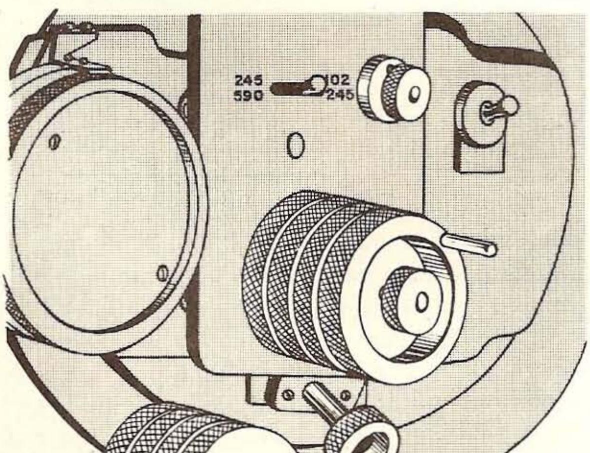
FORE AND AFT CROSSHAIR SHOULD MOVE TO RIGHT

RATE END

8. TURN "BS" SWITCH *ON*

This switch completes the electrical circuit to the sighthead. It energizes the vertical gyro, the bubble lights, and the crosshair rheostat. It also sends current to the rate motor switch.





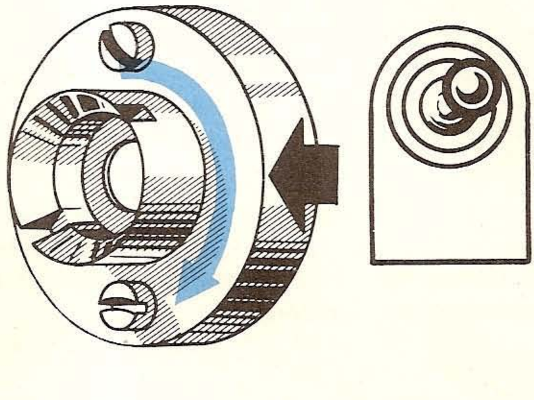
9. CHECK KNOBS ON RATE END

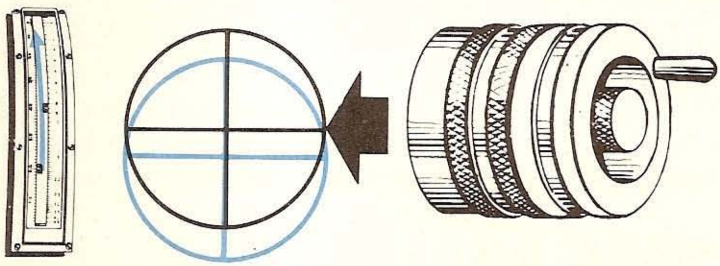
Checking the action of the rate, displacement and search knobs will reveal any binding in the gears or shafts. Checking the extended vision knob shows whether or not the action permits additional tilt to the mirror and whether or not it can be locked in normal position.

10. CHECK RATE MOTOR AND DRIVE OF OPTICS

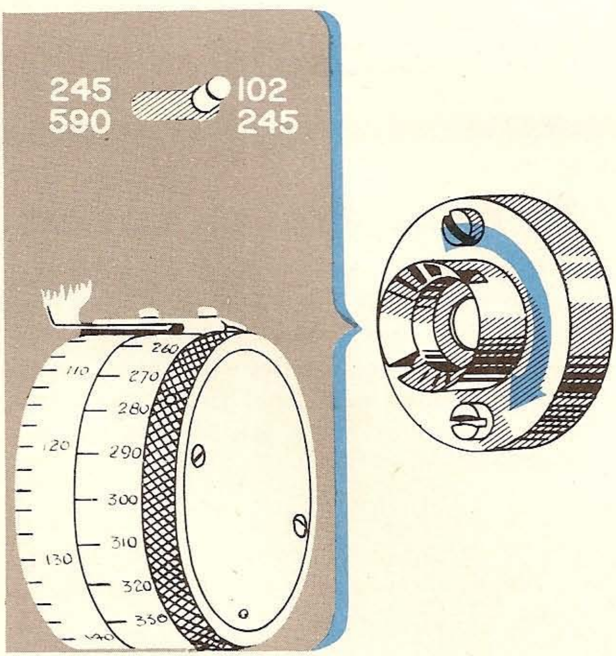
When you turn the rate motor switch ON, the tachometer adapter should rotate. If it does not rotate, make sure the disc speed gearshift is not in the neutral position.

When you engage the mirror drive clutch, it locks the lower traction gear and connects the drive from the disc and roller to the mirror. With the dropping angle index off the zero position, the optics will drive. This drive should be smooth. The sighting angle index should move faster as the dropping angle index is positioned at larger dropping angles.





11. CHECK DISC SPEED DRUM AND DISC SPEED GEARSHIFT



Shifting the disc speed gearshift changes the speed of rotation of the tachometer adapter. This tests the proper action of the clutch. By turning the disc speed drum through its entire range, the adapter's speed of rotation should increase as the drum is moved from minimum to maximum range. This tests for proper action of the springs within the drum.

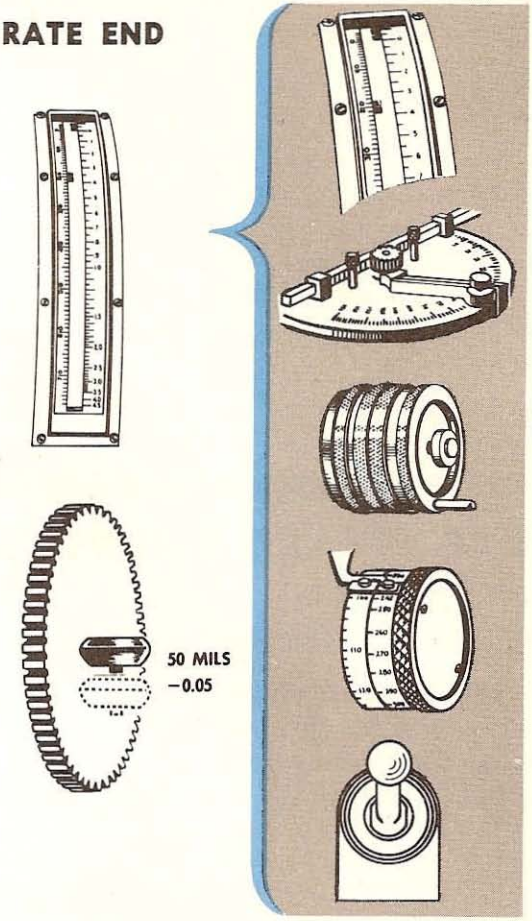
12. CHECK FOR PRE-SET TRAIL IN THE RATE END

SETTINGS: *Dropping angle index on –.05, trail arm on 50 mils, maximum disc speed, and small sighting angle. Engage mirror drive clutch and turn rate motor switch ON. Sighting angle index should not move.*

Setting the dropping angle index at –.05 positions the roller 50 mils below the center of the disc. When you move the trail arm out to 50 mils, the roller should then be moved back up to the center of the disc, and the sighting angle index should not drive.

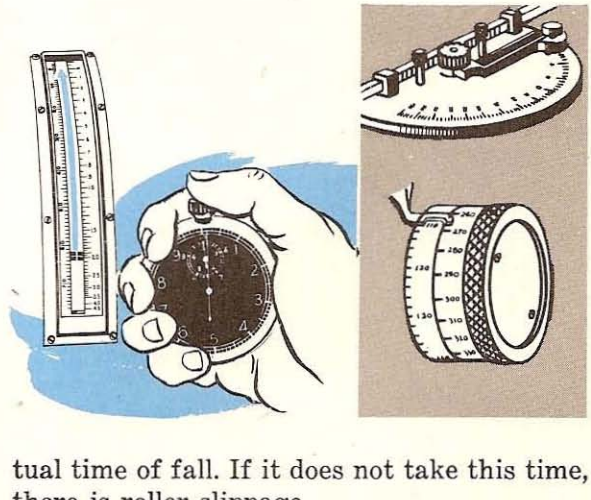
If you have to move the trail arm less than 50 mils to stop the movement of the sighting angle index, **positive** pre-set trail is present. You can find the amount present by subtracting the amount shown on the trail plate from 50 mils. Negative pre-set trail exists if you have to move the trail arm more than 50 mils to stop the movement of the sighting angle index.

Maximum disc speed and a small sighting angle are used to give the greatest apparent motion if any pre-set trail is present. Turn rate motor switch OFF as soon as check is completed to prevent excessive wear of disc and roller.



13. CHECK FOR ROLLER SLIPPAGE

SETTINGS: *Zero trail and disc speed of 265 rpm (set by tachometer). Clock the travel of the sighting angle index from the instant it is opposite the dropping angle index until it reaches zero. Repeat this operation with the dropping angle index at three different settings. With the disc speed at 265, the time of travel should be 20 seconds for each dropping angle index setting. A tolerance of .2 seconds is allowed for human error.*



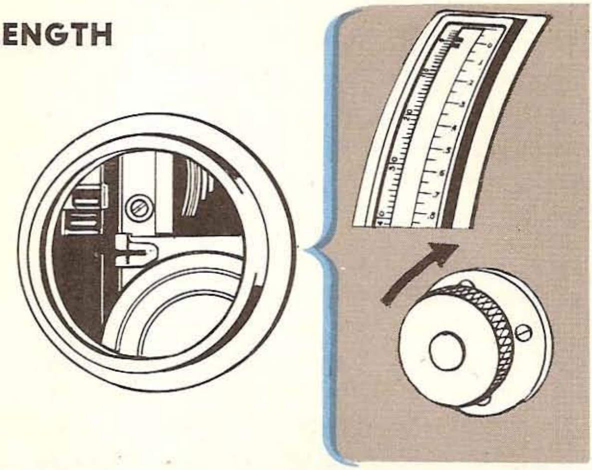
During actual time of fall, the sighting angle index should drive through an angle that subtends whole range. With no trail set in the sight, any position of the dropping angle index is the tangent of the whole range angle. Therefore, the time it takes the sighting angle index to drive from the dropping angle index position to zero should equal actual time of fall. If it does not take this time, there is roller slippage.

Although you can make this check with any ATF, a disc speed of 265 rpm is best because it gives you an even number of seconds (20) to work with.

14. CHECK MIRROR DRIVE CABLE LENGTH

SETTINGS: *Sighting angle index at zero and no extended vision.*

Look through the eyepiece and check coincidence pointers. The pointers are forward and left of the telescope. The coincidence pointers should match. If they do not match, the cable is not the correct length.

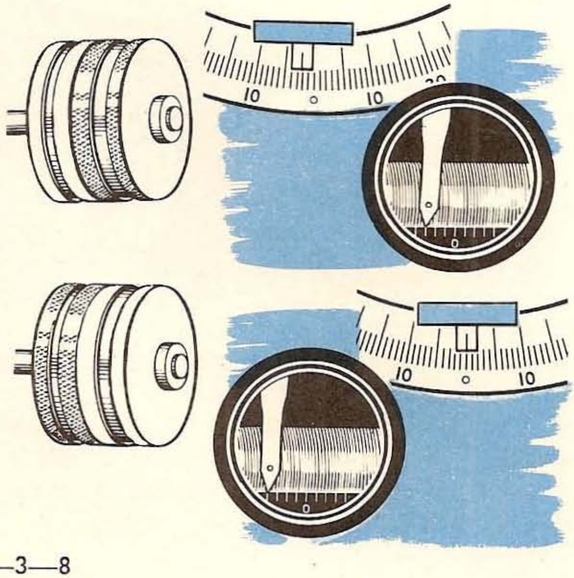


STABILIZER AND COURSE KNOBS

15. TURN "SERVO" SWITCH ON

The switch marked "SERVO" completes the circuit to the torque unit. Since the torque unit aids in stabilizing the directional gyro, it must be ON before you make the next checks.

16. CHECK ACTION OF COURSE KNOBS AND PDI



Engage bombsight clutch and turn sighthead through its limits with the turn knob. You can tell by the "feel" of the knob whether or not the turn worm and stabilized gear sector mesh properly.

Move the PDI brush through its limits with the drift knob. You can tell whether or not the drift worm and drift gear are meshed properly.

After the PDI hits its stops, the drift gear clutch should slip when you continue to turn the drift knob. If the clutch is too loose, PDI action will be erratic.

The PDI brush should move smoothly when using either knob.

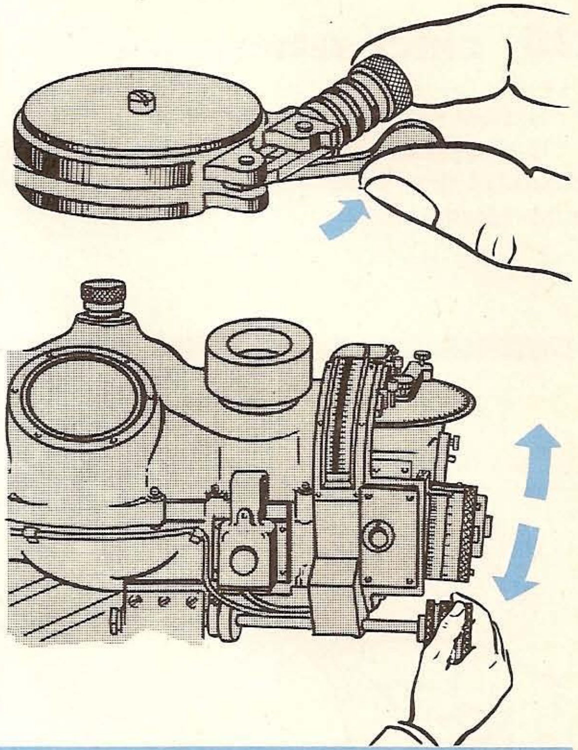
17. CHECK TORQUE UNIT AND BOMBSIGHT CLUTCH

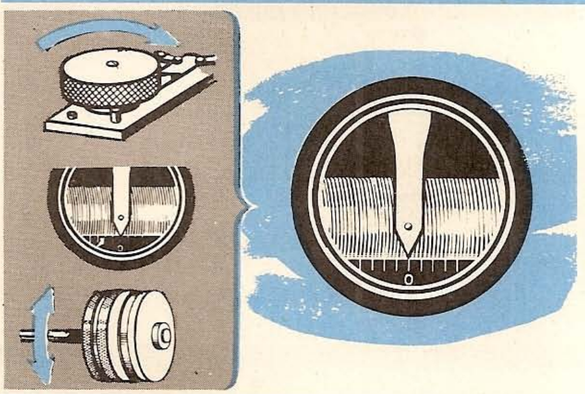
SETTINGS: *Engage bombsight clutch and apply torque to the sighthead in both directions. The sighthead should resist turning.*

If the bombsight does not resist turning, either the torque unit or the bombsight clutch is not operating properly.

A malfunction of the torque unit causes the directional gyro to precess against the case and lose all stability when you apply torque to the sighthead. You apply torque in both directions to check both halves of the torque unit. When the sighthead resists turning in one direction but not in the other, this means that one half of the unit is not working.

A malfunction of the bombsight clutch causes a slipping of the sighthead when torque is applied. Either improper adjustment of the bombsight clutch or oil on the clutch will cause it to slip.





18. CHECK AUTOPILOT CLUTCH

Engage autopilot clutch with PDI on zero. Turn drift knob and watch PDI. It should not move. If it does, the autopilot clutch is slipping. With autopilot clutch disengaged, PDI should move smoothly through its limits.

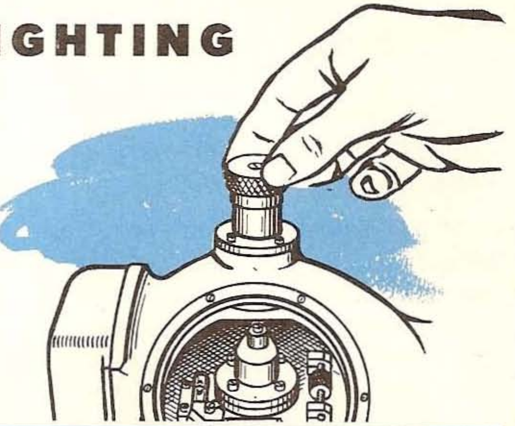
19. CHECK PDI WITH PILOT

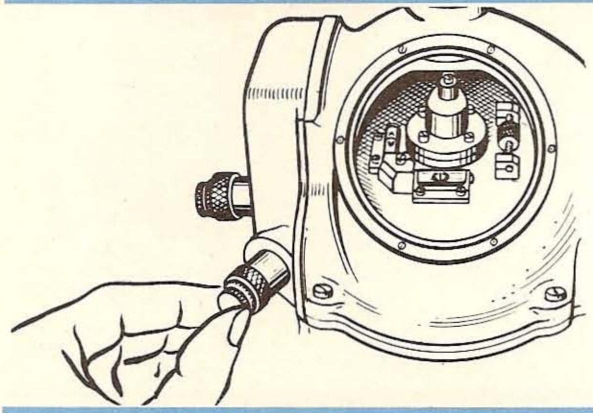
Engage bombsight clutch, disengage autopilot clutch. With drift knob, move PDI to center, left, and right positions. Pilot's PDI needle should be on center when your PDI is on center. When you move the PDI brush to your right, the pilot's PDI should move to the left, and vice versa.

SIGHT VERTICAL AND LIGHTING

20. CHECK VERTICAL GYRO

Uncage gyro. It should hold its position.
If the gyro does not hold its position, this indicates that it has not attained proper running speed.



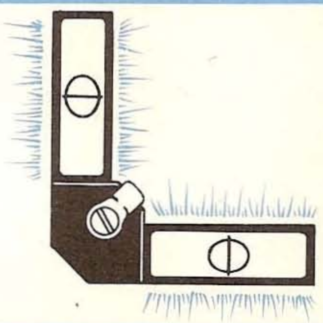


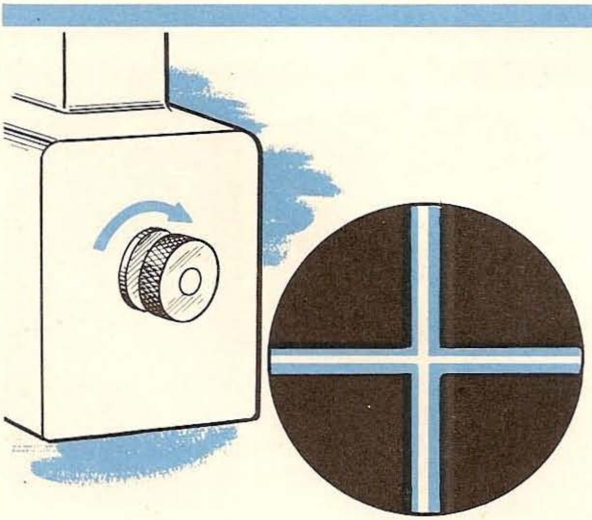
21. CHECK LEVELING KNOBS

Gyro uncaged. With each leveling knob precess gyro. Bubbles should move in same direction that you apply torque. Also check to see that leveling knobs return to their normal position when released.

22. CHECK BUBBLE LIGHT

With "BS" switch ON, bubbles should be lighted.

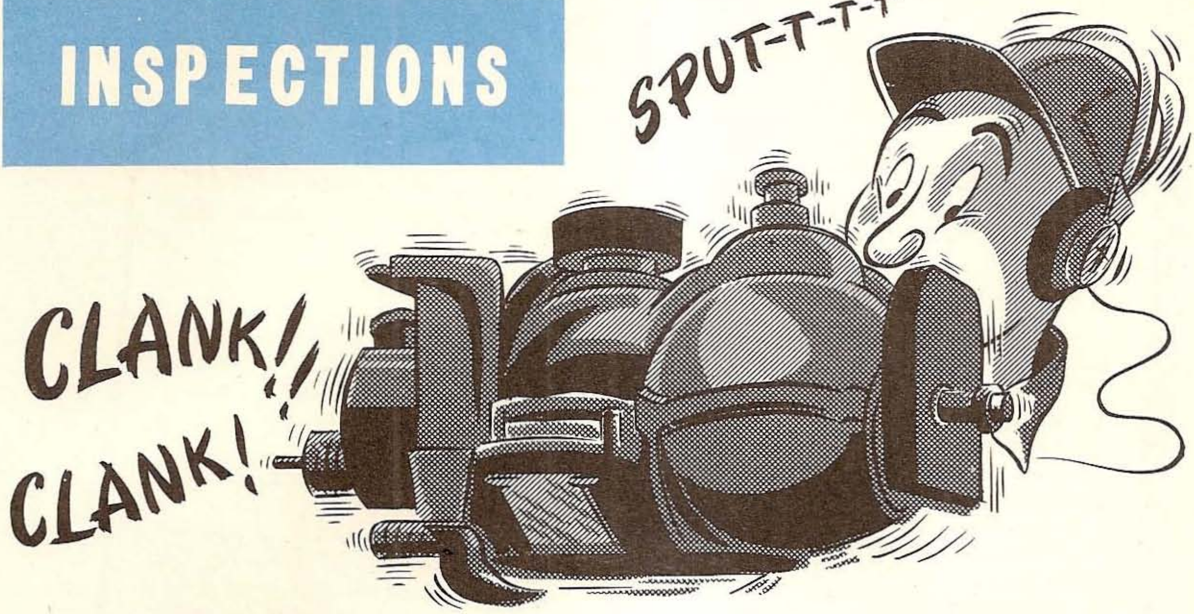




23. CHECK CROSSHAIR RHEOSTAT

Rheostat full right. Cover your head and the lower bombsight window with the bombsight cover. Look into the telescope. The crosshairs should be lighted. NOTE: This check is necessary only during the preflight for night missions.

INSPECTIONS



General

The more you know about your equipment, the better you can do your job. If you are familiar with inspections and know trouble shooting, it will help you to locate and report any malfunction that may be present. This will save the maintenance department time and trouble.

The Logbook

You should know the importance of the bombsight log. The log is the history of the bombsight from the time it leaves the factory until it is withdrawn from service for survey. It is an official document kept by the maintenance department.

It has been found from examination of log books which have been turned in with instruments for repairs and overhaul that:

1. Much work is done on bombsights which is not entered in the log.
2. Much upkeep work is done by inexperienced personnel.
3. There is a tendency to do more disassembly and adjustment than is necessary.

In order to give overhaul personnel complete data on the equipment, every adjustment or failure must be recorded fully. If failure and adjustments are listed accurately, it will give the manufacturers a clear idea of changes needed in design or construction.

Whenever a bombsight is withdrawn from service and turned in to the supply officer for storage or shipment, the bombsight officer must make a notation of the exact condition of the equipment. This notation which will be made immediately after the last previous entry in the log book, will include the following information:

1. This bombsight and/or stabilizer is in serviceable condition for re-issue without repair.
2. This bombsight and/or stabilizer should be forwarded to an overhaul shop for repairs or overhaul prior to re-issue.
3. This bombsight and/or stabilizer has been lubricated and prepared for temporary storage.
4. This bombsight and/or stabilizer has been lubricated and prepared for extended storage.

The logbook must be forwarded with the bombsight or stabilizer, whenever either instrument is turned in for overhaul or repair.

The shop receiving a serviceable sight should know whether it has been damaged in shipment. For this reason, the precession chart made on the last inspection should be inserted in the log book. You should record accurately all of the bombsight's running time. Inspections are based on the running time that you report.

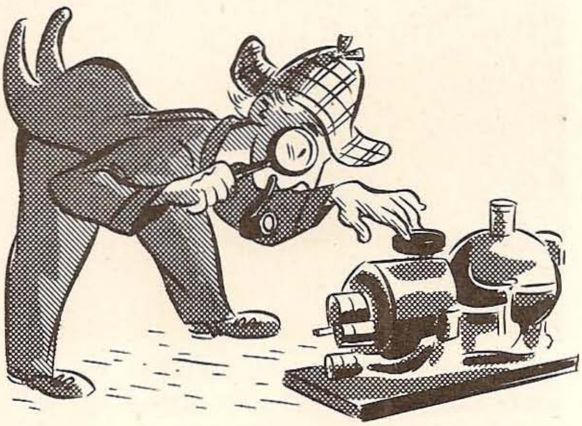
Inspection Sheet

INSPECTION

The asterisk precedes checks to be made on the 15-hour inspection. All checks are to be made on 50-hour inspection.

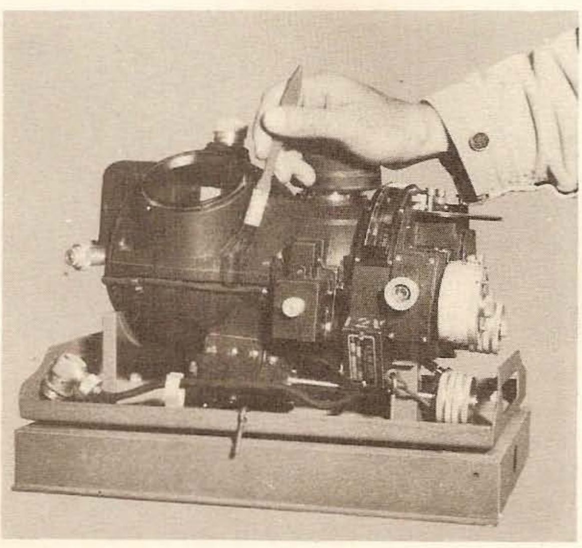
1. SIGHTHEAD
   *Outer case inspected . . . . ____
2. RATE END
   *Housing cleaned . . . . . . ____
   *Wiring checked . . . . . . ____
   *Gears checked . . . . ____
   *Bearings oiled . . . . ____
   *Disc and roller cleaned . . . ____
   *Brushes checked . . . . . . ____
   *Commutator cleaned . . . . ____
   *Rate motor breaker points cleaned . . . . ____
   *Disc speed drum checked . . ____
   Extended vision knob and spring checked . . . . . . ____
   Automatic release mechanism and indices checked . . . ____
3. CARDEN ASSEMBLY
   *Housing cleaned . . . . . . ____
   *Wiring checked . . . . . . ____
   *Brushes checked . . . . . . ____
   *Commutator cleaned . . . . ____
   *Gyro bearings oiled . . . . ____
   *Caging knob checked . . . ____
   *Leveling knobs checked . . ____
   Mirror drive cable checked . ____
   *Bubble light checked . . . . ____
   *Mirror cleaned . . . . ____
   *Flexible leads checked . . . ____
4. COURSE KNOBS
   Clearance checked . . . . . ____
   Stabilized gear sector checked . . . . ____
   Dovetail locking pin checked ____
5. CALIBRATION
   Crosshair light . . . . ____
   Dovetail alignment checked . ____
   Crosstrail mechanism checked . . . . ____
   *Roller zeroed . . . . ____
   Check telescope vertical . . ____
   Check roller slippage (at 265 DS or 20 sec. ATF) . ____
   Check Precession of vertical gyro . . . . ____
6. STABILIZER (External):
   *Outer case inspected . . . . ____
   *Clutch drums cleaned . . . . ____
   *Bombsight clutch cleaned . . ____
   *Autopilot clutch cleaned . . ____
7. TORQUE UNIT
   *Wiring checked . . . . . . ____
   *Brushes checked . . . . . . ____
   *Commutator cleaned . . . . ____
   *Gears cleaned . . . . ____
   *Clutches cleaned . . . . . . ____
   *Bayonet springs adjusted . . ____
   Clapper magnets checked . ____
   *Oil bearings if necessary . . ____
8. STABILIZER (Internal)
   Slip rings cleaned . . . . . ____
   Slip ring brushes cleaned . . ____
   *Brushes checked . . . . . . ____
   *Commutator cleaned . . . . ____
   *Bearings oiled . . . . ____
   Contact sector cleaned . . . ____
   Brush cleaned and adjusted . ____
   *Wiring checked . . . . . . ____
   *PDI coil checked . . . . . . ____
   *PDI brush cleaned and checked . . . . ____
9. CALIBRATION TENSION ADJUSTED ON:
   *Bombsight clutch (18-22) . . ____
   *Autopilot clutch (10-14) . . . ____
   *Drift gear clutch (6-8) . . . ____
   Precession check (stabilizer gyro) . . . . ____

INSPECTION PERFORMANCE



1. Sighthead Checks:

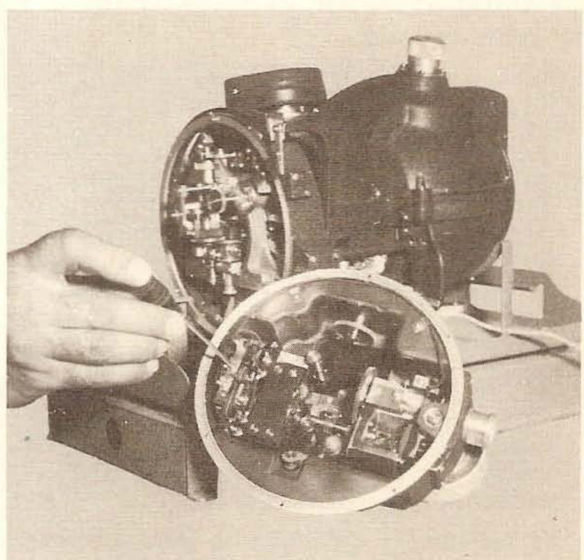
OUTER CASE INSPECTED: Check condition of paint as to peeling, chipping, etc. If there is corrosion underneath paint, scrape and polish that area thoroughly before retouching. Use a fast drying crackle finish lacquer on the exterior. You may detect corrosion of the magnesium alloy in the sight as a white powder or paste similar to the substance which is found in a "dead" dry cell battery. It must be removed completely by scraping it away from the bare metal. Polish the spot with crocus cloth or a hardwood stick and retouch with paint or rub in a small amount of bombsight oil. CAUTION: Always clean external parts of sight before opening the sight case.



2. Rate End Tests:

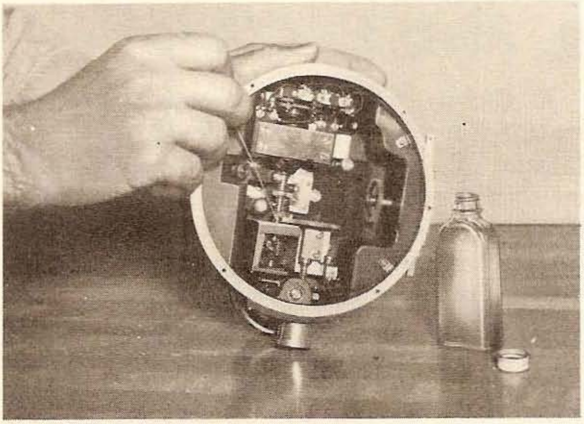
A. **CASE CLEANED:** Remove all foreign matter from inside of case. Pick up dirt from interior of case with carbon tetrachloride moistened cotton, or a swab stick. NEVER STIR UP DUST AND DIRT INSIDE CASE. Check for corrosion and rust on the bare metal. Remove corrosion and rust with acid-free kerosene and crocus cloth; dry clean the surface thoroughly with carbon tetrachloride and a clean white cloth. (White cloth is preferred because the dye from colored cloth may easily be deposited on the surfaces with which it comes in contact when used in conjunction with oil, solvents, etc.)

B. **WIRING CHECKED:** Check wiring for frayed or burned insulation and faulty terminals. Check terminal screws for tightness, stripped threads, bad screw driver slots, etc. Make the proper repairs and replacements. Check for proper shaping of all wiring; this includes pigtails and flexible leads. When necessary check wiring throughout with continuity tester.



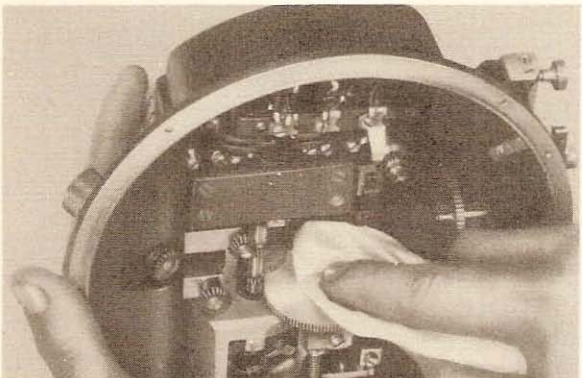
C. **GEARS CHECKED:** Clean with orange wood stick and carbon tetrachloride. Remove burrs with an Arkansas stone.

D. **BEARINGS OILED:** Oil rate motor shaft bearings with one drop of heavy bombsight oil if necessary. Oil governor bearing and disc speed drum shaft bearing with one drop of light bombsight oil, only if necessary.

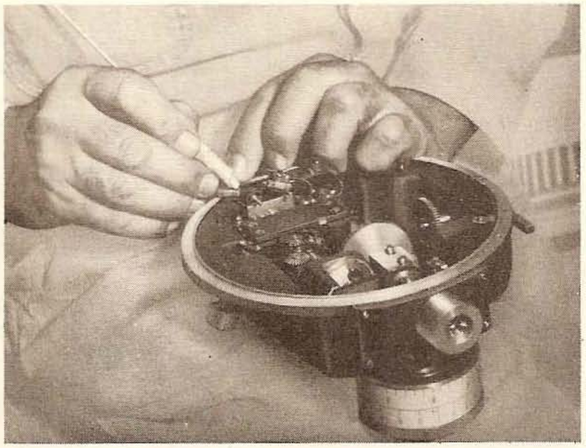


E. **DISC AND ROLLER CLEANED:** If there is any dirt, dust, or excess oil on the disc and roller, clean them with carbon tetrachloride. After cleaning, rub in some light bombsight oil and wipe off excess with clean cloth. The roller should not be kept at the center of the disc except for test purposes. If the roller is kept at the center of the disc, it will cause excessive wear, resulting in a flat spot on the roller and a depression in the center of the disc. The spring tension on the disc is tested for a 2 lb. tension.

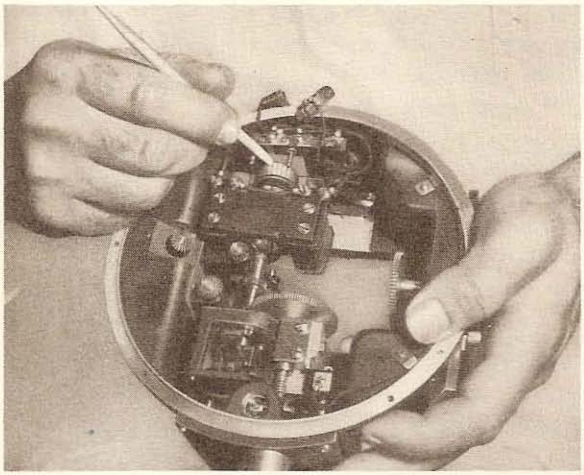
CAUTION: Do not use abrasives in cleaning roller and disc.



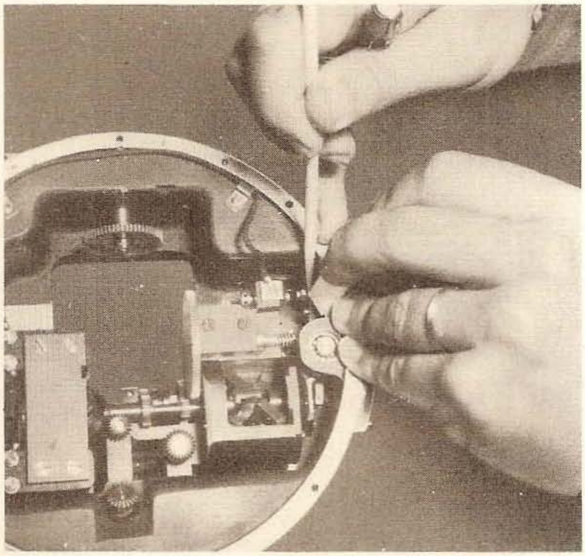
F. **BRUSHES CHECKED:** Before removing brushes, mark them so that you can replace them in the same positions. Clean brushes with carbon tetrachloride. Do not use benzine.



G. **COMMUTATOR CLEANED:** Use clean white cloth moistened with carbon tetrachloride (not alcohol) over the end of a soft wood stick for cleaning commutator. Keep using a clean section of the cloth until the cloth comes out clean. Scrape lightly between segments with a wedge-pointed orange stick. Use a strip of No. 400 aluminum oxide paper over the end of a wedge point to remove wire edges from segments. Re-clean with cloth. If commutator is rough, smooth with No. 400 aluminum oxide paper. Guide stick must be cut to fit commutator. Never use a metal instrument as a guide. Care must be taken to avoid tapering or hollowing of commutator. Brush against commutator must have at least an 85 percent contact.

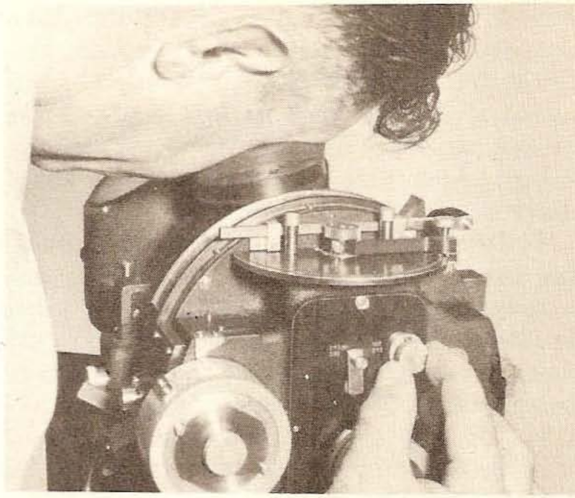


H. **BREAKER POINTS CLEANED:** Clean by pulling cigarette paper through closed points five or six times. Check to see that points have at least 30 percent contact. If contact surfaces are pitted or rough, resurface with a fine platinum point file. Polish contact surfaces with No. 400 aluminum oxide paper. Clean with dry white cloth. Do not use carbon tetrachloride or crocus cloth.

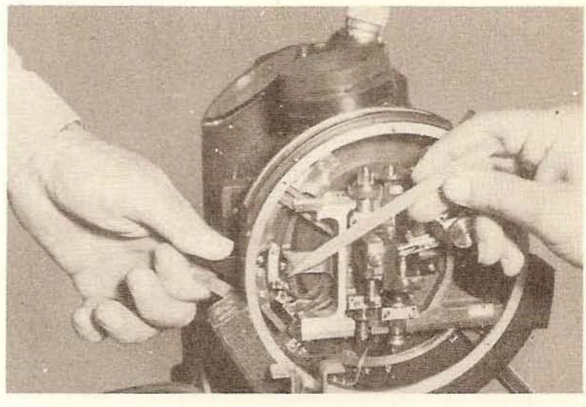


I. **DISC SPEED DRUM:** Remove cover and clean springs with carbon tetrachloride if necessary. Check to see that springs are secure around shaft. After cleaning with carbon tetrachloride, rub a small amount of light bombsight oil on springs to prevent rusting.

J. **EXTENDED VISION:** Check to see if knob works smoothly and spring returns knob to normal position. If sticking, remove and clean with carbon tetrachloride.



K. **AUTOMATIC RELEASE MECHANISM AND INDICES:** Set the automatic release points to close when the sighting angle and dropping angle indices are perfectly matched. Not more than 1/32 of an inch should be removed or dressed from the points.

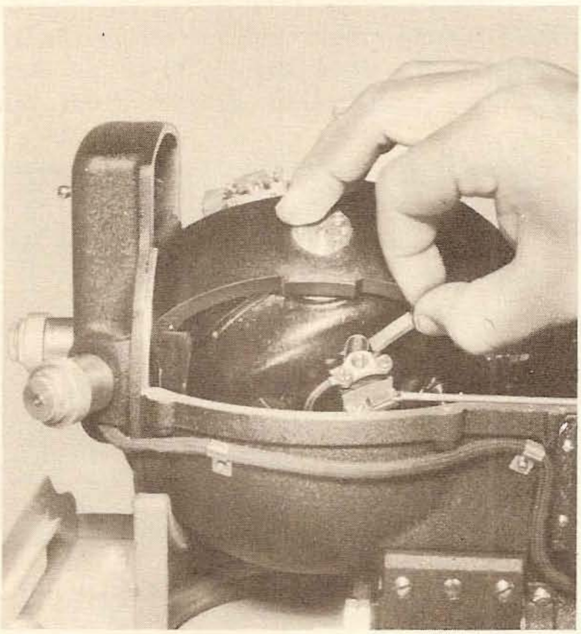


3. *Cardan Assembly Tests:*

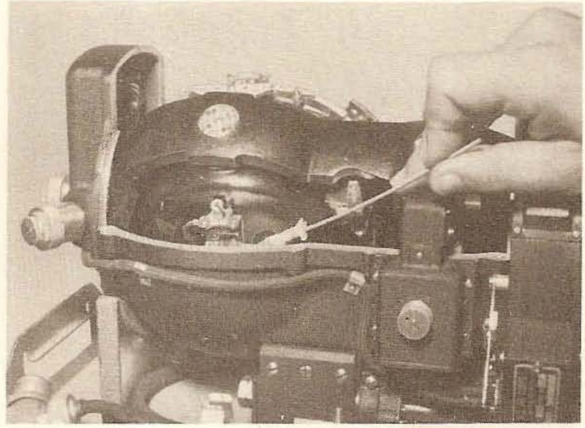
A. **CASE CLEANED:** Remove all foreign matter from inside of case. Pick up dirt from interior of case with carbon tetrachloride moistened cotton, or a swab stick. NEVER STIR UP DUST AND DIRT INSIDE THE CASE. Check for corrosion and rust on the bare metal. Remove rust or corrosion with acid-free kerosene and crocus cloth; dry clean the surface thoroughly with carbon tetrachloride and clean white cloth.

B. **WIRING CHECKED:** Check wiring for frayed or burned insulation and faulty terminals. Check terminal screw for tightness, stripped threads, bad screw driver slots, etc. Check for proper shaping of all wiring; this includes pigtails and flexible leads. Make proper repairs and replacements. When necessary check wiring throughout with continuity tester.

C. **BRUSHES CLEANED:** Before removing brushes, mark head of brush plug and measure the amount it extends from the brush tube. Mark brushes in such a way that you can replace them in the same position as before. Clean brushes with carbon tetrachloride. Do not use benzine. Check sides of brushes for shiny spots; shiny spots indicate that the brushes are sticking. To correct this, polish sides with crocus cloth. Re-clean. Clean brush tubes with carbon tetrachloride.



D. **COMMUTATOR CLEANED:** Use clean white cloth moistened with carbon tetrachloride (not alcohol) over the end of a soft wood stick for cleaning commutator. Keep using a clean section of the cloth until cloth comes out clean. Scrape lightly between segments with wedge-pointed orange stick. Use a strip of No. 400 aluminum oxide paper over the end of a wedge point to remove wire edges from segments. Re-clean with cloth. If commutator is rough, smooth with No. 400 aluminum oxide paper. Guide stick must be cut to fit commutator. Never use a metal instrument as a guide. Take care to avoid tapering or hollowing commutator. Brush against commutator must have at least an 85 percent contact.



E. **GYRO BEARINGS OILED:** Inspect gyro rotor bearings and oil with one drop of bombsight oil on each bearing. CAUTION: Never wait until bearing becomes dry before oiling. In most cases the rotor bearing must be oiled every 15 hours. Do not touch applicator to anything. After oiling bearings, run gyro for at least ten minutes and then wipe excess oil off commutator.

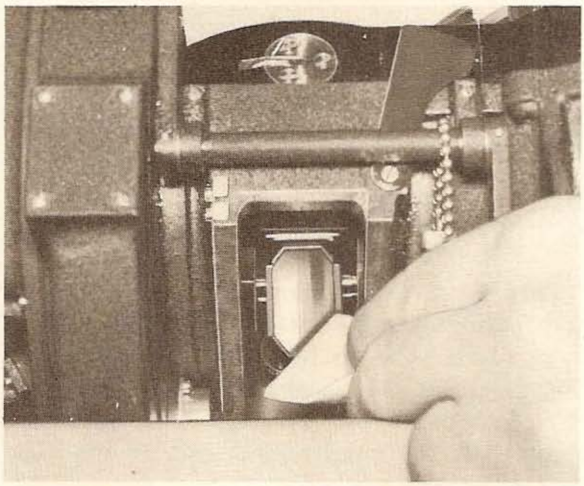
F. **CAGING KNOB:** Check for rust, dirt, and binding. Disassemble, clean, and lubricate with light bombsight oil.

G. **LEVELING KNOBS CLEANED:** Check for precession of gyro in proper direction as knobs are used. Bubbles should move in the same direction that the top of the knob is turned, when gyro is running. Check for binding of shafts due to dirt, corrosion, etc. Disassemble, clean, and oil if necessary.

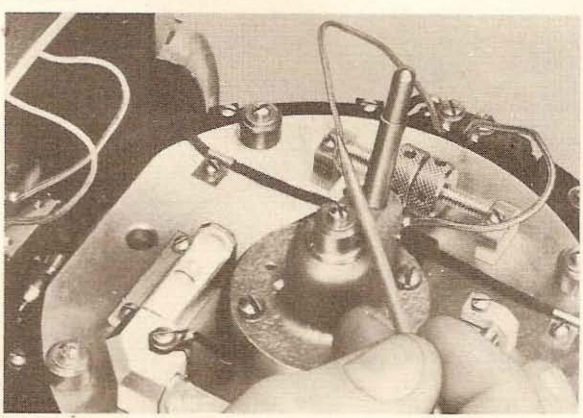
H. **MIRROR DRIVE CABLE CHECKED:** Test mirror drive cable for proper spring tension. (Spring tension should be 8 oz. when sighting angle index is at 30°.) Adjust spring tension by turning spring to new notch inside the spring housing. Fine adjustments can be made by turning spring housing 180°. Then move spring to new notch. Inspect cable for frays.

I. **BUBBLE LIGHT:** Check bubble light. Replace if necessary.

J. **MIRROR CLEANED:** Clean mirror and window with soft tissue paper. CAUTION: Do not use rough cloth or paper as the glass can easily be scratched.

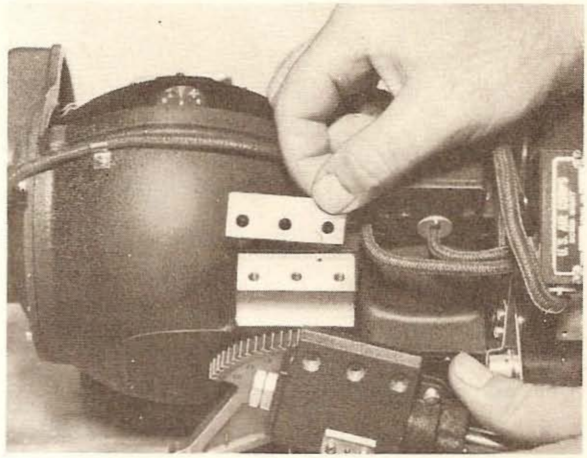


K. **FLEXIBLE LEADS CHECKED:** See that flexible leads on gyro do not contact the case or each other with gyro in any position. Shape leads with orange wood stick if necessary. Leads are shaped like a question mark. If flexible leads are re-shaped, precession runs will have to be made. CAUTION: Never use sharp edged instruments for shaping leads.

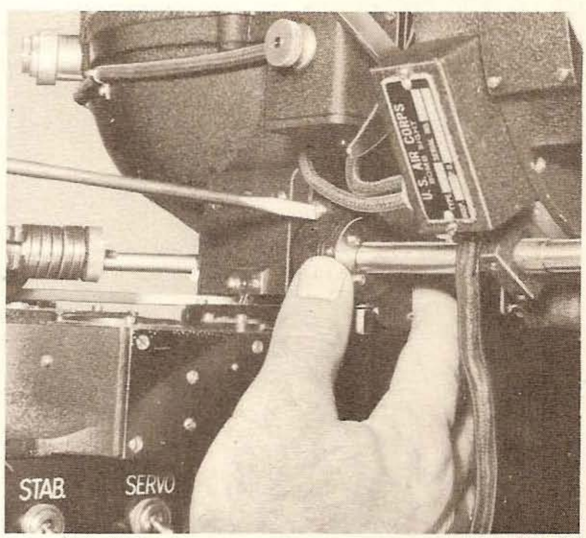


4. *Course Knobs:*

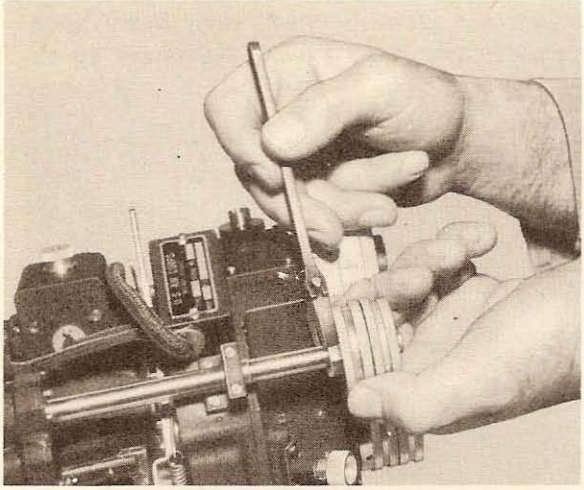
A. **CLEARANCES CHECKED:** Adjust end play of turn knob shaft by running locking nuts all the way down. Then back off one-half turn and lock. This play may easily be checked on end of shaft or between course knobs. Adjust back lash between turn worm and stabilized gear sector with shims. Always place more shims between turn worm housing and sight than will be necessary to ob-



tain clearance. Then remove .001 of an inch at a time to obtain minimum clearance without binding. The same number of shims should be placed between the drift knob shaft bracket and the sight case as there are between the turn worm housing and the sight case. This will prevent warping and binding of the drift knob shaft. Turn the knob through limits of stabilized gear sector.



Loosen set screw in drift worm housing and rotate housing until there is no binding or excess play. Tighten set screw. Drag should be equal on each knob. Remove burrs from all gear teeth before adjusting clearances. To adjust clearance between knobs, loosen lock nut on drift knob shaft and turn drift knob until you get desired clearance. Then tighten lock nut.

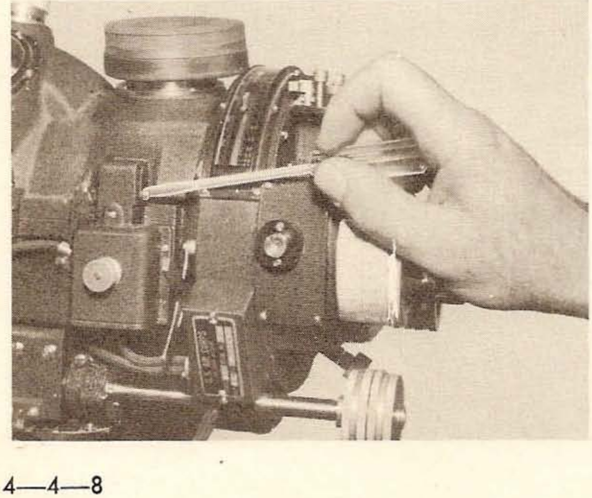


B. **STABILIZED GEAR SECTOR CHECKED:** Check for burrs and remove them. Then clean with carbon tetrachloride.

C. **DOVETAIL LOCKING PIN CHECKED:** Check for security of pin. Replace if pin has any play.

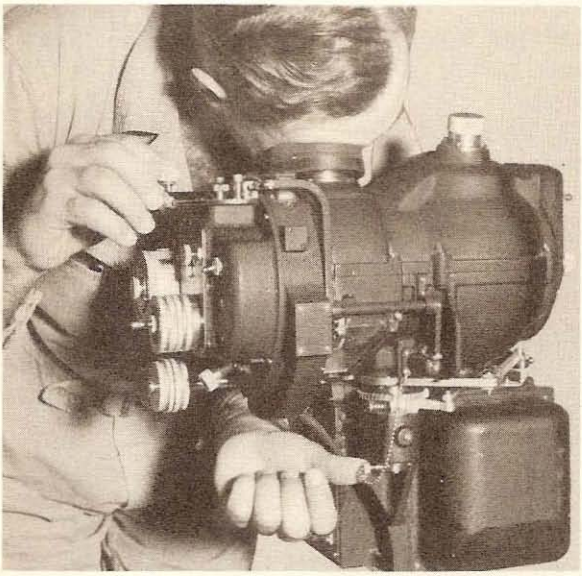
5. *Calibration:*

A. **CROSSHAIR LIGHT:** If bulb is lighted, and crosshairs are not visible, move mirror adjusting arm until beam is on crosshairs.



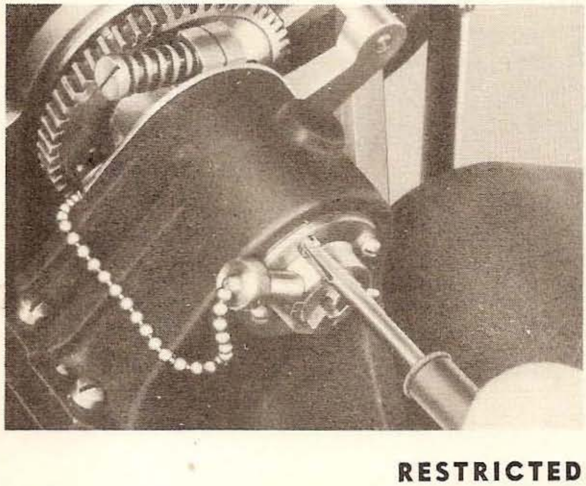
B. **DOVETAIL ALIGNMENT:**

1. Settings: Set sight on zero drift. Set sighting angle index on zero. Set dropping angle index at center of scale. Check to see that dovetail locking pin is in.



2. Check: While moving trail arm back and forth through entire range, look into telescope and observe fore and aft crosshair. The fore and aft crosshair should not move. If it does move, the dovetail is out of alignment with the longitudinal axis of the stabilizer.

3. Correction: Loosen the four screws of the dovetail locking bracket and turn bracket in the elongated screw holes until motion of the fore and aft crosshair stops when trail arm is moved. CAUTION: This adjustment is very fine and when tightening screws do it slowly to make sure the bracket does not move.

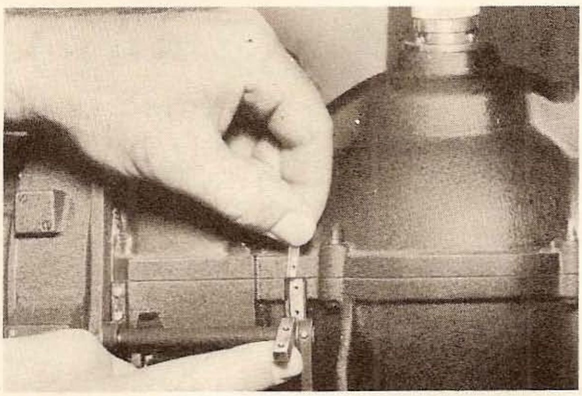


C. **PRESET TRAIL IN CROSSTRAIL MECHANISM:**

1. Settings: Set trail arm and sighting angle index at zero. Remove dovetail locking pin.

2. Check: Look into telescope and rotate bottom of dovetail shaft back and forth. The fore and aft crosshair should not move. If it does move, it means that pre-set trail is in the crosstrail mechanism.

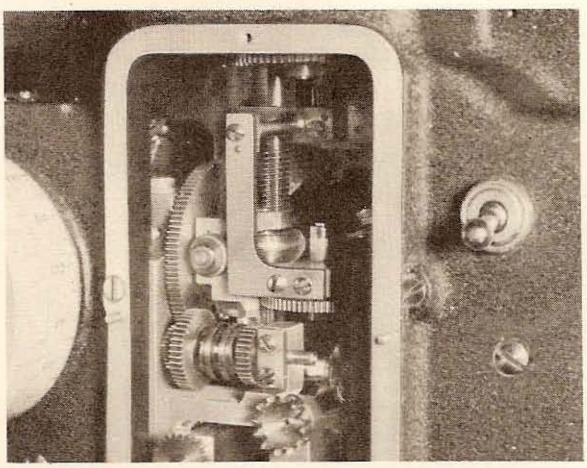
3. Correction: Check to see that the scribe mark on the trail rack is opposite the scribe mark on the trail arm pinion, when trail arm is at zero. If not, remove trail arm pinion and align scribe mark with trail arm set at zero. If this condition does not exist, it means that the trail bell crank linkage from the trail rack to the push rod is out of alignment. Change shims of trail bell crank to correct.



D. **ROLLER ZEROED:**

1. Settings: Set trail arm on zero, and lock; dropping angle index zero and maximum disc speed. Remove rate end inspection plate.

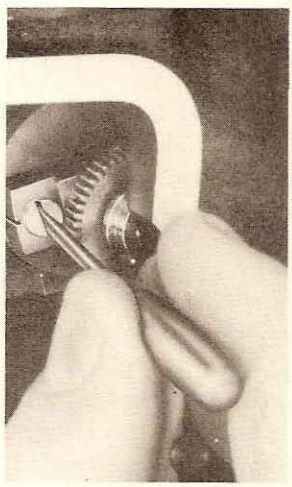
2. Check: Observe roller. If it is moving, pre-set trail is in the sight.

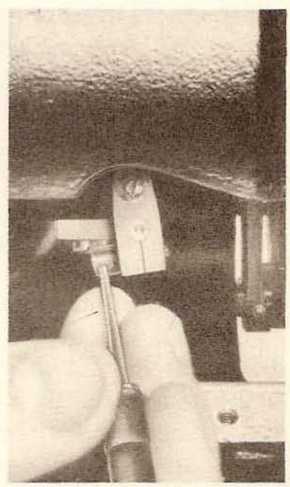


3. Correction: Loosen trail arm clamp screw and turn trail setting gear displacing roller below the center of the disc (the roller should be turning clockwise) and then center roller by turning the trail setting gear until roller stops rotating. Tighten clamp screw and check operation. NOTE: Displacing the roller below the center and bringing it back to center eliminates an error caused by back lash.

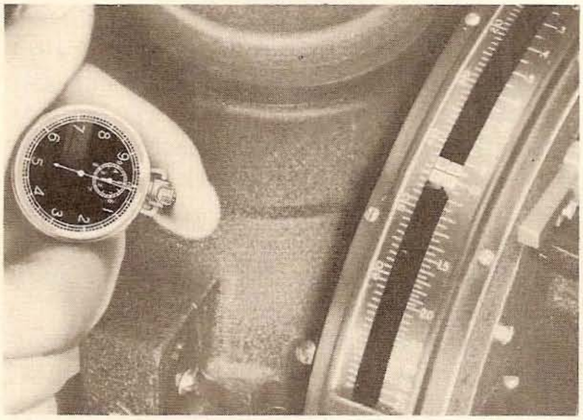
E. **TELESCOPE VERTICAL:** Establish the vertical gyro in the vertical, using the bubbles as reference. Gyro is locked in this position by wooden wedges or clamps. Place precision mirror directly beneath telescope and level with spirit level. If you use a bowl of mercury, it is not necessary to level it as mercury will seek its true level. With bubbles level and sighting angle index at exactly zero, look through telescope into mirror beneath. You should see two images or circles. The crosshairs should split or bisect the rear image. If the lateral crosshair is off, it can be corrected by turning the eccentric screw on first sheave. (Before you make this correction, be sure to check the sighting angle index and bubbles for correct positions.)

If the fore and aft crosshair is off, the correction is made by loosening the turret head screw on crosstrail bell crank and gently tapping the top of the telescope in the desired direction until fore and aft crosshair is centered. Then carefully tighten the turret head screw so as not to disturb the setting. CAUTION: Check to see 20° extended vision is not in the sight when establishing telescope in vertical.





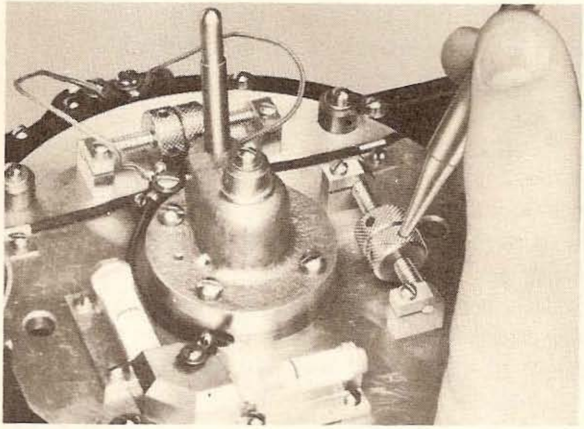
F. **CHECK ROLLER SLIPPAGE:** Set trail arm on zero. Set disc speed of 265 and position dropping angle index at tangent 1.5. Clutch in mirror drive clutch and time the travel of sighting angle index from the time indices meet until sighting angle index reaches zero. Record time with a stop watch. The time recorded should equal the actual time of fall in seconds for this disc speed. (5,300 divided by the disc speed equals ATF). Take reading several times at different tangent values greater than .3 through the range of the tangent scale. If the readings do not coincide, it indicates roller slippage. If roller is slipping, check for excessive oil on disc and roller, proper spring tension and friction through gear train.



G. **PRECESSION CHECK:** Check flexible leads and let the gyro run for at least 50 minutes before making precession runs. This is done to allow the gyro to attain running temperature. Set zero drift and zero sighting angle and place the sight on a North heading. Looking through the telescope, use leveling knobs to precess crosshairs on to the center of the grid, which is calibrated in mils. After two minutes observe position of fore and aft crosshair and note the amount and direction of precession. Repeat this operation on the opposite heading. Easterly precession should be equal on both headings, but not to exceed 9 mils.

If it is not equal, you must move the fore and aft precession weight mounted on the top right hand side of the gyro housing. To counteract precession to the right, move the weight forward. To counteract precession to the left, you move the weight to the rear.

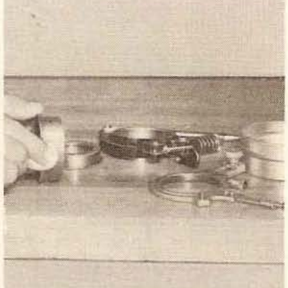
The operation is the same when checking for precession on East and West headings except that now you will observe the lateral hair and use the lateral weight to counteract precession. If the hair moves forward, move the weight to the left; if hair moves to the rear, move weight to the right.



6. *Stabilizer (External):*

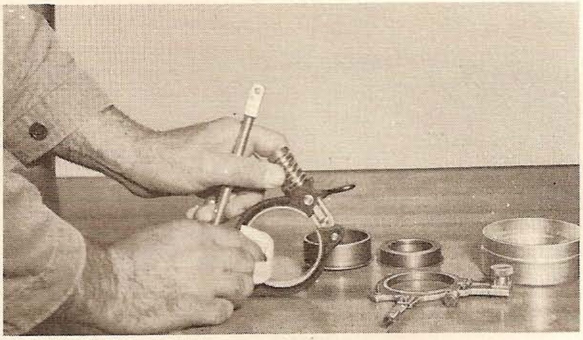
A. **OUTER CASE INSPECTED:** Check condition of paint as to peeling, chipping, etc. If there is corrosion underneath paint, scrape and polish that area thoroughly before retouching. Use a fast drying crackle finish lacquer on the exterior. You may detect corrosion of the magnesium alloy in the sight as a white powder or paste similar to the substance which is found in a "dead" dry cell battery. Remove it completely by scraping it away from the bare metal. Polish the spot with crocus cloth or a hardwood stick and retouch with paint or rub in a small amount of bombsight oil. CAUTION: Always clean external parts of stabilizer before opening the case.

B. **CLUTCH DRUMS CLEANED:** Remove clutches and clean drums with carbon tetrachloride. Rub oil into surface and wipe off excess oil with a clean dry cloth.



C. **BOMBSIGHT CLUTCH CLEANED:** Remove clutch and clean with carbon tetrachloride. Rub oil into surface and wipe off excess oil with dry clean cloth.

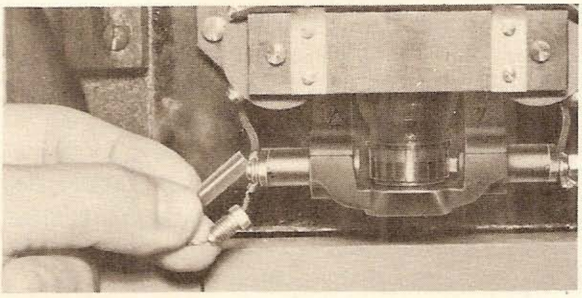
D. **AUTOPILOT CLUTCH CLEANED:** Remove clutch and clean with carbon tetrachloride. Rub oil into surface and wipe off excess oil with dry clean cloth.



7. *Torque Unit:*

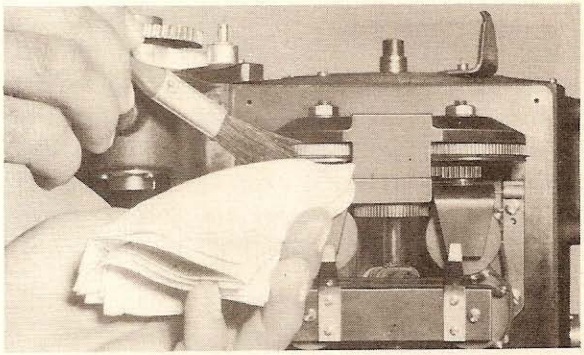
A. **WIRING CHECKED:** Check wiring for frayed or burned insulation and faulty terminals. Check terminal screws for tightness, stripped threads, bad screw driver slots, etc. Check for proper shaping of all wiring; this includes pigtails and flexible leads. Make proper repairs and replacements. When necessary check wiring throughout with continuity tester.

B. **BRUSHES CHECKED:** Before removing brushes, scribe head of brush plug and measure the amount it extends from the brush tube. Mark brushes in such a way so that you can replace them in the same positions as before. Clean brushes with carbon tetrachloride. Do not use benzine. Check sides of brushes for shiny spots; shiny spots indicate that the brushes are sticking. To correct this, polish sides with crocus cloth. Reclean. Clean brush tubes with carbon tetrachloride.

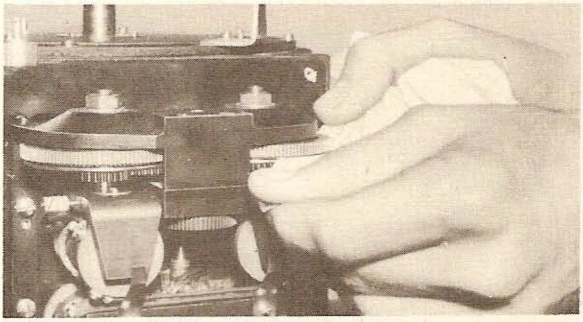


C. **COMMUTATORS CLEANED:** Use clean white cloth moistened with carbon tetrachloride (not alcohol) over the end of a soft wood stick for cleaning commutator. Keep using a clean section of the cloth until cloth comes out clean after being used. Scrape lightly between segments with wedge-pointed orange stick. Use a strip of No. 400 aluminum oxide paper over the end of a wedge point to remove wire edges from segments. Reclean with cloth. If commutator is rough, smooth with No. 400 aluminum oxide paper. Guide stick must be cut to fit commutator. Never use a metal instrument as a guide. Take care to avoid tapering or hollowing commutator. Brush against commutator must have at least 85 percent contact.

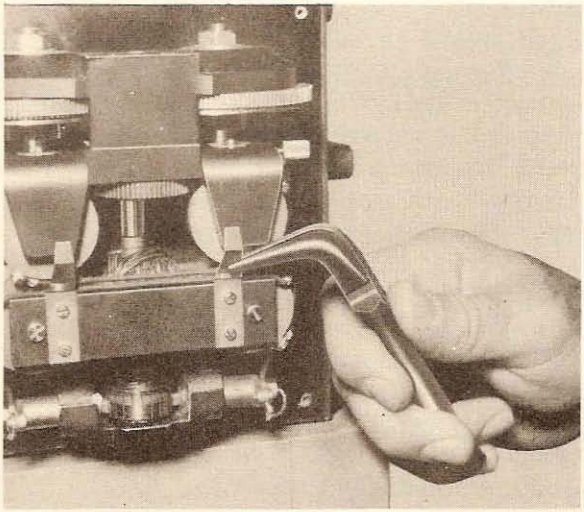
D. **GEARS CLEANED:** Clean clutch drive gears with carbon tetrachloride. Check gears for burrs. Remove burrs with smooth Arkansas stone and polish with crocus cloth.



E. **CLUTCHES CLEANED:** Clean torque clutches with clean white cloth. Place cloth between clutch disc and cork, wedge gyro, and turn the torque motor switch ON. Be very careful to hold cloth out of gear teeth and to keep clutch surfaces free of lint. Keep using new section of cloth until no oil or dirt appears on it. CAUTION: Keep cork facings free of oil. Oil will cause clutch slippage.



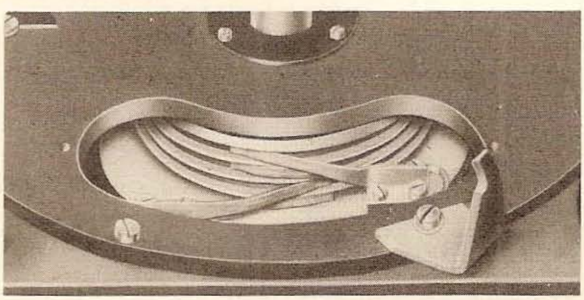
F. BAYONET SPRINGS ADJUSTED: Check adjustment of springs to insure that cork facing on clutch plate is not contacting surface of clutch drive gear when clapper magnet is de-energized.



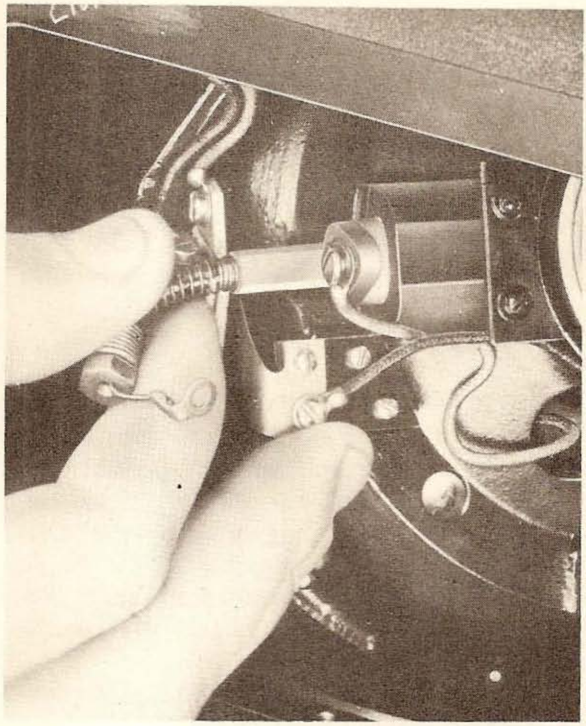
G. CLAPPER MAGNETS CHECKED: Check operation of clappers through contact brush on isolated sector. Check to see that counter-forces applied by torque unit are steady and in the right direction. You make this check by trying to precess the gyro manually while both stabilizer and torque motor switches are on. Check clapper pins for freedom and security.

8. *Stabilizer (Internal):*

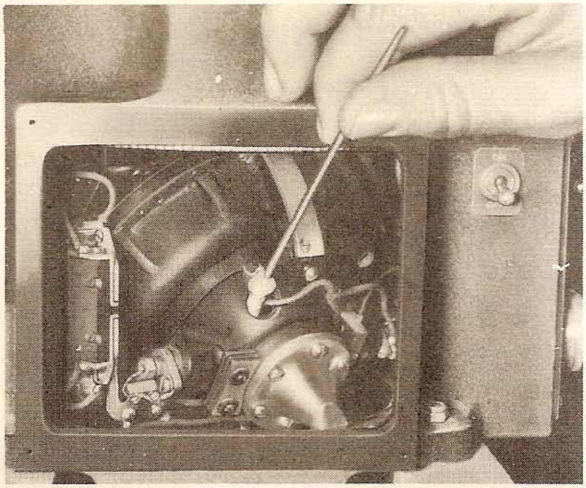
A. SLIP RINGS CLEANED: Check for rough spots and faulty insulation between the slip rings. Remove rough spots with No. 400 aluminum oxide paper. Clean rings with dry white cloth. Clean slip ring brush surfaces by inserting crocus cloth between slip ring and brush and pulling it through five or six times. Dirt should be removed with carbon tetrachloride.



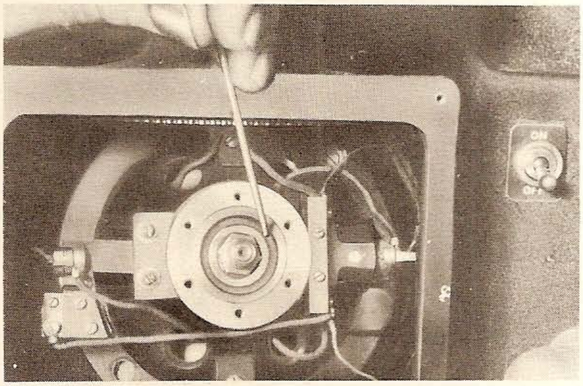
B. BRUSHES CHECKED: Before removing brushes scribe head of brush plug and measure the amount it extends from the brush tube. Mark brushes in such a way that you can replace them in the same position as before. Check sides of brushes for shiny spots; shiny spots indicate that the brushes are sticking. Clean brushes with carbon tetrachloride.



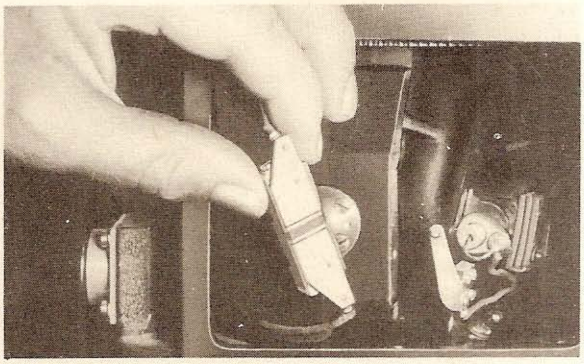
C. COMMUTATORS CLEANED: Use clean white cloth moistened with carbon tetrachloride (not alcohol) over the end of a soft wood stick for cleaning commutator. Keep using a clean section of the cloth until cloth comes out clean after being used. Scrape lightly between segments with wedge-pointed orange stick. Use a strip of No. 400 aluminum oxide paper over the end of a wedge point to remove wire edges from segments. Re-clean with cloth. If commutator is rough, smooth with No. 400 aluminum oxide paper. Guide stick must be cut to fit commutator. Never use a metal instrument as a guide. Brush against commutator must have at least an 85 percent contact. CAUTON: Be sure that no foreign matter drops down into bearing. Cover bearing with a clean cloth while working on the commutator.



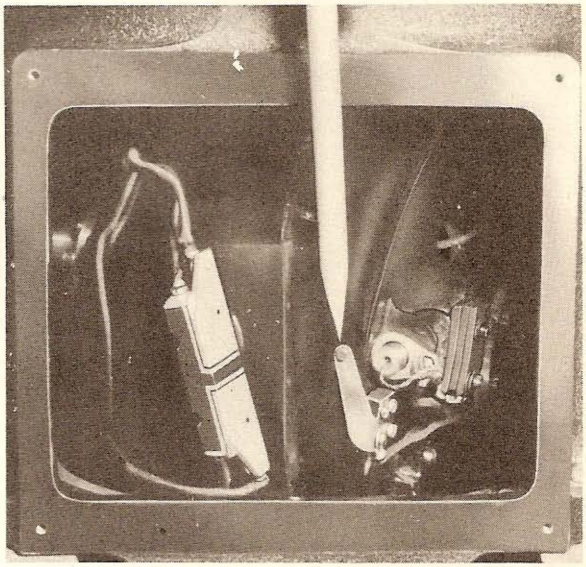
D. **BEARINGS OILED:** Oil rotor bearings with one drop of bombsight oil if necessary. Never wait until bearing becomes dry. After oiling, run gyro at least 10 minutes. Then wipe oil from the commutator. This will keep excess oil from the commutator.



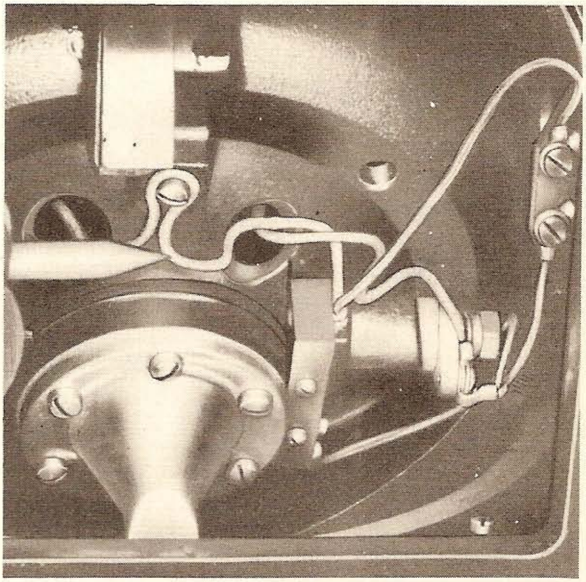
E. **CONTACT SECTOR CLEANED:** Inspect sector for arcing. Remove pits and burns with aluminum oxide paper. Lay paper on flat surface and rub the sector across the paper in alignment with the brush movement. Wash sector with carbon tetrachloride and replace.



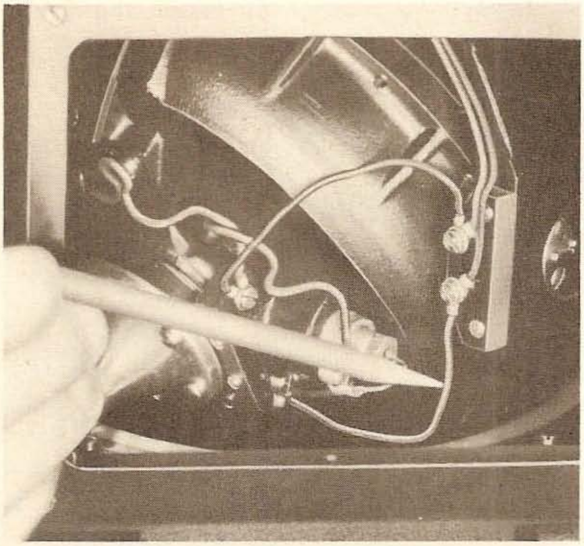
F. **CONTACT BRUSH:** Clean brush surface with the dry white rag. There should be a 1/32 of an inch bevel on the top and bottom of the point. Obtain 100 percent contact between flat surface of point and sector. Brush should ride half way up on upper sector when gyro is cold.



G. **WIRING CHECKED:** Check wiring for frayed or burned insulation, and faulty terminals. Check terminal screw for tightness, stripped threads, bad screw driver slots, etc. Check for proper shaping of all wiring; this includes pigtails and flexible leads. Make proper repairs and replacements. When necessary check wiring throughout with continuity tester.

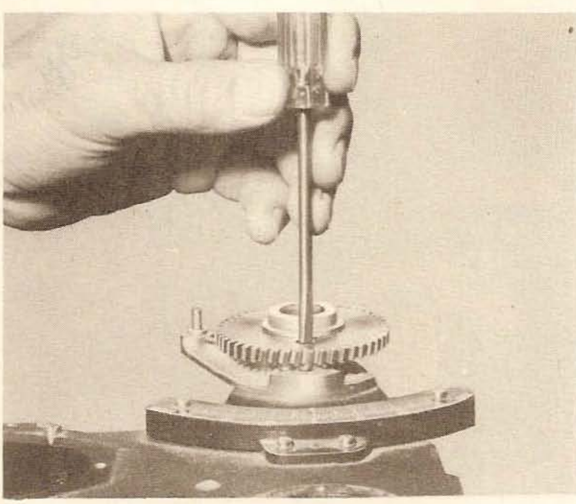


H. **FLEXIBLE LEADS CHECKED:** Check to see that leads do not touch any part of case or each other when gyro is moved to its limits. Shape as necessary.



I. **PDI COIL CHECKED:** Check to see that coil contact surface is smooth. Polish if necessary and clean with carbon tetrachloride.

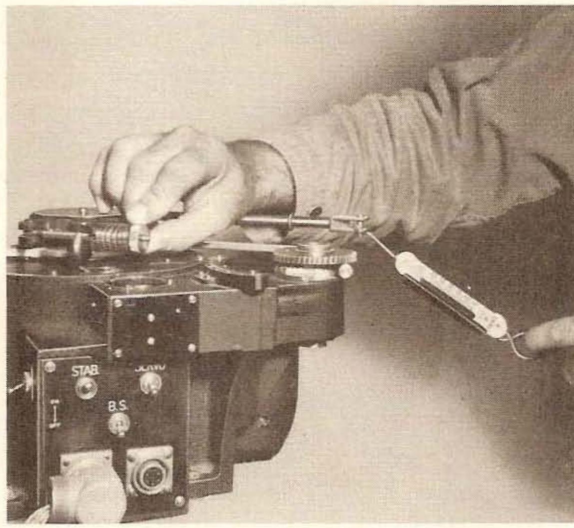
J. **PDI BRUSH:** Clean contact point and check tension of point on coil. Check autopilot clutch pushed first against one stop, then the other. The PDI brush should move an equal amount from zero in either direction. To adjust brush to this movement, loosen the center screw under the drift gear (through the hole in gear). Hold autopilot clutch against one stop and move the brush to $5\frac{1}{2}°$ from zero on that side. Tighten screw.



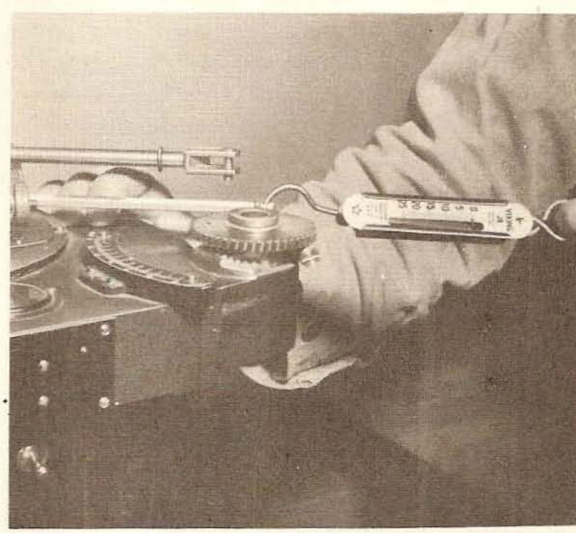
9. *Calibration:*

A. **CLUTCH TENSIONS ADJUSTED:** It is very important to adjust the tensions of the clutches to the proper amounts and at the correct points. Using a spring scale, make the adjustments with the stabilizer and torque motor ON.

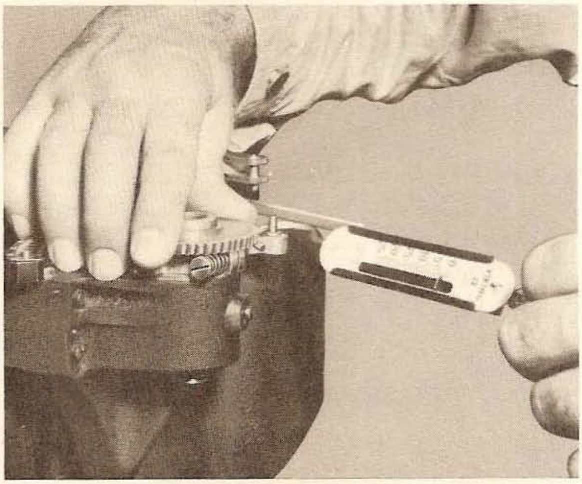
B. **BOMBSIGHT CLUTCH:** 18-22 lbs. Attach spring scale to end of bombsight connecting rod and pull at 90° to the clutch radius. Adjust spring tension with spring screw on clutch collar.

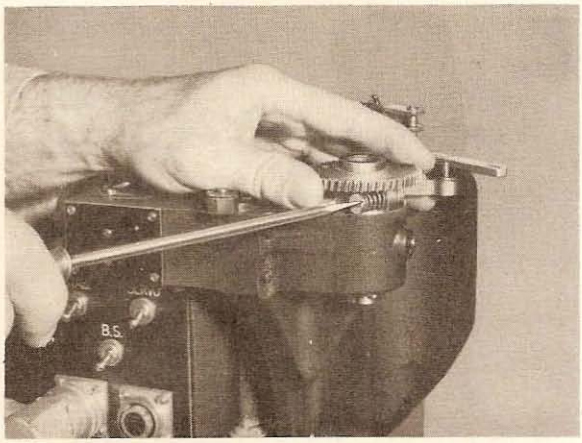


C. **AUTOPILOT CLUTCH:** 10-14 lbs. Attach spring scale to autopilot connecting rod and pull at 90° to clutch radius. Adjust spring tension by rotating turret head screw on clutch collar.

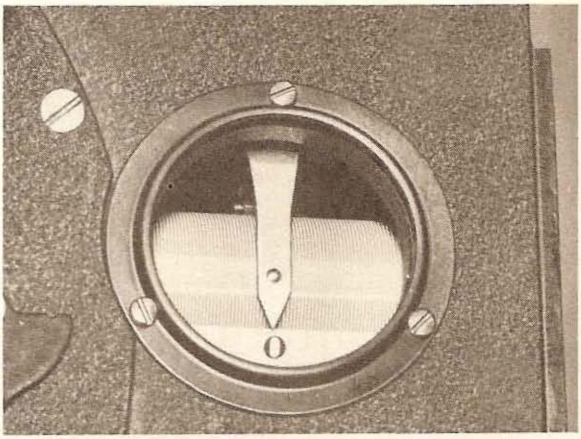


D. **DRIFT GEAR CLUTCH:** 6-8 lbs. Attach spring scale to stud on drift gear clutch arm and pull at 90° to clutch radius. Adjust spring tension by spring screw on collar below drift gear.





E. **PRECESSION:** Run stabilizer at least 15 minutes. Turn on torque motor and set PDI at exactly zero. Engage autopilot clutch. The directional gyro should not precess in 15 minutes. Apply the following rules for correcting:



1. If precession is clockwise: Add weight to the brush end of the gyro housing or remove weight from the other end.
2. If precession is counter-clockwise: Remove weight from the brush end of the gyro housing or add weight to the other end.

OVERNIGHT STORAGE:

OVERNIGHT STORAGE: Observe the following precautions to insure proper handling while you are preparing the bombsight for overnight storage.

1. **CAGE THE GYRO.** This prevents damage to gyro bearings, and the telescope cradle will not hit case.
2. **SET STABILIZED GEAR SECTOR ARM UNDER THE SIGHT.**
3. **SET TRAIL ARM AT 0.**
4. **KEEP DROPPING ANGLE INDEX OFF ZERO.**
5. **SET SIGHTING ANGLE INDEX AT 70°.**
6. **SET DISC SPEED DRUM AT 102.** This relieves tension on springs in the disc speed drum.
7. **TURN CROSSHAIR RHEOSTAT FULL LEFT.**
8. **ENGAGE ALL CLUTCHES.** This relieves tension on clutch springs.
9. **TURN OFF ALL SWITCHES.** This protects electrical circuits from damage.

Trouble Shooting

Checks for Determining Malfunction

When you have bombing errors or apparent malfunctions, although you are not certain there is a malfunction, make the following checks before you submit a malfunction report:

1. Make complete preflight inspection of all bombing equipment.
2. Check bombing altitude and true airspeed computations for correctness.
3. Check corrections of bombing tables and target information used.
4. Check correctness of data set in sight. (Proper use of tachometer.)
5. Check all switches and controls for proper position.
6. Check extended vision knob for proper position.
7. Check leveling knobs for sticking.
8. Turn switches OFF and ON several times when some unit fails to operate.
9. Check disc speed gear shift for proper position.
10. Check fuses that bombardier can replace.
11. Check generators for switches ON and voltage output.

Deflection Errors

Most deflection errors are caused by malfunctions of the crosstrail mechanism or stabilizer unit. However, if the telescope is out of the vertical, you would also have a deflection error. When deflection errors occur, look for:

PRE-SET TRAIL IN THE CROSS-TRAIL MECHANISM.
DOVETAIL MISALIGNMENT.
ERRATIC PDI SIGNALS.
LATERAL LEVELING KNOB STICKING.
BOMBSIGHT CLUTCH SLIPPING.
DRIFT GEAR CLUTCH SLIPPING.
DIRECTIONAL GYRO FAILURE.
TORQUE UNIT FAILURE.
COURSE KNOBS STICKING.
TELESCOPE OUT OF VERTICAL.
VERTICAL GYRO FAILURE.
AUTOPILOT CLUTCH STICKING.

Range Errors

Malfunctions in the rate end cause most range errors. When range errors occur, look for:

PRE-SET TRAIL IN RATE END.
IMPROPER LENGTH OF MIRROR DRIVE CABLE.
ROLLER SLIPPING.
ERRATIC DISC SPEED.
FORE AND AFT LEVELING KNOB STICKING.
VERTICAL GYRO FAILURE.
AUTOMATIC RELEASE MECHANISM FAILURE.
RANGE KNOBS FAILURE.

NOMENCLATURE

Automatic release mechanism—Located on quadrants in rate end. It provides automatic electrical release when the indices match and the release lever is held up.

Autopilot clutch—Located on the top of the stabilizer. It transmits stability of the directional gyro to the directional panel.

Autopilot clutch engaging knob—Located on autopilot clutch and is used to engage autopilot clutch to the directional gyro.

Autopilot connecting rod—It connects the autopilot clutch to the drift gear clutch, allowing turns to be made from the bombsight through the directional panel.

Bombsight clutch—Located on the top of the stabilizer. It transmits stability from the directional gyro to the sighthead.

Bombsight connecting rod—The link between bombsight clutch and stabilized sector.

Bombsight switch—Located on right side of stabilizer. It completes or breaks the circuit to the sighthead and the vertical gyro.

Bubbles—Located on the top of the vertical gyro housing. They indicate the position of the vertical gyro's axis.

Bubble light—Located at junction of bubble tubes. It lights bubbles for night bombing.

Caging knob—Located on top of sighthead case. It locks the vertical gyro to the case.

Clevis pin—The pin which fastens bombsight connecting rod to the stabilized sector.

Coincidence pointers—Two pointers, one on telescope cradle, the other on mirror sector, used in checking length of mirror drive cable.

Course knobs—Two knobs located on lower right side of sighthead. They are used to set up the course of the airplane.

Crosshair rheostat—Located on rear of sighthead case beneath eyepiece. It controls intensity of the light on the crosshairs.

Degree scale—Seen through index window in top right side of sighthead case. It is used to measure the sighting angle.

Directional gyro—Located inside the stabilizer. It is used to give the azimuth stabilization of the bombsight and the autopilot.

Disc speed drum—Located on rate end. It determines speed of rate motor by the spring tension holding breaker points.

Disc speed gear shift—Located on the rate end. It is used to select the range of the disc speeds: 102-245 or 245-590.

Displacement knob—Located on the rate end. It is the outer of the range knobs, used to displace the lateral crosshair without changing range synchronization.

Dovetail locking pin—The pin which fastens the dovetail shaft to the dovetail locking bracket on stabilizer.

Drift gear—Located on top, right forward corner of stabilizer. It transmits motion from drift worm to drift gear clutch.

Drift gear clutch—Located below the drift gear. Transmits motion or stabilization from the stabilizer to the PDI brush.

Drift knob—Located on rate end. It is the inner course knob, used to displace PDI and direct airplane without changing the line of sight.

Drift pointer and scale—Pointer is located on rear lower part of sighthead. Drift scale is on stabilizer under pointer. They indicate amount of drift set into bombsight.

Drift worm—Located on sighthead below turn worm and meshed with drift gear. Transmits motion from drift knob to drift gear.

Dropping angle index—Seen through index window on left side of tangent scale. It indicates the tangent of the dropping angle.

Extended vision knob—Located on rate end. It increases forward vision 20° in M-7, M-9.

Fore and aft bubble—Located on top and left of vertical gyro housing. It indicates the fore and aft position of vertical gyro axis.

Fore and aft crosshair—Located on the lens inside telescope tube. It serves as a reference to synchronize for course.

Fore and aft leveling knob—Located on left side of sighthead. Used for movements of gyro's axis to the front or rear.

Lateral bubble—Located on the top and rear of vertical gyro housing. It indicates lateral position of the axis of vertical gyro.

Lateral crosshair—Located on the lens inside the telescope tube. It serves as a reference to synchronize for range.

Lateral leveling knobs—Located on left side of sighthead. Used for movements of gyro's axis to the left and right.

Mirror drive clutch—Located in center of displacement knob. It engages the mirror drive by locking the lower traction gear.

Pilot director indicator (PDI)—Located on pilot's instrument panel. An electrical meter that indicates to the pilot the direction to correct the airplane's flight.

PDI brush and coil—Located on top of stabilizer. Brush is attached to drift gear clutch collar and moves over coil. Brush moving over coil sends a signal to pilot's PDI.

PDI switch—Located on rear of stabilizer. Switch for PDI circuit to pilot's PDI.

Range knobs—Two knobs located on the rate end. They are used to determine and set up the dropping angle (range) at which the bomb is released.

Rate end—Located on right side of sighthead. It solves the range problem by determining groundspeed and dropping angle.

Rate knob—The inner of the two range knobs. It is used to determine the speed of closure and set up the dropping angle.

Rate motor—Located inside rate end of sighthead. It is used to rotate the disc.

Rate motor switch—Located on rate end. It completes the circuit to rate motor.

Release lever—Located on right rear of sighthead. It permits automatic release points to close and complete bomb release circuit.

Search knob—Located on the lower part of the rate end. Allows you to make rapid displacement of the lateral crosshair.

Sighthead—The upper unit of the bombsight assembly. It stabilizes the optics in pitch and roll and solves the range problem.

Sighting angle index—Seen through index window on right side of degree scale. It indicates the sighting angle in degrees.

Sight stem—Located on the bottom of the sighthead. A projection tube which fits into sight stem sleeve on the stabilizer.

Sight stem sleeve—Located on the front of the stabilizer. It is the bracket in which the sighthead is mounted.

Stabilized gear sector—Located on the underside of the sighthead. It aids in transmitting stability to the sighthead and positioning the sighthead in azimuth.

Stabilizer—Lower units of bombsight assembly. It stabilizes sighthead in azimuth.

Stabilizer switch—Located on the right side of stabilizer. Completes or breaks the circuit to stabilizer and directional gyro.

Tachometer adapter—Located on rear of sighthead. It is connected to a shaft running from disc. A tachometer can be fit into adapter to read the disc speed in rpm.

Tangent scale—Seen through index window on top right side of sighthead case. It is used to measure the dropping angle.

Telescope—Located inside the sighthead on the telescope cradle. The unit in the bombsight that magnifies the target image and projects the crosshairs on the mirror.

Torque motor switch (SERVO)—Located on the right side of the stabilizer. It completes or breaks the circuit to the torque unit.

Torque unit—Located inside front of stabilizer. It keeps spin axis of directional gyro horizontal in relation to stabilizer case.

Trail arm and trail plate—Located on top of rate end. It provides a method of putting desired trail into the bombsight.

Trail arm clamp screw—Located on the end of the trail arm. It provides a method of locking the trail into the sight.

Trail arm pinion—Located on top and at the pivot point of trail arm. It transmits motion from the trail arm to trail rack.

Trail bell crank—Located on front of sighthead. It transmits motion from trail rack to push rod. This sets in potential cross-trail.

Trail rack—Located on trail plate. Transmits motion from trail arm pinion to trail bell crank.

Trail scale—It is marked on the trail plate in mils to allow the proper trail setting.

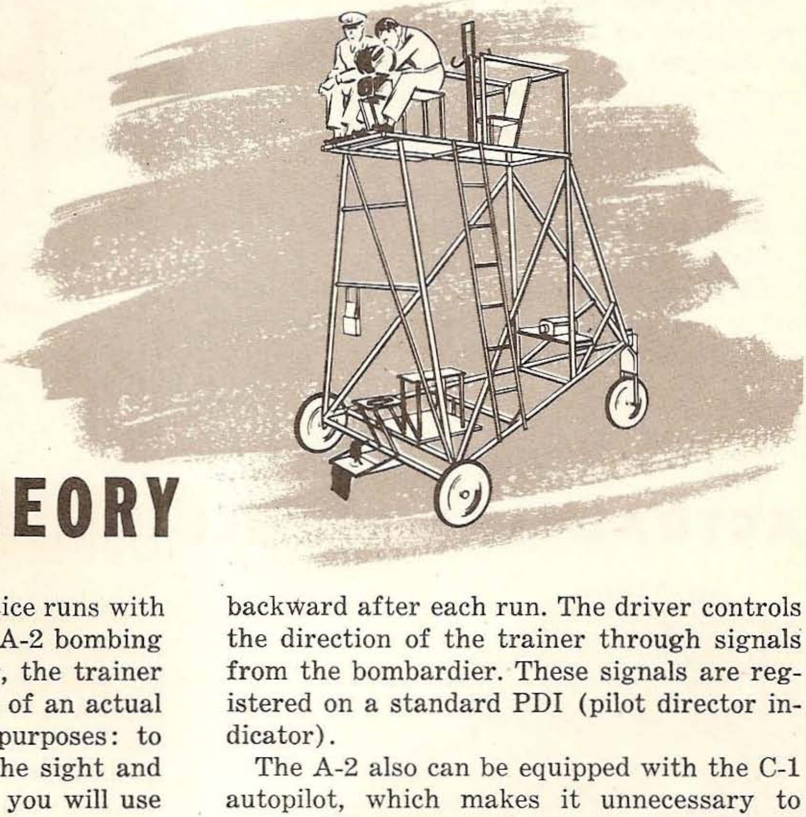
Turn knob—Located on rate end. It is the outer course knob. It turns sighthead around stabilizer gear sector, changing the line of sight and displacing PDI.

Turn worm—It is mounted on the turn knob shaft and meshed with the stabilized gear sector. It transmits stability from stabilized gear sector to sighthead.

Vertical gyro—Located inside left end of sighthead. Stabilizes optics in pitch and roll.

SECTION 5

Bombing Trainer



TRAINER THEORY

You will make your first practice runs with the M-Series bombsight on the A-2 bombing trainer. Used inside the hangar, the trainer simulates the principal features of an actual bombing mission. It has two purposes: to help you learn how to operate the sight and to help you learn the procedure you will use in the air.

The trainer consists of two platforms mounted in a framework that rolls on three wheels. There are seats for the bombardier, driver and instructor. You use the upper platform for synchronous bombing, and the lower to simulate fixed-angle bombing missions.

An electric motor drives the trainer. Newer types have a reversible motor, which makes it unnecessary to push the trainer backward after each run. The driver controls the direction of the trainer through signals from the bombardier. These signals are registered on a standard PDI (pilot director indicator).

The A-2 also can be equipped with the C-1 autopilot, which makes it unnecessary to have a driver.

The trainer target is attached to the "bug," a box-like device rolling on three wheels. The bug, electrically driven, moves at a constant speed, and can be positioned to move in any direction. Your "hits" with the sight are marked on the target by a marker solenoid which is mounted on a metal plate connected to the trainer between the two front wheels.

BOMBING ALTITUDE

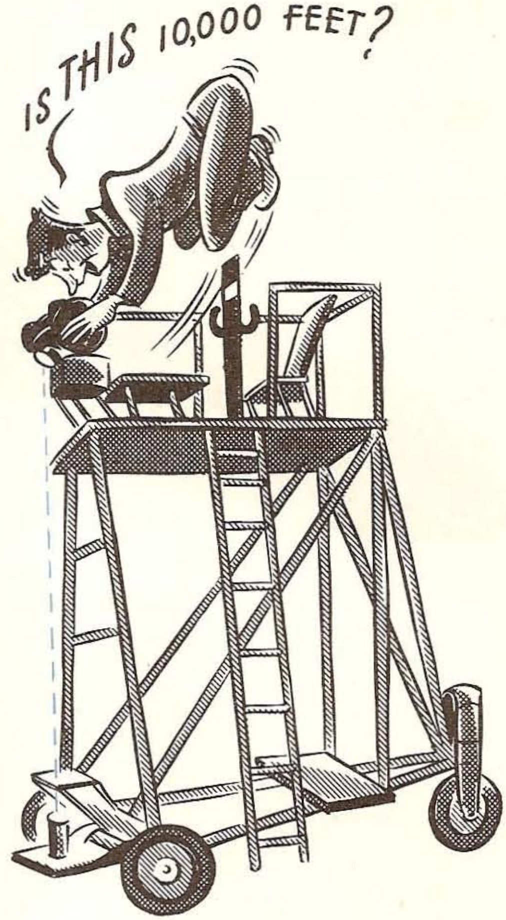
Bombing altitude from the upper platform is considered to be the distance from the center of the optics, in the sight, to the top of the bug. This distance is 10 feet or 120 inches. You can see that since a mil is 1/1,000 of the bombing altitude, a mil on the trainer target is 0.12 inch (1/1,000 of 120 in.).

If you were simulating a bombing altitude of 10,000 ft. and the impact of the plunger was 1.2 inches from the center of the target, you would have a 10 mil error. This would be an error of 100 ft. on the ground if you actually had been bombing from that altitude ($10 \times 10 = 100$).

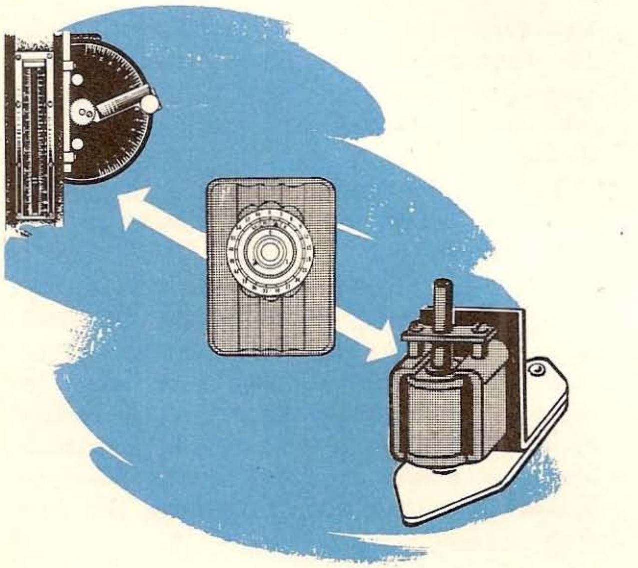
But suppose you were simulating a bombing altitude of 5,000 ft. and the plunger fell at the same point—1.2 inches from the center of the target. The error would simulate an error of 50 ft. on the ground ($5 \times 10 = 50$).

To find the error on the ground in feet from your trainer error in inches, do this:

Divide your error in inches by .12—the value of one mil on the trainer—to find your mil error. Multiply that by 1/1,000 of the simulated bombing altitude.



ACTUAL TIME OF FALL



You simulate the time that it would take the bomb to fall from your simulated bombing altitude (ATF) on the trainer, by use of a clock which energizes the marker solenoid ATF seconds after bomb release. You set ATF in seconds on the clock and the corresponding disc speed into the sight.

$$\text{Disc speed} = \frac{5300}{\text{ATF}}$$

When the sighting angle index meets the dropping angle index and the release lever is up, the sight's automatic release system sends an electric signal to start the clock running. When ATF has "run out" the clock sends the signal on to energize the marker solenoid. It plunges downward, marking the trainer target to simulate a bomb impact.

TRUE AIRSPEED

True airspeed is simulated by the speed at which the trainer moves across the hangar floor. This simulated true airspeed bears the same relationship to the actual speed of the trainer as the simulated bombing altitude does to the actual height of the trainer. That is:

$$\frac{\text{Simulated TAS}}{\text{Trainer Speed}} \text{ Equals } \frac{\text{Simulated Bombing Altitude}}{\text{Trainer Height}}$$

WIND

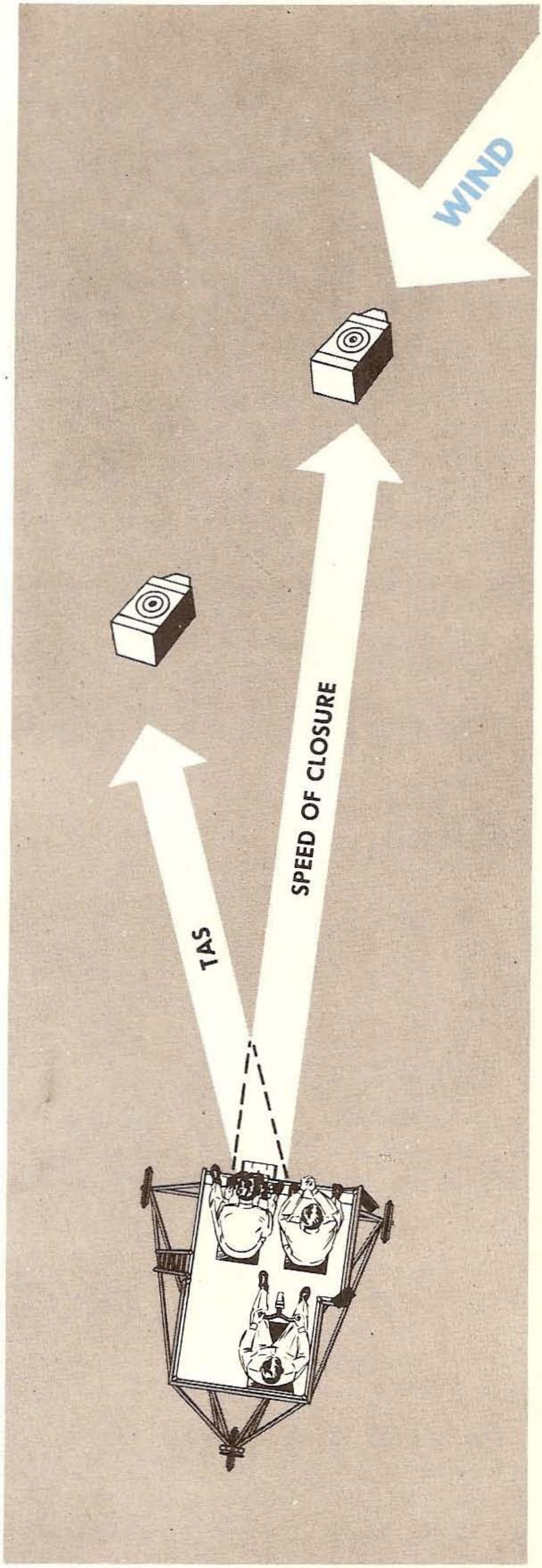
Wind direction and speed are simulated by the direction and speed at which the bug moves across the hangar floor. The direction **toward** which the bug moves simulates the direction **from** which the wind is blowing. Thus if the **bug** is moving **toward** the **east,** it simulates a **wind** blowing **from** the **east.**

The simulated wind speed bears the same relation to actual speed of the bug as the simulated bombing altitude does to the actual height of the trainer. That is:

$$\frac{\text{Simulated Wind Speed}}{\text{Bug Speed}} \text{ Equals } \frac{\text{Simulated Bombing Altitude}}{\text{Trainer Height}}$$

GROUNDSPEED AND SPEED OF CLOSURE

Groundspeed and true airspeed are identical when you make a run on a stationary bug. The speed at which the distance between the trainer and the bug is covered or closed is called the speed of closure. You may think of the moving bug as representing a wind or a moving target. Ordinarily you think of the moving bug as representing wind. Then the speed of closure represents groundspeed.

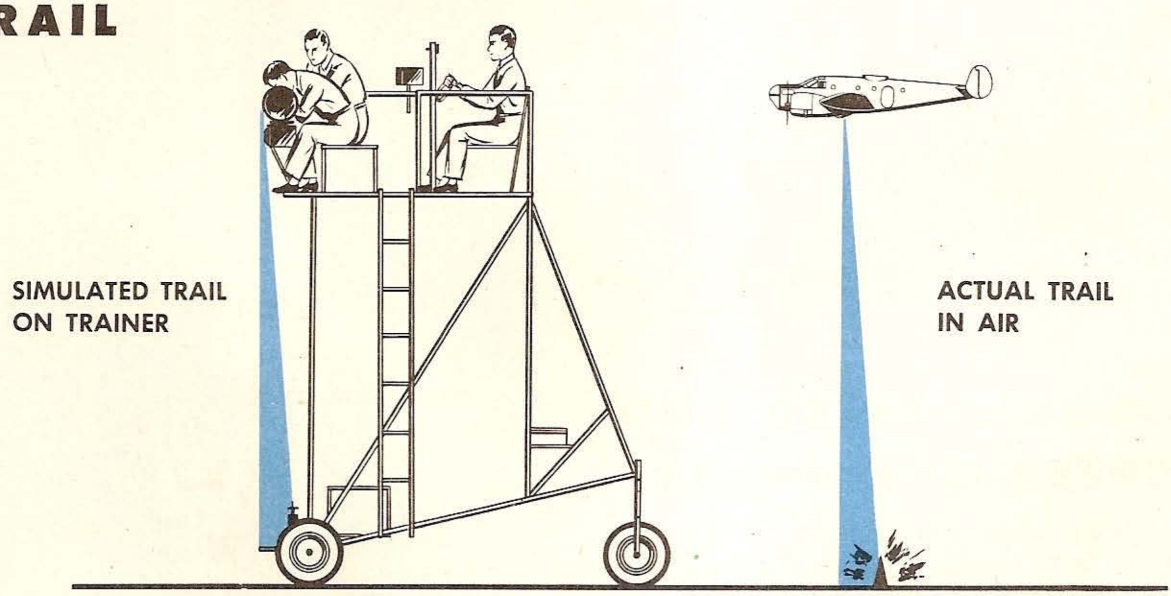


DRIFT

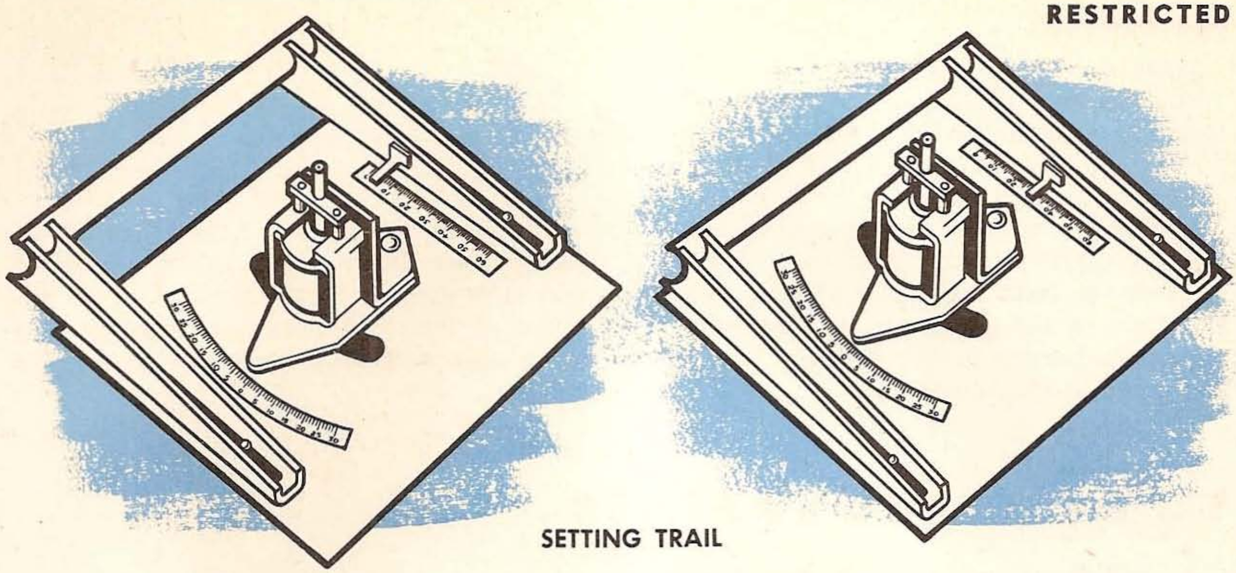
When the bug is moving—but not directly toward or directly away from the trainer—drift is simulated. Remember that the direction **the bug moves** simulates the direction **from which the wind is blowing.** Seen through the optics, a bug moving from west to east appears the same as if you were in an airplane drifting west through the air because of a wind blowing from the east. In both cases, the target moves in the same direction from west to east across the field of vision in the optics of the sight.

The metal arm which holds the marker solenoid is pivoted so that it can be moved either to the right or left on its drift scale. This is necessary because when you put drift into the sighthead the optics move in an arc around the pivot point—the sight stem—and change their position in relation to the marker Solenoid. The marker solenoid arm is moved to a position matching the direction and amount of drift set on the sight. You do this to keep the solenoid either directly under the center of the optics, or directly behind it if trail is being used. This is not done to simulate crosstrail.

TRAIL



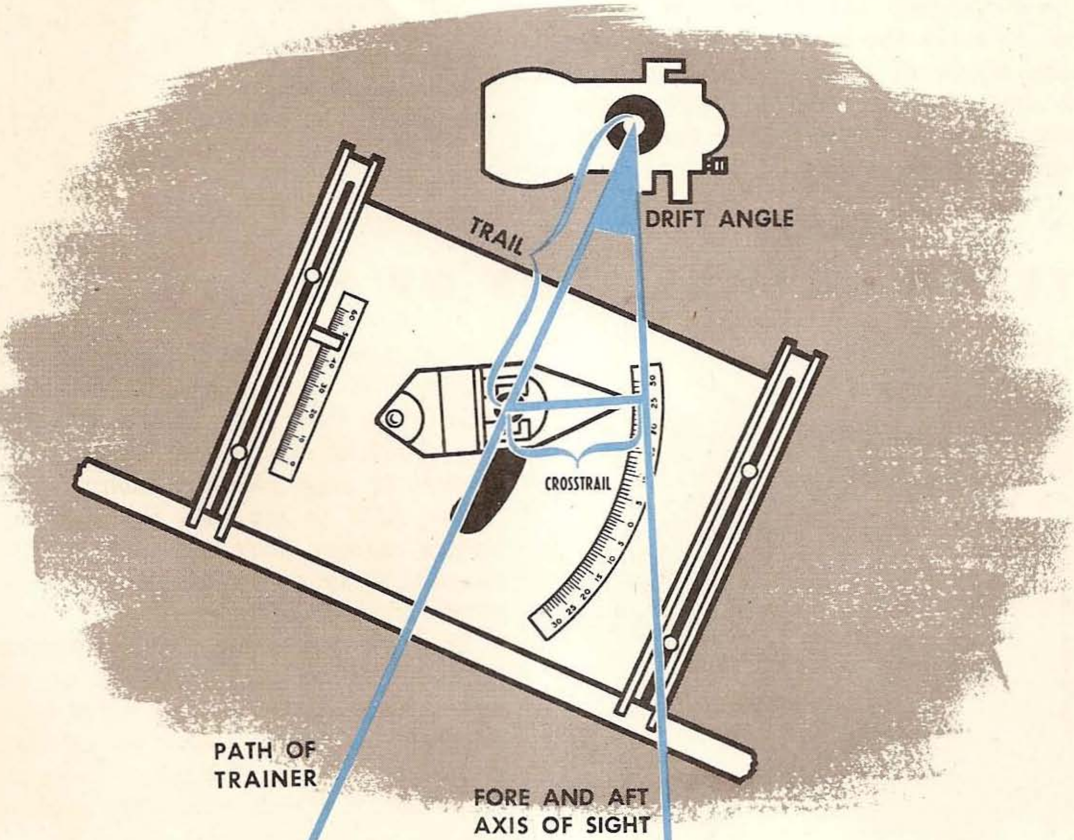
You can also simulate trail on the trainer. In the air, trail causes the bomb to hit behind the airplane. On the trainer, trail is simulated by moving the marker solenoid plate holding the marker solenoid trail distance toward the rear of the trainer. There is a trail scale on the marker solenoid plate and you can set in up to 60 mils of trail. Of course, you set the same trail in the sight that you set on the marker solenoid plate.



SETTING TRAIL

CROSSTRAIL

When trail and drift are set into the sight, it automatically sets up crosstrail. The optics are tilted, thus causing the trainer to be steered crosstrail distance upwind. At the moment of impact, the solenoid will be crosstrail distance downwind and trail distance behind the optics. Thus, crosstrail is automatically simulated on the trainer, and you do not have to worry about it.



Setting up the Trainer

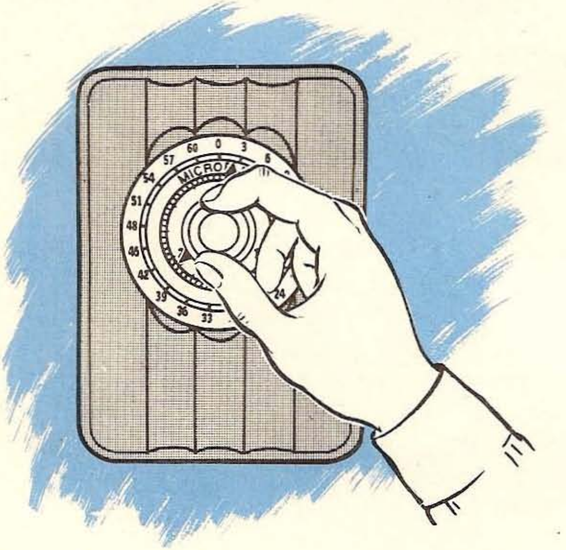
Before you turn on the generator, which supplies current to the sight, first find out whether the sight uses 12 or 24 volts. When you turn on the generator, set the voltage regulators for the proper voltage. Turn ON and preflight the bombsight.

You want the marker solenoid to be directly under the crosshairs when the sight's optical system is in the vertical, since the action of the marker solenoid simulates the bomb impact. This is known as zeroing the trainer.

TO ZERO THE TRAINER

1. Roll the trainer up to the bug. You do this to eliminate any error that might result from an uneven hangar floor.
2. Set the marker solenoid arm pointer to zero drift on the marker solenoid plate.
3. Set zero drift on the sight and engage the bombsight clutch.
4. Engage the mirror drive clutch and set the sighting angle index at zero degrees.
5. Uncage and level the gyro.
6. Look through the optics and direct someone to move the marker solenoid plate until the center of the marker solenoid is directly under the crosshairs. Re-check the previous setting, particularly the gyro level, to be sure they are correct.

SETTING ACTUAL TIME OF FALL



When you do synchronous bombing on the trainer you must choose a "bombing altitude." You then look up the ATF and the corresponding disc speed for this bombing altitude in your bombing tables.

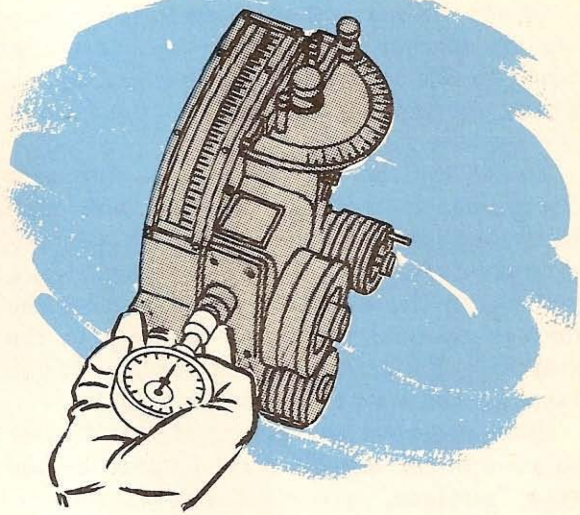
The ATF is set into the **clock** on the trainer, so the clock will cause the marker solenoid to be energized just ATF seconds after "bomb away."

Then the disc speed, which corresponds to the ATF, is set into the sight on the disc speed drum. Since the disc speed should be accurate within a fraction of an rpm, it is necessary to check it closely. There are two convenient methods which are also used in the air.

TACHOMETER METHOD

Engage the tachometer in the tachometer adapter located on the right rear of the sight head. When using the tachometer, hold it firmly in the adapter but do not exert a pressure for this can slow down the speed of the disc.

To start the tachometer, press the lever only once, which will zero the needle. Then release to begin the check. Never touch the lever until the needle stops moving. At the stopping point take your reading. Adjust the disc speed drum as necessary. Try two or three tachometer readings on your final disc speed setting. **Do not** remove tachometer from the adapter between readings.



STOP WATCH METHOD

Set **zero trail** and a large dropping angle in the sight. Then time the travel of the sighting angle index from coincidence with the dropping angle index to 0 (zero). This time should equal the ATF as shown by your bombing tables. If the stop watch reading exceeds the ATF, increase your rpm; if the reading is too small, reduce your rpm.

TRAINER METHOD

On the bombing trainer you can check the disc speed against ATF **as measured by the clock.** If the disc speed is correct, the sighting angle index will drive from coincidence with the dropping angle index to zero during ATF. For example, if your assumed bombing altitude is 4,000 ft., you will:

1. Set (ATF) 16.28 sec. into the trainer clock.
2. Set zero trail into the sight.
3. Set 325.5, the disc speed for 4,000 ft., on the disc speed drum. A preliminary check of disc speed with tachometer or stop watch can be made at this point.
4. Set dropping angle index at a large tangent value.
5. Position sighting angle index at a larger tangent value.
6. Turn rate motor switch ON, hold up release lever and engage mirror drive clutch.
7. Watch the drive of the sighting angle index. The marker solenoid should drop the moment the sighting angle index reaches 0 (zero). Also, if the gyro is level, the crosshairs should intersect the top of the marker solenoid the moment it drops.

If the marker solenoid drops before or after the sighting angle index reaches zero, it means that your disc speed does not agree with your ATF (clock) setting. Since the ATF (clock) setting simulates the bombing altitude of your airplane, the correction should be made in the disc speed. That is, you change the disc speed settings on the sight to agree with your bombing altitude (clock setting).

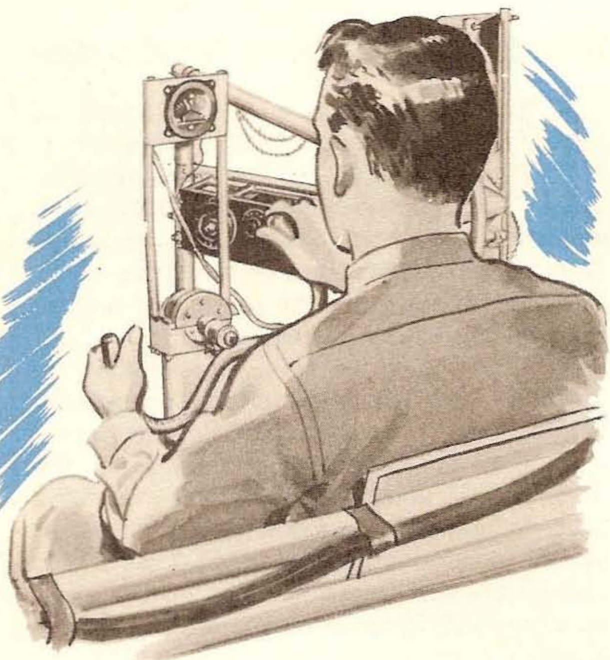
SETTING TRAIL

On the trainer you simulate trail by causing the marker solenoid to strike trail distance to the rear of the bombsight optics, which themselves simulate the position of the airplane.

To set trail on the trainer, you first zero the trainer in the usual manner. Note that the marker solenoid plate scale may not indicate zero after the trainer is zeroed. Next, you set in the desired trail by moving the marker solenoid plate trail distance to the rear from its zeroed position. Gauge the distance by the scale on the solenoid plate.

Since you have now arranged your trainer so your bomb will hit trail distance behind your "airplane," you must also set the correct trail in your bombsight. The resulting smaller dropping angle will cause the bombsight to delay release (delay starting the clock) a little longer, and will thus give you the correct point of impact.

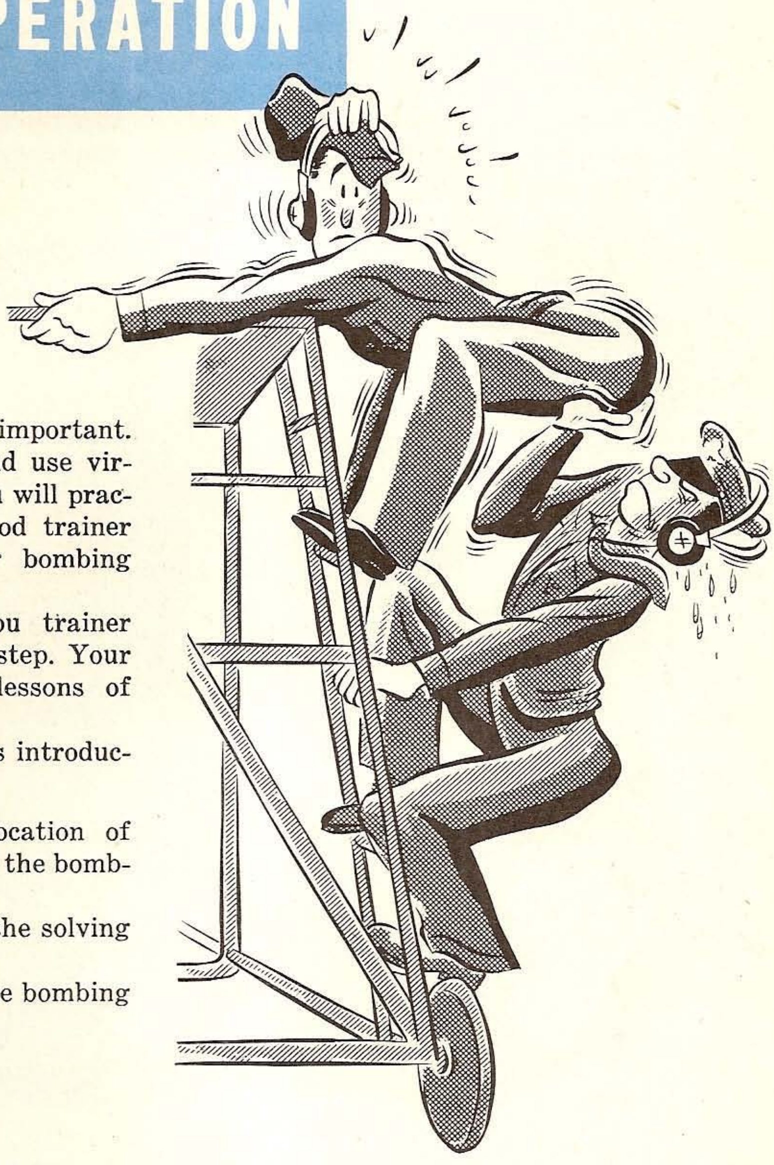
DRIVING THE TRAINER



If the trainers are not equipped with the C-1 autopilot, you will have to drive for other students while they are using the sight. Much of the efficiency and accuracy of the man on the sight depends on the way you follow the PDI.

You drive the trainer with a steering wheel which is connected by cables to the rear wheel of the trainer. If the PDI needle goes off center, turn the wheel quickly but smoothly in the direction the PDI is off center. Continue this smooth movement until the needle stops and starts back to the zero position. Then smoothly return the wheel toward center so that the trainer will resume a straight course when the PDI needle reaches center. At the beginning of the run you usually need larger corrections and as you near the release point corrections should be smaller. Be careful not to over-correct at the end of the run. Follow the PDI until the marker solenoid drops.

TRAINER OPERATION



Your work on the trainer is important. Here you learn to synchronize and use virtually the same procedure that you will practice later in actual air work. Good trainer procedure now will mean better bombing later.

Your instructor will teach you trainer technique and procedure step by step. Your job will be to coordinate the lessons of ground school, trainer, and flying.

Your first hour on the trainer is introductory. You will learn these things:

1. The name, purpose, and location of knobs, switches, and other parts of the bombsight.
2. The relation of the sight to the solving of the bombing problem.
3. How the trainer simulates the bombing problem.
4. How to operate trainer.

Tips

Learn the location of each knob and switch. Your ease and accuracy in using them depends on how well you know them. Develop "knob touch."

Be sure you set in the proper voltage for the sight that is on your trainer.

Handle all equipment with care. Do not misuse it!

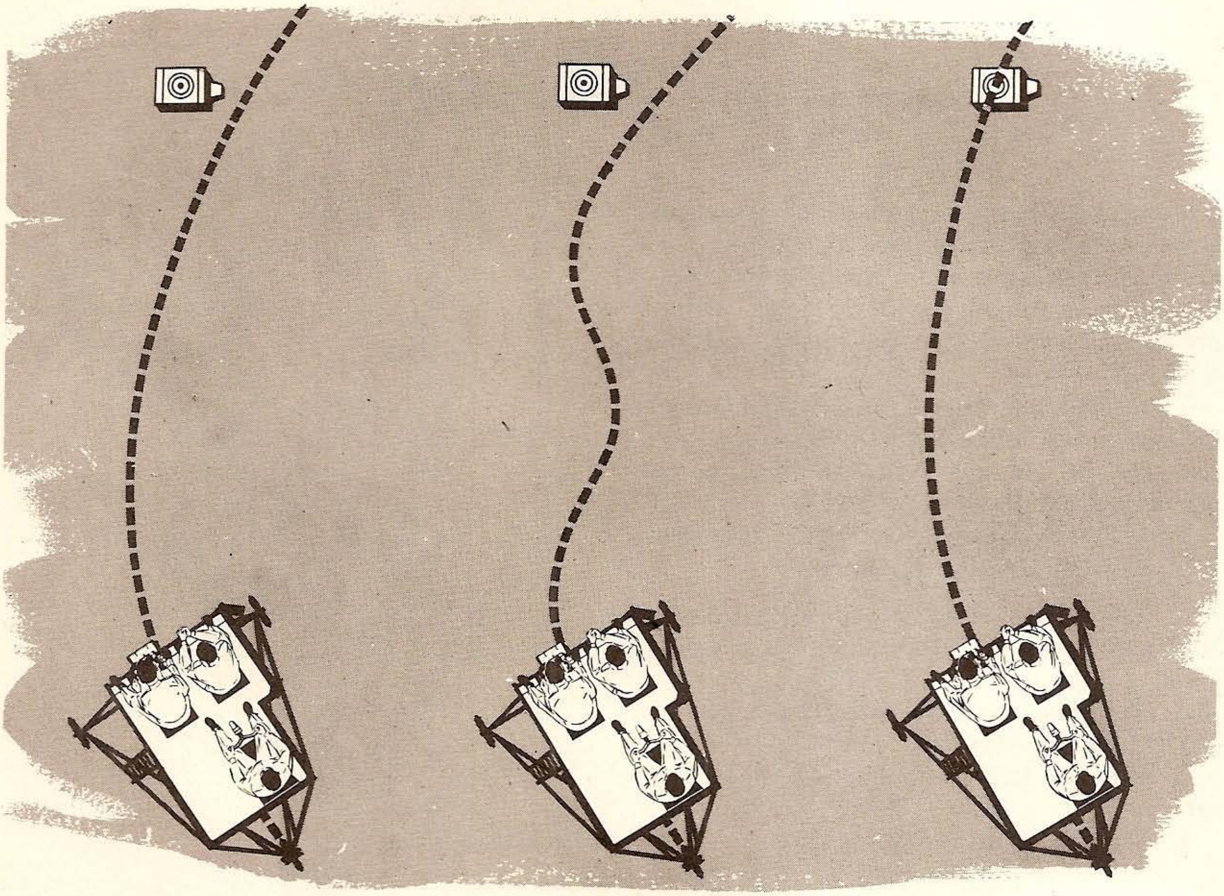
Questions

1. How is groundspeed simulated by the trainer?
2. What are the steps for turning on the generator?
3. What is the purpose of the disc speed gear shift?
4. What is the purpose of the clock on the trainer?

COURSE

Your first trainer runs for course corrections are made on a stationary target. As you progress, you will take course runs on a moving bug. Master the technique of making smooth course corrections. Learn to establish course quickly and accurately.

You must zero the trainer before you start any runs. Your instructor will help you do this the first time, but after that you are on your own.



Tips

Double grip the course knobs to kill drift. Use the turn knob to put the fore and aft crosshair back on the target.

Hold the PDI on center with the autopilot clutch before engaging the bombsight clutch.

Make all your course corrections smooth!

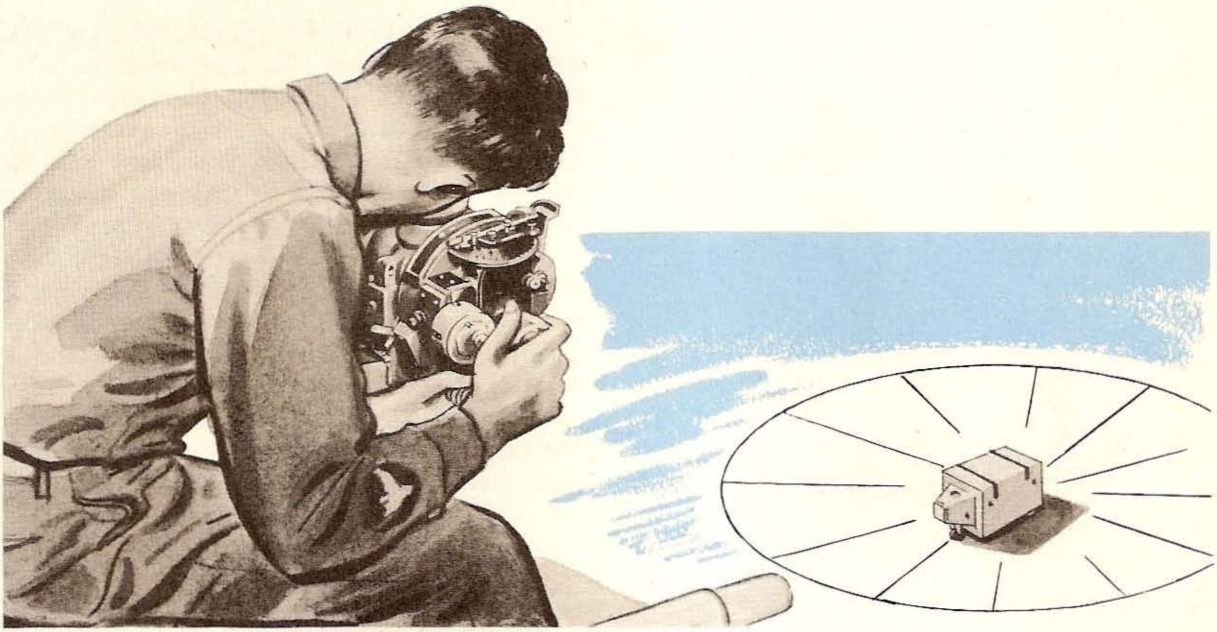
Do not put in course corrections faster than the driver can take them out.

Learn how to zero the trainer now.

Questions

1. What happens if you put in corrections faster than the driver can take them out?
2. What is an over-correction? How can you prevent an over-correction?
3. If the fore and aft crosshair is moving off toward your left, which direction do you turn the course knobs?

RATE



Your first runs for rate are made on a still bug or a slow moving target which rides on a tape machine. However, after you learn the basic technique of setting up rate, you will make runs on a moving bug or a faster moving tape. Think about what is happening in the sight. This will help you to refine your corrections. Know the purpose of each motion you make and how it helps to solve the bombing problem.

After a few runs on rate, you discover that the rate knobs are fast-correcting knobs. You must develop "knob touch." Make your corrections smoothly.

Tips

Turn the rate knob to stop apparent motion of the lateral crosshair. Use the displacement knob to put it back on the target.

Don't twirl or peck at the rate knob. Remember the rate knob positions three things: the roller, the dropping angle index, and the automatic release points.

When possible, pre-set approximate dropping angle.

Questions

1. Why must you engage the mirror drive clutch before you can move the lateral hair with the displacement knob?
2. What is meant by saying your rate synchronization is "slow" or "fast?"
3. Why is rate important?

COURSE AND RATE COMBINED

Now you will combine course, rate, and the release lever, to see just how accurate your first synchronous bombing runs are. Good synchronization is the key to every good bombing run. Everything you learn later is for the one purpose of helping you solve for course and rate in the quickest and best way.

Your first runs are on a stationary bug with a small ATF set into the sight and trainer clock. As you improve, your instructor will have you use a larger ATF and a moving bug.

During this part of the trainer program, the sight's vertical gyro is caged; therefore, you leave it caged when you zero the trainer.

Tips

Start to work as soon as the trainer starts and work the full length of the run. Every second counts. Don't waste time while preparing to make a run.

Always kill course before rate.

Learn to refine your synchronization toward the end of the run.

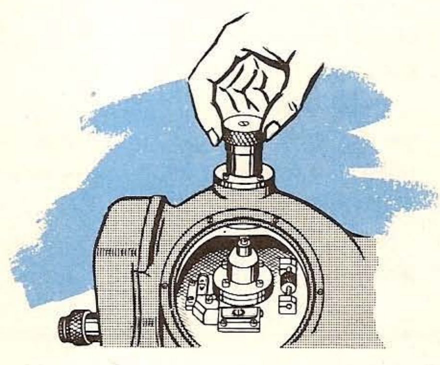
In making corrections, don't jump back and forth between course and rate. Get course first, then rate.

Questions

1. Why is it impossible to set up rate before course?
2. Why must you engage the bombsight clutch before making course correction? Why must the autopilot clutch be disengaged?
3. At what time in the bombing run do you turn the rate motor switch ON?

COURSE AND RATE WITH GYRO UNCAGED

As your ability to synchronize improves, other steps are added to your procedure. You begin to make runs with the vertical gyro uncaged. Your instructor shows you how and when to level the bubbles.



Tips

When using the sight with the gyro uncaged, be sure to zero the trainer with the gyro uncaged and level.

Look at your PDI before leveling. Never take a level if the PDI is off center.

Don't turn, twist, or screw the leveling knobs! Push them in and apply torque in the direction you want the bubble to move.

After leveling, *always* use the turn and displacement knobs to put the crosshairs back on the target.

Don't "chase" the bubbles. Take your time and level them properly.

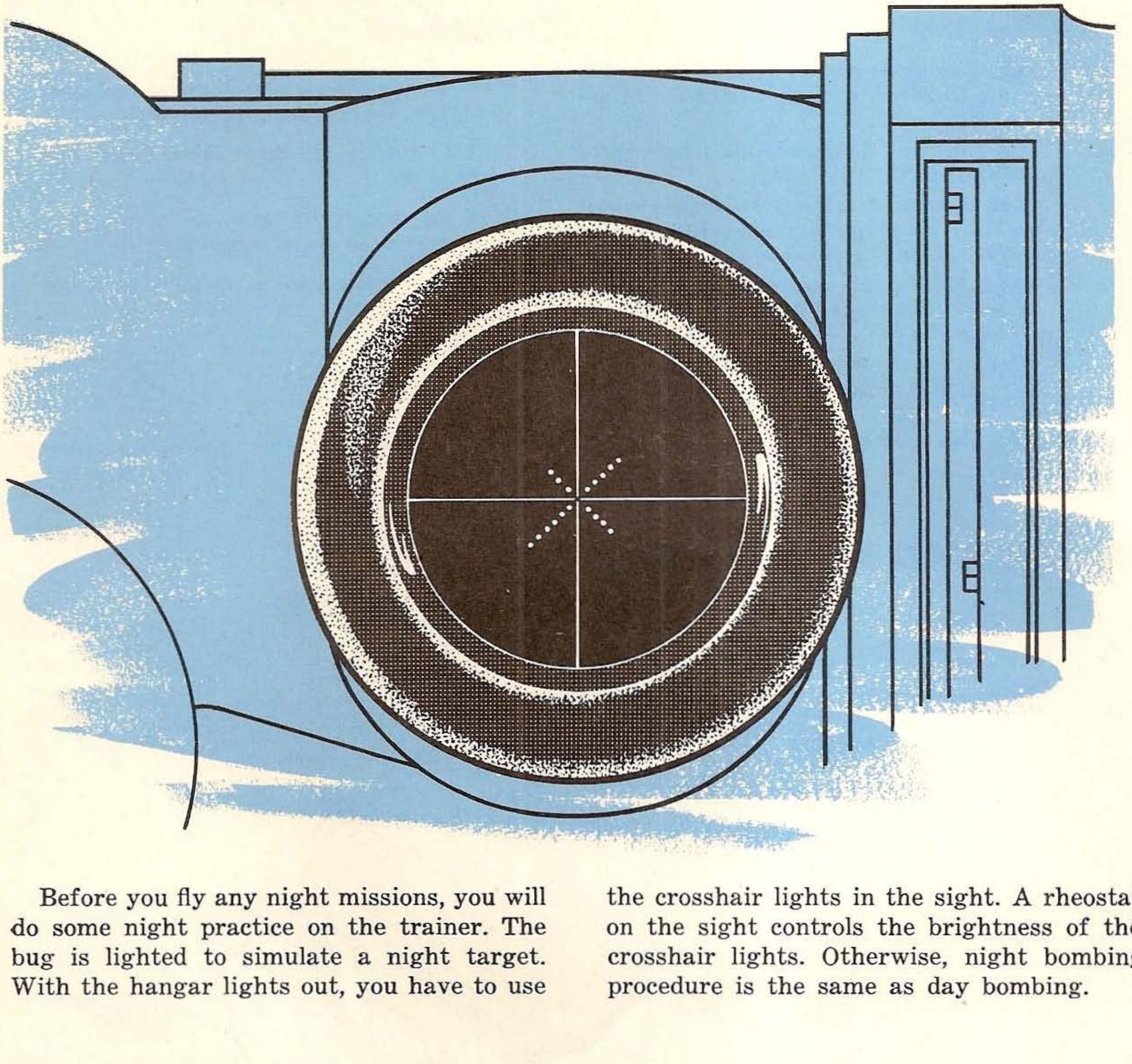
Questions

1. Why must the gyro be uncaged and level before you can bomb accurately?
2. Why must the PDI be on center before leveling the gyro?
3. If the lateral bubble is off to the right, where will the bomb impact be?
4. Why is leveling more important at higher altitudes?

INTERPHONE PROCEDURE

Because there must be some system of communication between you and your pilot, you must learn interphone procedure. This can be done either by talking over the microphone or clicking it. Whatever the method is, agree on the signals before you take off. If your trainer lacks an interphone system, use some other means for signals. There's an excellent reason for this. It assures the pilot that you understand. If you learn to do this on the trainer, it will be much easier when you start your actual air work. For the same reason, call "Bomb away!" on the trainer when you hear the automatic release.

NIGHT BOMBING



Before you fly any night missions, you will do some night practice on the trainer. The bug is lighted to simulate a night target. With the hangar lights out, you have to use the crosshair lights in the sight. A rheostat on the sight controls the brightness of the crosshair lights. Otherwise, night bombing procedure is the same as day bombing.

Tips

Always check to make *sure* the crosshair light is ON. Check this on the *preflight* inspection.

Swing the sight on the target carefully. Be sure that your fore and aft crosshair passes through the target. Remember, at night you do not have the ground check points to aid you in picking up the target.

Questions

1. Why are the crosshairs lighted for night bombing?
2. How do you control the brightness of the crosshairs?

SIMULATED MISSION ON THE TRAINER

Your instructor will give you the figures you need to compute your bombing altitude on a simulated mission. You will then set the proper data in the bombsight and the trainer to correspond to the simulated bombing altitude and true airspeed.

The best and quickest way to get all your data down on paper is to use the 12-C form. Practice in recording and using the data in this way will make it second nature to you by the time you're ready to start flying.

You will learn the proper use of the extended vision knob on the trainer. Practice rolling in extended vision and locking it. This will give you a thorough understanding of it by the time you start your actual flying.

You often will hear your instructor insist that your technique be "smooth." He wants to impress you with the necessity of being smooth and definite in every movement and operation.

Tips

Learn to compute your bombing altitude quickly and accurately. Don't do this mechanically. Know the factors that enter into the problem.

Know your 12-C form. Learn to fill it out quickly, so you can spend most of the time on the ground in analyzing the mission with your instructor.

Understand extended vision and its proper use.

Questions

1. What factors do you need to compute your bombing altitude?
2. How will filling out the 12-C form on the trainer help you when you start flying?
3. What error results, if you do synchronous bombing with 20° extended vision locked in?

TRAINER PROCEDURE

Now, when you combine all the steps you have learned, you have the same basic procedure that you will use later in the air. These are the steps:

Preparation

1. Zero or pre-set drift angle.
2. Center bombsight connecting rod.
3. Roll sighting angle index back to 70° and engage mirror drive clutch.
4. Pre-set dropping angle.
5. Center PDI (if using manual pilot).
6. Place bomb release handle to select.

The Trainer Run

1. Pilot signals **on course and level.**
2. Uncage gyro.
3. Swing sight on target.
4. Engage bombsight clutch and disengage autopilot clutch.
5. Signal pilot.
6. Set up course.
7. Level gyro, if necessary.
8. Turn desired rack switch ON.
9. Turn rate motor switch ON.
10. Set up rate.
11. Hold up release lever.
12. Refine course and rate.
13. Signal pilot when **bomb is away.**

After Release

1. Put release lever down.
2. Turn rack switch OFF.
3. Call out drift.
4. Check synchronization.
5. Check position of bubbles and cage gyro.
6. Analyze bomb release (call shot).
7. Turn rate motor switch OFF.
8. Watch for bomb impact.

After Marker Hits Target

1. Engage autopilot clutch and disengage bombsight clutch.
2. Analyze run.
3. Prepare for next run while trainer is being returned to starting position.

Tips

Uncage gyro in order to level it. Practice doing this quickly and accurately.

In swinging on, hold course knobs with right hand and align sight with the target by sighting along the trail rack. Then look through the optics immediately and put fore and aft crosshair on the center of target.

Engage bombsight clutch and disengage autopilot clutch with one movement. This transfers stability to the sighthead and allows your bombsight to send corrections to the PDI.

Signal pilot when the bomb is away. He will continue to follow the PDI until the marker hits.

Be sure to look through the optics and check synchronization after each release. (Call shot.) After checking synchronization, be sure to turn rate motor switch OFF before the sighting angle index reaches zero.

Questions

1. Why must you disengage the autopilot clutch in order to make course corrections?
2. If you lose the target from the field of vision in the optics, what is the first thing you should do?
3. Why should you turn the rate motor switch OFF before the sighting angle index reaches zero?

TACTICAL BOMBING PRACTICE

You make your first simulated combat runs on the trainer and learn how to make a short approach with the aid of pre-set data. In presetting the data, you can use either the automatic bombing computer or the E-6B.

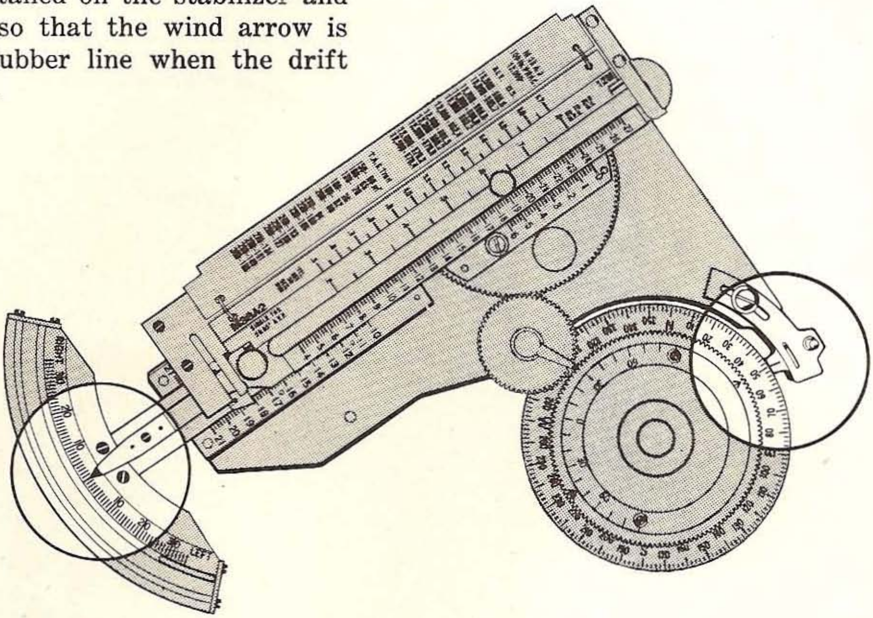
On the trainer you learn the basic principles of evasive action. The objective of such action, of course, is to out-maneuver anti-aircraft fire. Underlying all effective evasive action, you must remember, is a good deal of pre-planning and foresight. You must make your plans ahead of time.

Another technique you learn is how you can bomb accurately with a defective sight, merely by recognizing the cause of the failure and making the necessary compensations.

USE OF THE ABC COMPUTER ON THE TRAINER

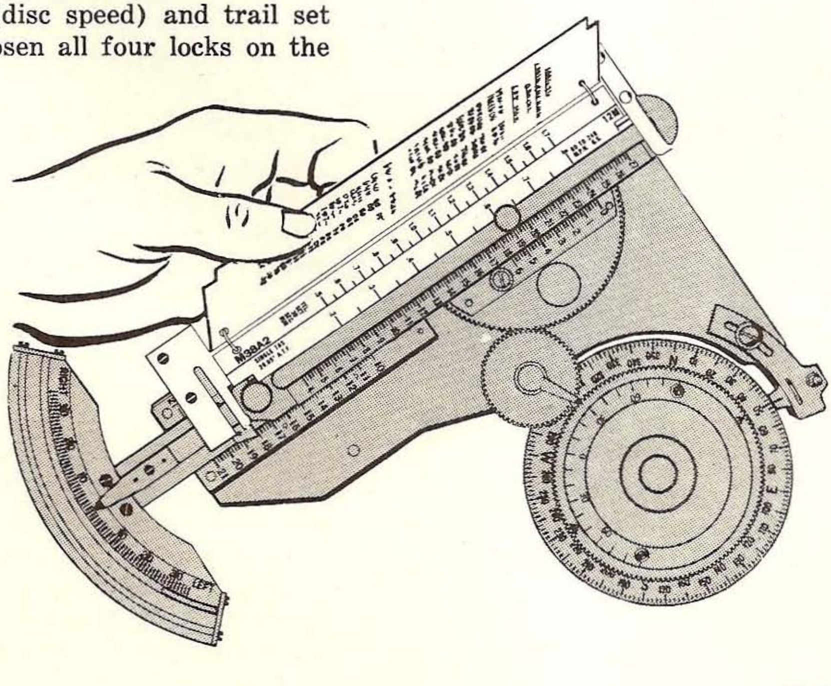
Zeroed

Make certain that the AB computer has been properly installed on the stabilizer and has been zeroed so that the wind arrow is pointing at the lubber line when the drift pointer is at zero.



Tangent Scale

Attach, on the groundspeed bar of the AB computer, the tangent scale for the simulated bombing altitude (disc speed) and trail set into the sight. Loosen all four locks on the AB computer.



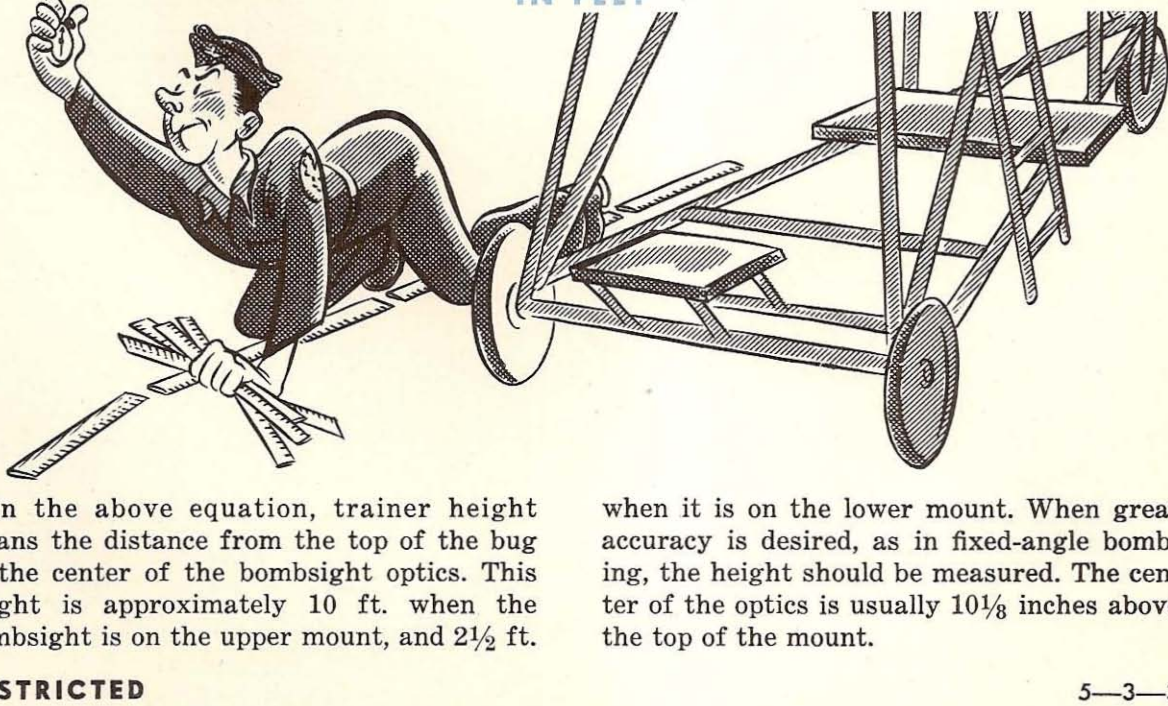
True Airspeed

Set the true airspeed simulated by the trainer on the true airspeed scale and lock. Trainer speed simulates true airspeed. Obviously, you cannot compute true airspeed from instrument readings at flight level, as you would in an airplane. You can find the true airspeed your trainer simulates by the following method:

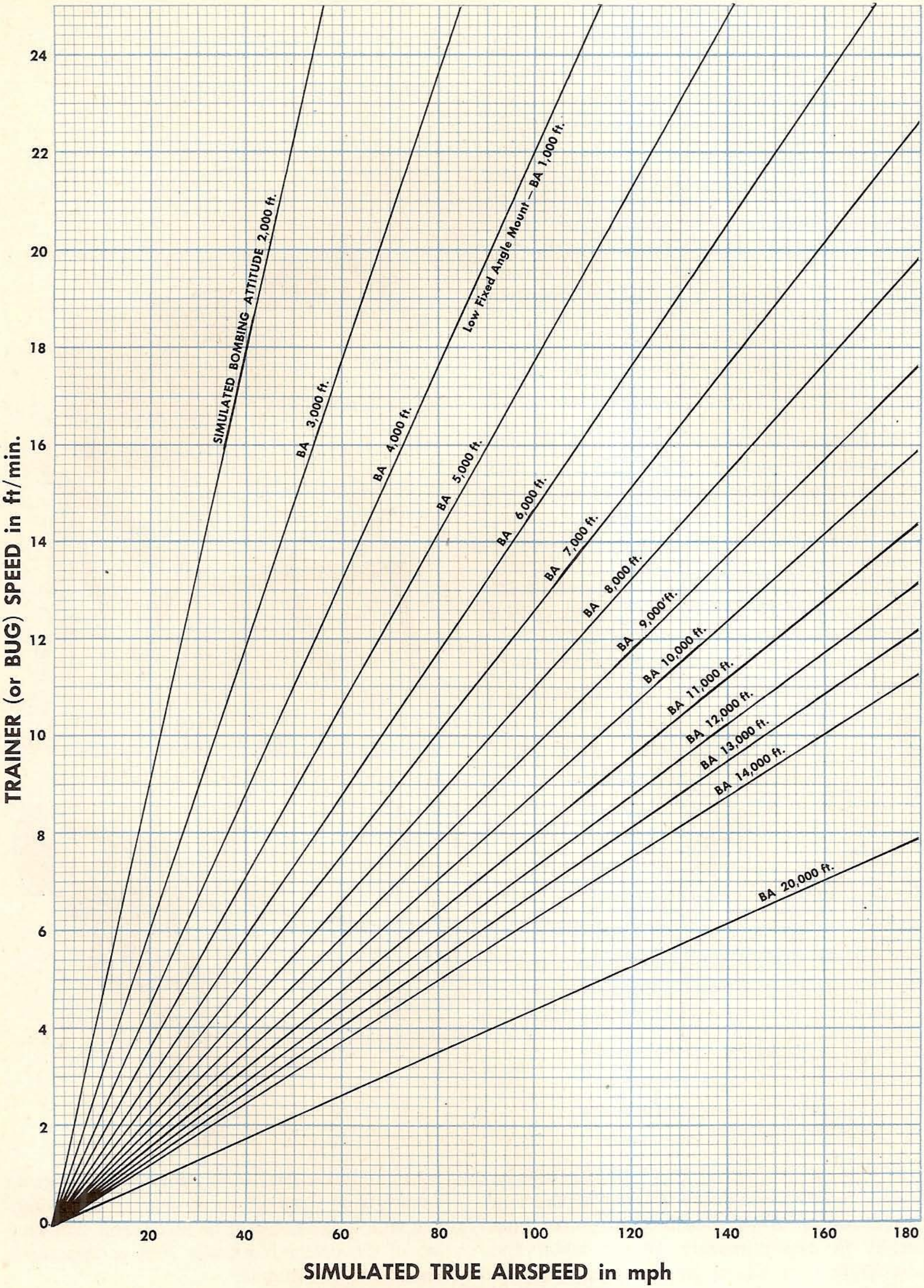
1. Determine how many ft/min. the trainer travels. Do this by timing the trainer with a stop watch over a distance measured on the hangar floor.
2. Divide the simulated bombing altitude by the actual trainer height above the target. This division shows how much distance is simulated by each foot the trainer moves.
3. Multiply the trainer speed in ft/min. by the distance simulated by each foot the trainer moves, to determine the simulated true airspeed in ft/min.
4. Convert this simulated true airspeed in ft/min. to mph by dividing by 88. Eighty-eight is the number you get when you divide the number of feet in a mile (5,280) by the number of minutes in an hour (60).

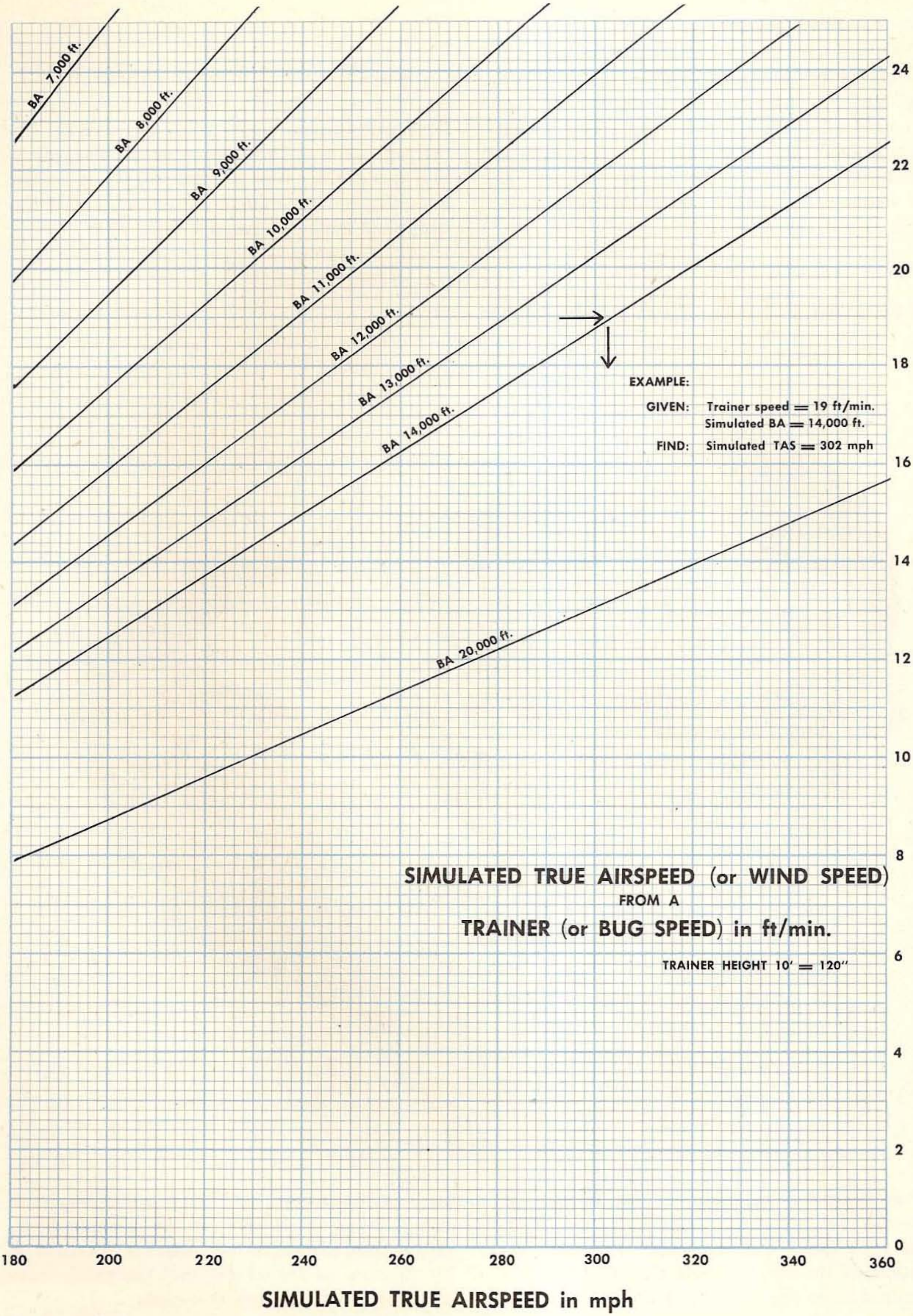
The following equation summarizes these steps:

$$\text{SIMULATED TRUE AIRSPEED IN MPH} = \frac{\text{SIMULATED BOMBING ALTITUDE}}{\text{TRAINER HEIGHT IN FEET}} \times \frac{\text{TRAINER SPEED IN FT/MIN.}}{88}$$



In the above equation, trainer height means the distance from the top of the bug to the center of the bombsight optics. This height is approximately 10 ft. when the bombsight is on the upper mount, and 2½ ft. when it is on the lower mount. When great accuracy is desired, as in fixed-angle bombing, the height should be measured. The center of the optics is usually 10⅛ inches above the top of the mount.


TRAINER (or BUG) SPEED in ft/min.
SIMULATED TRUE AIRSPEED in mph
0
2
4
6
8
10
12
14
16
18
20
22
24
20
40
60
80
100
120
140
160
180
SIMULATED BOMBING ATTITUDE 2,000 ft.
Low Fixed Angle Mount—BA 1,000 ft.
BA 3,000 ft.
BA 4,000 ft.
BA 5,000 ft.
BA 6,000 ft.
BA 7,000 ft.
BA 8,000 ft.
BA 9,000 ft.
BA 10,000 ft.
BA 11,000 ft.
BA 12,000 ft.
BA 13,000 ft.
BA 14,000 ft.
BA 20,000 ft.


BA 7,000 ft.
BA 8,000 ft.
BA 9,000 ft.
BA 10,000 ft.
BA 11,000 ft.
BA 12,000 ft.
BA 13,000 ft.
BA 14,000 ft.
BA 20,000 ft.
EXAMPLE:
GIVEN: Trainer speed = 19 ft/min.
Simulated BA = 14,000 ft.
FIND: Simulated TAS = 302 mph
SIMULATED TRUE AIRSPEED (or WIND SPEED)
FROM A
TRAINER (or BUG SPEED) in ft/min.
TRAINER HEIGHT 10' = 120"
0
2
4
6
8
10
12
14
16
18
20
22
24
180
200
220
240
260
280
300
320
340
360
SIMULATED TRUE AIRSPEED in mph

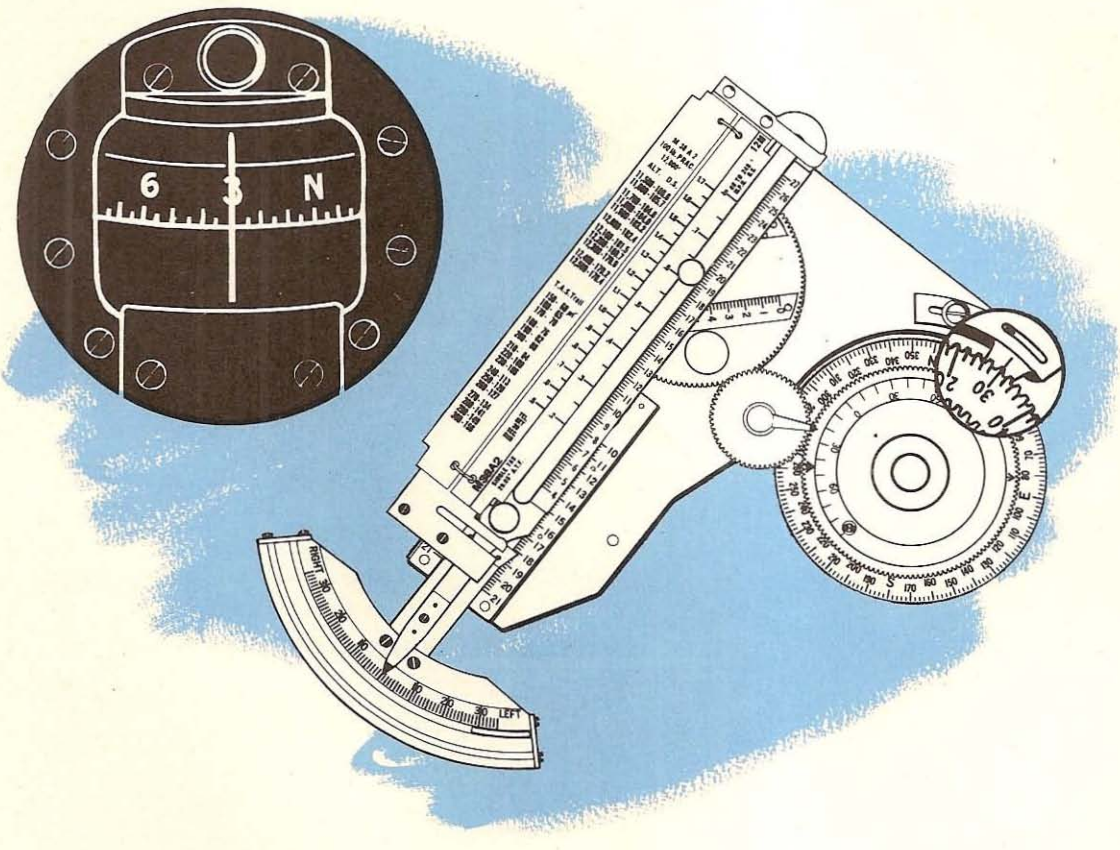
True Airspeed (Cont.)

You can also find simulated true airspeed by making a synchronous run on a stationary bug. On the trainer, with a stationary bug (no wind conditions) the true airspeed equals groundspeed. You can find groundspeed and true airspeed by substituting the tangent of the whole range angle found on this run in the groundspeed equation:

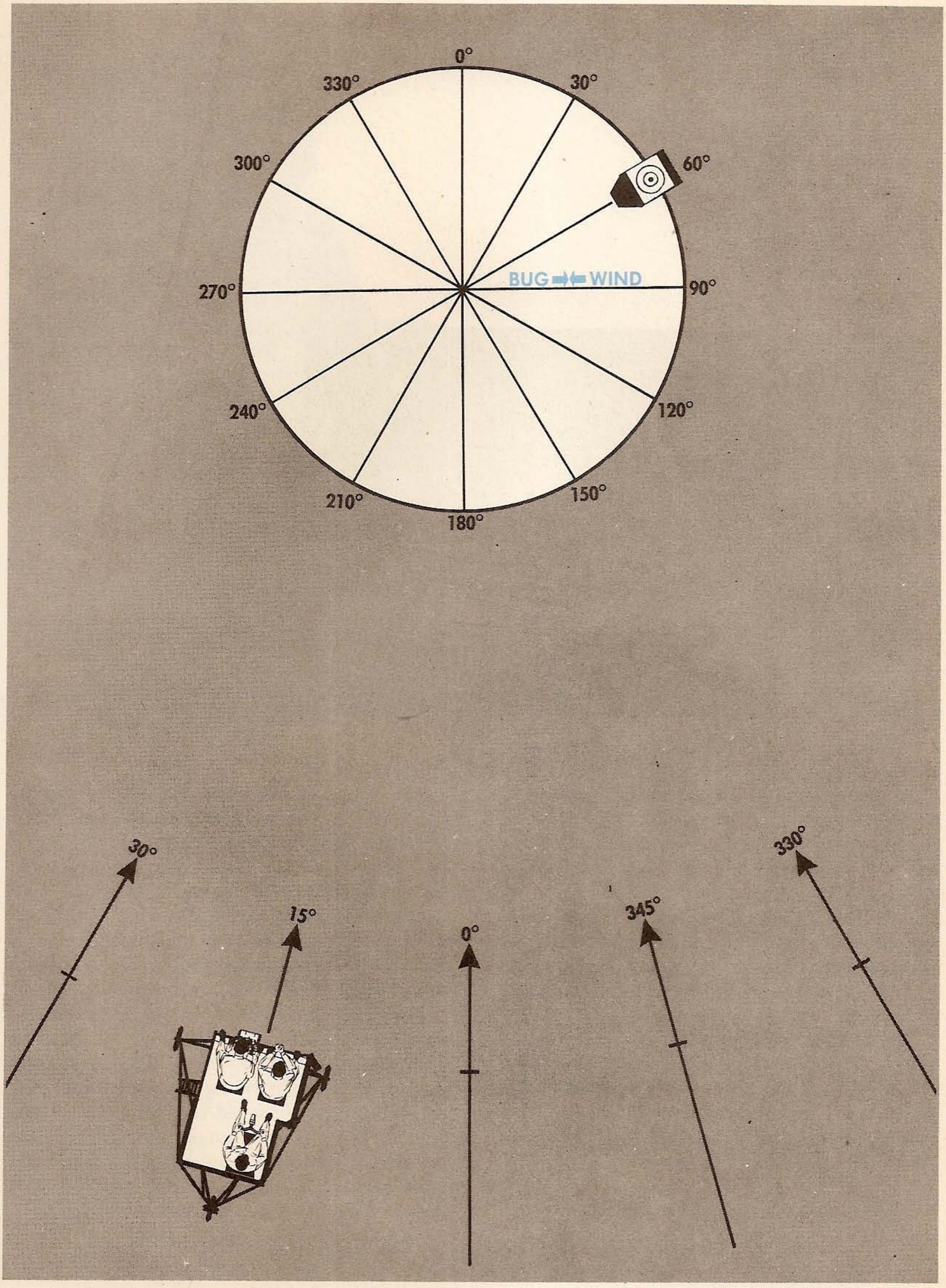
$$GS = \frac{DS \times \text{Simulated BA} \times (\text{Tan WR} \angle)}{7773}$$

This equation is worked out for you on the tangent scale of the AB computer. Therefore, you can readily find the true airspeed on the groundspeed scale opposite the tangent of the dropping angle on the AB computer.

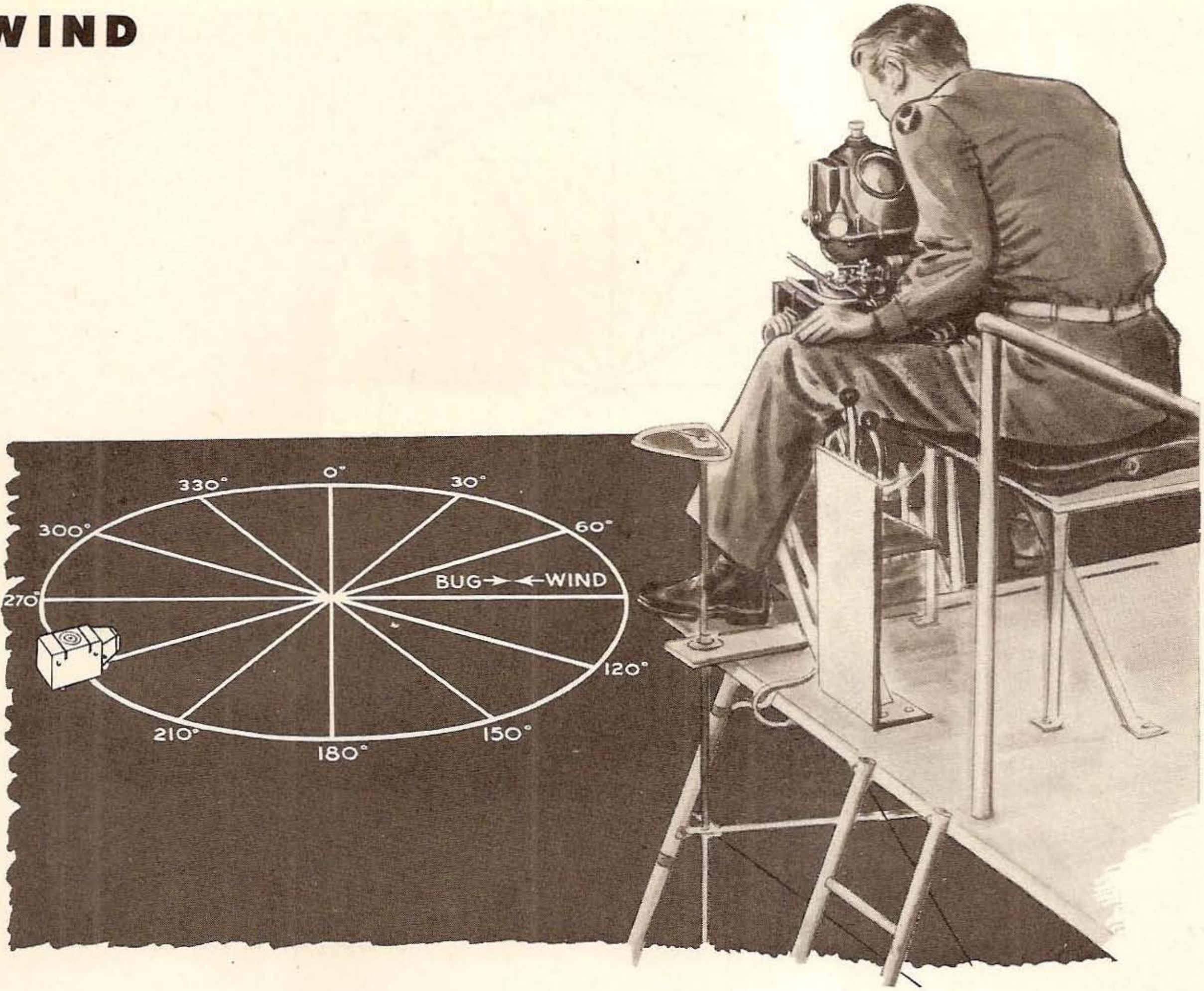
MAGNETIC HEADING



Set magnetic heading of the trainer on compass rose under lubber line, and lock compass rose lock. You can find the magnetic heading of the trainer from a compass, if one is mounted on the trainer. If there is no compass on the trainer, find the heading from the compass rose laid out on the hangar floor. Align the rear wheel and marker solenoid of the trainer on one of the lines radiating from the center of the compass rose.


0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
BUG ➡⬅ WIND
30°
15°
0°
345°
330°

WIND



Set the magnetic direction of the wind on the wind gear and the speed of the wind on the wind speed scale. Lock the wind gear lock and the wind speed lock. The direction in which the bug moves simulates a wind moving in the opposite direction. The bug speed simulates a wind speed. Note the direction in which the bug moves across the hangar floor. If the bug moves **toward** the east, the wind is **from** the east.

The wind speed simulated by a moving bug can be found from the chart or calculated by the same method that you use to compute simulated true airspeed. To do this, substitute the bug speed in ft/min. for the trainer speed. Thus,

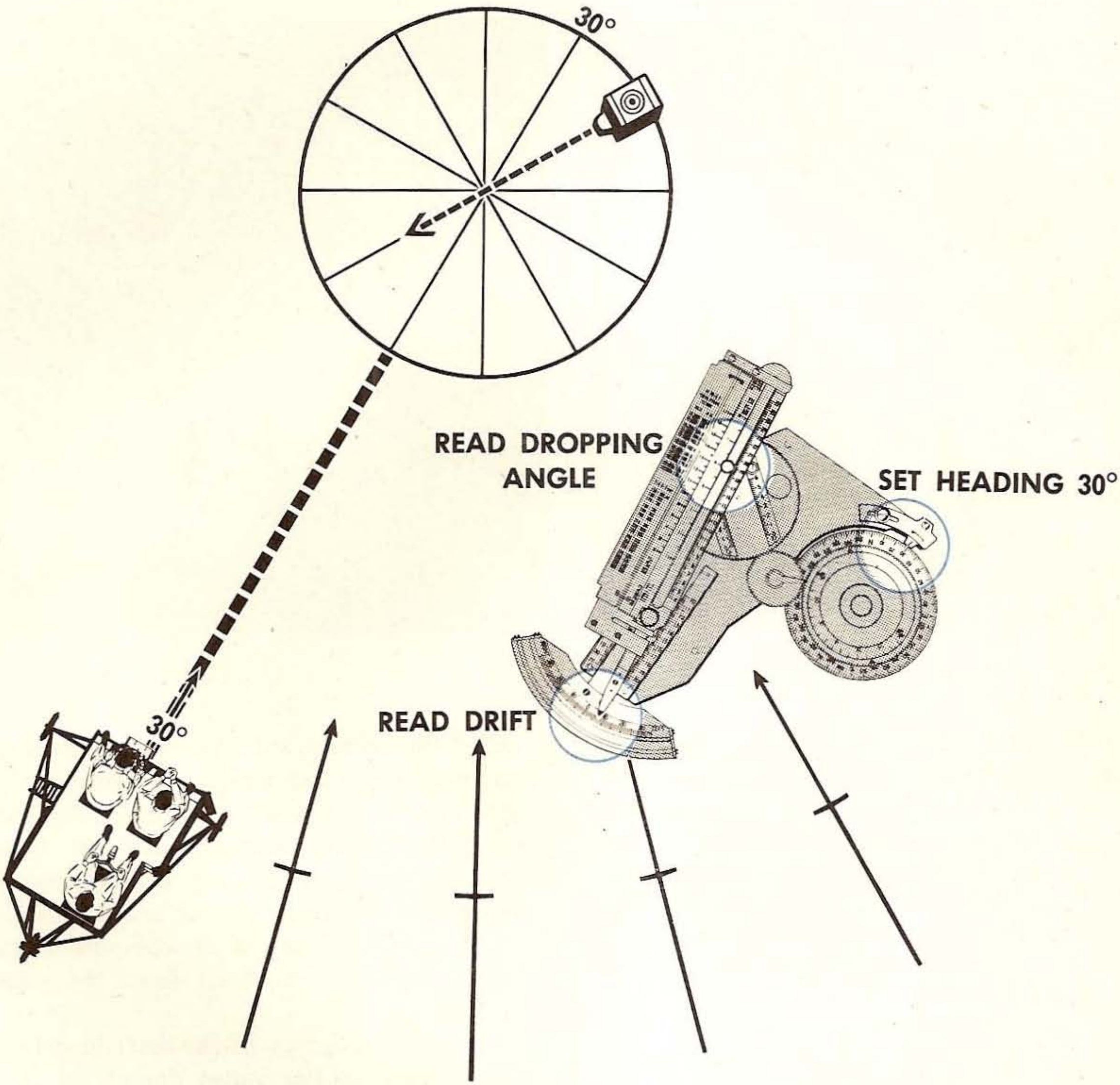
Simulated Wind Speed in mph =

$$\frac{\text{Simulated Bombing Altitude}}{\text{Trainer Height in Feet}} \times \frac{\text{Bug Speed in Ft/Min.}}{88}$$

You can also solve for the wind direction and speed on the AB computer, by using the drift and dropping angle found in making a synchronous run on the moving bug. Be sure the simulated true airspeed is set on the true airspeed scale and locked. Set magnetic heading on the compass rose at lubber line and lock. Use the magnetic heading of the trainer found at the end of the synchronous run.

Turn the wind arrow to the approximate direction of the wind. Set drift pointer at drift angle determined from sight. Hold drift pointer in this position and rotate wind gear to position groundspeed indicator at the tangent of the dropping angle determined from the sight. Lock the wind speed lock and the wind gear lock. The magnetic direction and speed of the wind are now set on the ABC.

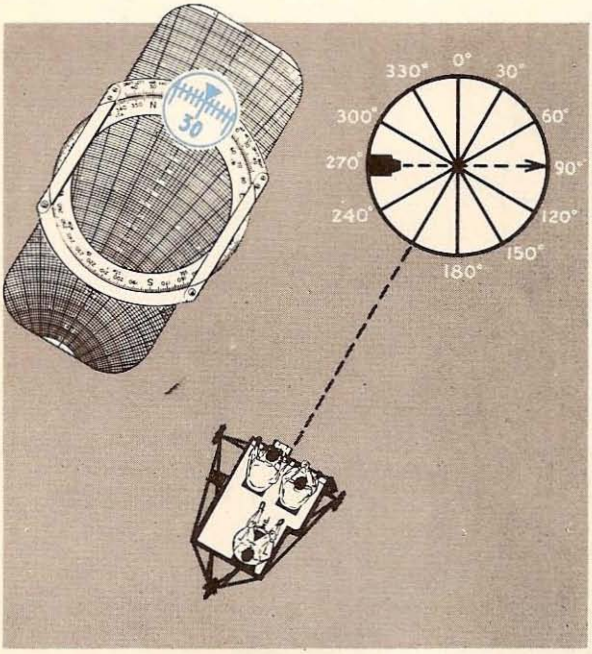
DRIFTS AND DROPPING ANGLES

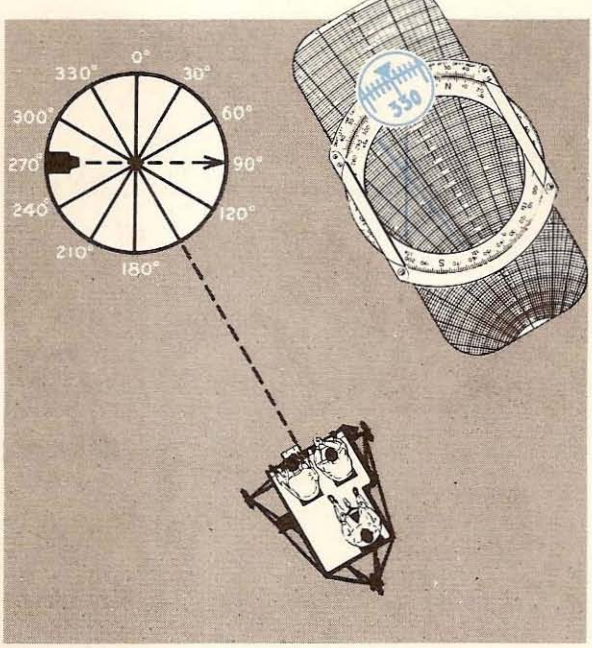


You can now find the drift and dropping angle from the AB computer for any magnetic heading of the trainer. If the magnetic heading indicated on the compass rose of the AB computer is not the same as the magnetic heading of the trainer, the AB computer will not indicate the correct drift and dropping angle for the magnetic heading of the trainer. Be sure to set the magnetic heading of the trainer on the compass rose under the lubber line at the start of each run, and lock the compass rose lock.

The direction of the bug's movement must remain constant, as it is simulating a definite wind from one direction only. That is, the bug must be re-positioned at the same starting place and move in the same direction to simulate a constant wind direction and speed.

USE OF THE E-6B COMPUTER ON THE TRAINER





You can use the E-6B and the AB computer interchangeably on any bombing mission. You will find it much easier to solve a double drift solution for fixed-angle bombing by use of the E-6B computer. You can practice double drift solutions on the bombing trainer by using the same compass rose laid out on the hangar floor for practice in use of the AB computer.

You can find simulated true airspeed by timing the trainer with a stop watch over a distance measured on the hangar floor and using the chart or equation. Set this true airspeed under the grommet of the E-6B.

Find the first drift by making a drift run on the bug while it is moving on a straight course in any direction. The direction of the bug movement must remain the same throughout the problem because it is simulating a definite wind direction.

Set the magnetic heading of the trainer at the magnetic index of the computer. Use the magnetic heading of the trainer **after** course is killed. Trace on the computer the drift from the first drift run.

Find the second drift reading by making a drift run on the bug while it is moving in the same direction, but with the magnetic heading of the trainer changed about 60° to 90° from the first run. Set the second magnetic heading of the trainer, after course is killed, at the magnetic index of the computer. Trace on the computer the drift from the second drift run.

Set the intersection of the drift lines below the grommet on the center line of the chart. Find the true direction of the wind at true index, or magnetic direction at the magnetic index. Draw wind arrow from grommet to intersection of drift lines. Measure wind speed from grommet down center line of chart to point of wind arrow.

The drift and groundspeed (dropping angle) can now be found from the E-6B computer for any magnetic heading of the trainer. You can also set the wind on the AB computer to solve the drift and dropping angle for any magnetic heading of the trainer.

SHORT RUNS WITH EVASION ACTION

On the trainer you can simulate the principles of evasive action, compute the length of your run and, using the AB computer, you can pre-set drift and dropping angle. This is the basis of a tactical bombing approach.

You will use the E-6B or the AB computer to find the wind, which will give you the drift and dropping angle on any heading. Knowing the wind, drift, and dropping angle, you can plan evasive action to the point where the bombing run should start. You can arrive at this point with the trainer crabbed upwind the proper drift correction and with the dropping angle pre-set, so you have only to refine rate synchronization.

You must start your bombing run far enough back from the release point to allow yourself time to level the bubbles, refine the course and rate, and release the bomb at the proper moment. The time of the run should be as short as possible to do the job well. Decide time and starting point of run, considering BA, the importance of accuracy, the effectiveness of the anti-aircraft fire, etc.

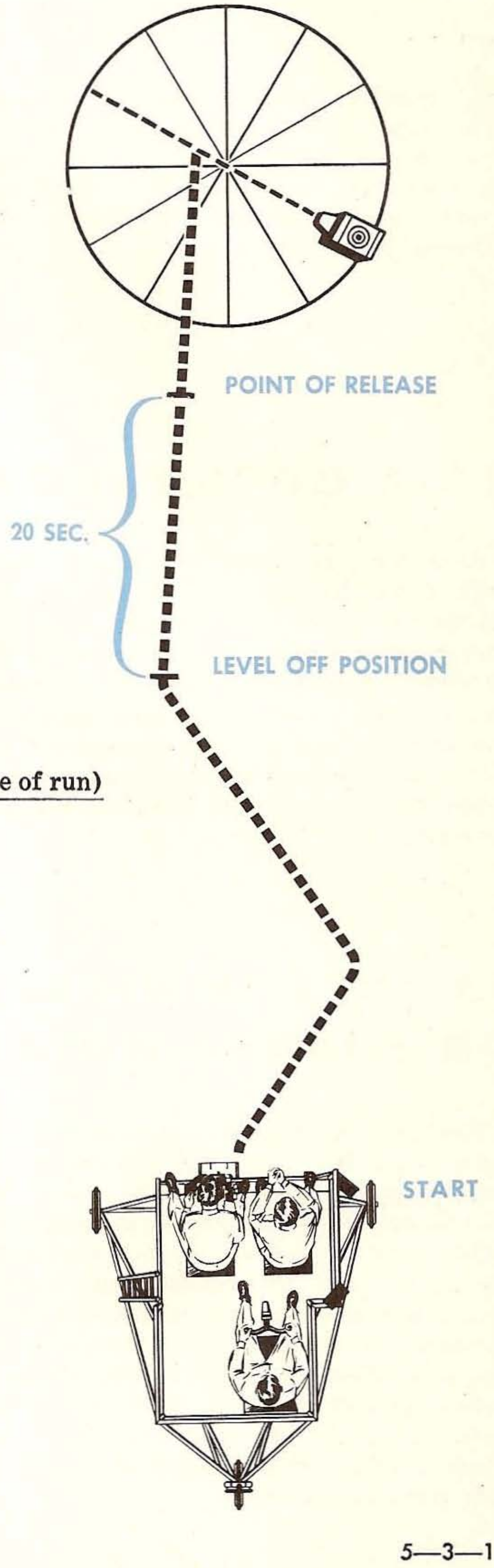
You locate the starting point by reference to the dropping angle, using this equation:

$$\text{Tan sighting angle} = \text{Tan drop}\angle + \frac{(\text{Tan WR}\angle \times \text{time of run})}{\text{ATF}}$$

That is, the sighting angle to start the run equals the tangent of the dropping angle plus tangent of whole range angle times length of run desired divided by the ATF.

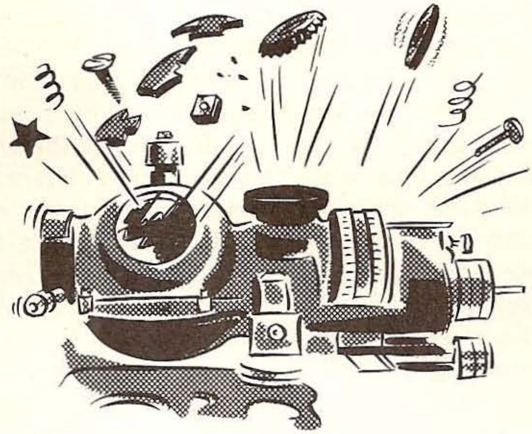
You can also find the sighting angle at which you start your bombing run by a simple computer, by trial and error timing of the sighting angle index, or by doing fast calculations in your head, which you often will be able to do. For example, if you desire a 30 sec. run when you are at 17,000 ft. where ATF is 35 sec., you can double the tangent of the dropping angle to find the tangent of the sighting angle at which you start your run.

You should employ evasive action during your bombing approach, from the initial point to the point at which you start your run. You cannot change the trainer's altitude, but you should practice changing its heading from 5° to 15° every 10 to 20 secs. Use the compass rose on the AB computer to measure the heading change. You can estimate the time by counting.



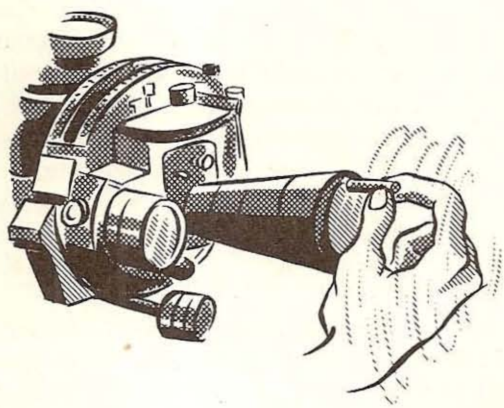
Bombing With Defective Sight

A defective sight should not seriously affect your bombing accuracy at bombing altitudes up to 5,000 or 6,000 ft., if you make the necessary compensations to limit your errors. But the errors will increase as your bombing altitude increases.



RATE MOTOR INOPERATIVE

Solve for your drift by taking a double drift, using the sight as a drift meter. Preset your drift angle in the sight and direct your pilot over the target. You can do this by directing your pilot over the interphone or displacing the PDI with your hand. You can solve the range problem as usual, but presetting the dropping angle will enable you to spend most of your time directing the pilot for course.



FAILURE IN DIRECTIONAL GYRO OR TORQUE MOTOR

First, you solve for a groundspeed by taking a double drift. From this you can find the dropping angle in your bombing tables. Preset this pre-determined dropping angle in the sight. When the lateral crosshair approaches the target, turn the displacement knob to keep the crosshair on the target. Otherwise, the bombing procedure is the same as usual. The only difference is that you do the same work manually that the rate motor does mechanically. If you solve for the proper dropping angle, by the double drift solution, your error will be small.

FAILURE OF SIGHT GYRO

If your sight gyro loses its stabilization you must make your bombing run with the gyro caged. Before you go "on course," have the pilot level the airplane and adjust the stabilizer mount so the fore and aft bubble is level. While adjusting the stabilizer mount, also notice the position of the lateral bubble. If the lateral bubble is off center, offset the aiming point in the opposite direction to compensate for the error caused by the gyro's being out of the vertical.

TACHOMETER INOPERATIVE; SETTING UP ATF WITH STOP WATCH

With the tachometer inoperative, you can set up disc speed with a stop watch. To set a disc speed in the sight with a stop watch, you must **remove all trail** from the sight. Determine the actual time of fall to be used for your bombing altitude and true airspeed. You can find the actual time of fall for your bomb from the bombing tables. Set disc speed drum at approximate disc speed. With the stop watch, time the travel of the sighting angle index from the instant it is opposite the dropping angle index to the instant it is opposite zero sighting angle. This length of time should be the same as the actual time of fall of the bomb.

If the stop watch reading is too much, increase the rpm to get the desired actual time of fall reading. If the stop watch reading is too small, decrease the rpm on the disc speed drum.

Train Bombing

AND THE USE OF THE INTERVALOMETER

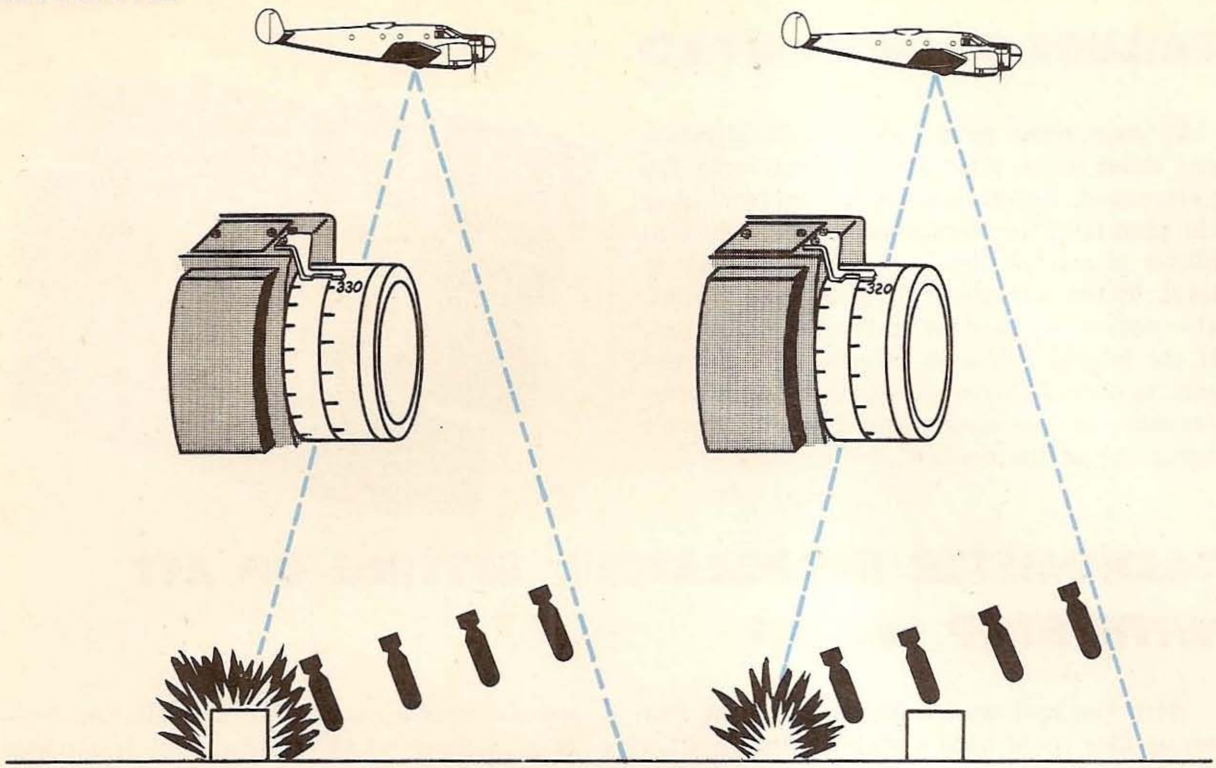
Train bombing means the dropping of a row of bombs at regular intervals across the target. Train bombing is very effective against long, narrow targets such as ships and bridges, and in formation "plowing" of enemy airfields and other area targets.

In using this method, you space the bombs close enough together to insure destruction of any bracketed objective.

The even spacing of the bombs in train bombing is controlled by an instrument known as the intervalometer, a clock-like mechanism which is connected to the bombsight. The intervalometer is energized by the bomb release signal from the bombsight, and in turn operates the bomb release stations to release bombs at regular intervals.

You must make three settings on the intervalometer: the number of bombs, the interval in feet, and the groundspeed. To turn ON the intervalometer, you must also turn the train selector switch to the "train" position.

In releasing a train of bombs, you want the center of the train to hit the center of the target. To do this, the first bomb must hit half the train-length short of the target.



To find the length (in feet) of a train of bombs, you multiply the number of bombs minus one, by the interval between bombs. Half the length of the train, in feet, divided by the value of a mil $\left(\frac{BA}{1{,}000}\right)$ will determine how many mils short the first impact should be.

FOR EXAMPLE:

GIVEN: 13 bombs to be dropped in train with 60-ft. intervals between bombs.

18,000 ft. bombing altitude; 180 mph groundspeed.

Set up intervalometer with 13 bombs and set 180 mph groundspeed opposite 60 ft. interval.

FIND LENGTH OF TRAIN:

$(13-1) \times 60 \text{ ft.} = 720 \text{ ft.}$

First bomb should hit 360 ft. short.

The number of mils the first bomb should hit short is: $360 \times \left(\frac{1{,}000}{18{,}000}\right) = 20$ mils.

These calculations can be summarized in the following equation:

$$₥ \text{ short} = \frac{500 \text{ (No. Bombs} - 1) \text{ (Interval in Ft.)}}{\text{Bombing Altitude}}$$

$$₥ \text{ short} = \frac{500\ (13-1)\ (60)}{18{,}000} = 20 \text{ mils}$$

Next reduce trail or disc speed so the sight will release the first bomb the proper distance short. You can subtract 20 mils from the trail set into the sight. This could cause an appreciable crosstrail error. Therefore it is better to decrease disc speed. The decrease in disc speed depends on the groundspeed. You find from the bombing aids chart that, at 180 mph groundspeed, 1 rpm of disc speed will move the first bomb 3.4 mils. Therefore, decrease the disc speed approximately 6 rpm to move the first bomb 20 mils short.

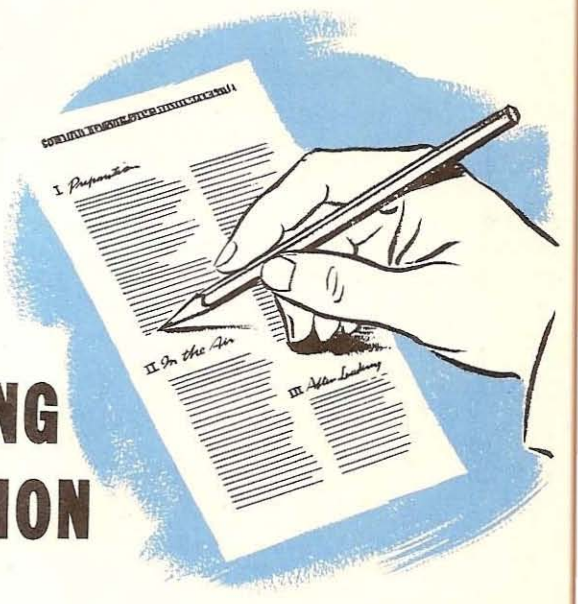
Approximate Number of Mils Impact Point is Changed if Disc Speed is Changed 1 rpm.

Ground-speed	Mils per Rpm	Ground-speed	Mils per Rpm
20	.4	180	3.4
40	.7	200	3.7
60	1.1	220	4.1
80	1.5	240	4.5
100	1.9	260	4.85
120	2.2	280	5.2
140	2.6	300	5.6
160	3.0	320	6.0

Data based on M38A2 Bomb from 6,000 ft., but is accurate within .2 mil for any bombing altitude between 1,500 and 12,000 ft.

SECTION 6

Bombing Procedures



CONDUCT OF A TRAINING QUALIFICATION MISSION

General

The principles of bombing procedures are the same, regardless of the minor individual differences among various instructors in teaching the procedures. Always keep in mind the bombing problem with your procedure. As you become more experienced, you will gain something that can be described only as "bombing sense." Tactics change constantly, but not bombing sense. It is something that experience builds in the bombardier's mind: it is a thinking attitude that eliminates mistakes due to carelessness.

Bombing is like a game. You do not become an expert ball player in a day, but only as a result of keen observation and practice. Listen carefully at briefings. Get a thorough picture of what is required. Plan your mission and know what to expect when you're in the air. Remember that you cannot check yourself too closely while working on the sight.

The following is an outline of a typical day on the line. There will be deviations from this procedure, but it will be helpful as a reminder and for instructional purposes.

Before reporting to the line, be sure you take with you all necessary equipment for the day's work.

Conduct of a Training Qualification Mission

I. *Preparation*

A. Briefing:

1. Type of mission.
2. Time of take off.
3. Target information.
4. Pressure altitude.
5. Indicated airspeed.
6. Metro information.
7. Bombardier pilot coordination.

B. Equipment:

1. Bombardier's kit.
2. Parachute.
3. Camera
4. Tachometer.
5. 12-C forms.
6. Oxygen mask.
7. ABC tangent scales.

C. Pre-flight:

1. Bombs, racks and controls.
2. Oxygen supply.
3. Autopilot (second Bombardier or Pilot).
4. Interphone.
5. Bombsight.
6. AB Computer.
7. Instruments.
8. Record runway pressure altitude and temperature.
9. Fill out Form 1.

II. *In the Air*

A. During Climb:

1. Remove arming pins.
2. Put on headset and throat microphone.
3. Turn all necessary switches ON.
4. Turn autopilot master switch ON. (second Bombardier or Pilot).
5. Record temperature at 1,000 ft.
6. Put on oxygen mask and adjust supply.
7. Compute bombing altitude.
8. Compute true airspeed.
9. Set data in sight—(D.S. and trail).

B. At Fight Level:

1. Check bombing altitude and true airspeed.
2. Check data set in sight (D.S. and trail).
3. Open bomb bay doors.
4. Engage and adjust autopilot (second Bombardier or Pilot).
5. Level stabilizer.
6. Solve for and pre-set drift and dropping angle.
7. Prepare bombsight for bombing approach.
8. Orient yourself in relation to the target.
9. Place bomb release handle to SELECT.
10. Be sure Instructor's cut-off switch is ON.

C. Bombing Approach:

1. Pilot signals on *course and level.*
2. Uncage gyro, while airplane is level.
3. Swing sight on target.
4. Engage bombsight clutch and disengage autopilot clutch.
5. Signal pilot.
6. Set up course.
7. Level gyro, if necessary.
8. Turn desired rack switch ON.
9. Turn rate motor switch ON as lateral crosshair intersects target.
10. Set up rate.
11. Check gyro level.
12. Hold up release lever.
13. Refine course and rate.
14. Signal pilot when *bomb is away.*

D. After Bomb Release:

1. Put release lever down.
2. Turn rack switch OFF.
3. Check sychronization, altitude and airspeed.
4. Check position of bubbles and cage gyro.
5. Analyze bomb release—(Call shot).
6. Turn rate motor switch OFF.
7. Note drift and compass heading.
8. Watch for bomb impact.

E. After Bomb Impact:

1. Note time and point of impact.
2. Engage autopilot clutch and disengage bombsight clutch.
3. Signal pilot *ready to turn.*
4. Note tangent of dropping angle.
5. Record all data on 12-C form.
6. Prepare for next run.

F. After Last Bomb Impact:

1. Signal pilot *bombing is completed.*
2. Close bomb bay doors.
3. Place bomb release handle to safe position.
4. Turn bombardier's control panel switches OFF.
5. Turn bombsight switches OFF.
6. Set trail arm at zero.
7. Set disc speed drum at minimum setting.
8. Cover bombsight.
9. Fill out 12-C form as completely as possible.

III. *After Landing*

A. At Airplane:

1. Check entry in Form 1.
2. Fill out report on any malfunctions of bombing equipment.

B. Turn in Equipment:

1. Parachute.
2. Camera.
3. Tachometer.
4. ABC tangent scales.
5. Bombsight time.

C. Critique:

1. Analyze mission with instructor.
2. Turn in all reports and forms.

I. Preparation

A. BRIEFING

The purpose of a briefing is to inform you of last minute changes and to insure that everyone understands the mission. The briefing officer will give you the altitude and airspeed to be flown, and he will emphasize the target to be bombed, whether it will be record or practice mission. The weather man will give you the pressure altitude, temperature, winds aloft, and general weather forecast for the mission.

1. **TYPE OF MISSION.** The briefing officer will tell you whether mission is record or practice, qualification or combat, and the altitude to be flown.

2. **TIME OF TAKE-OFF.** This is important for the operation of any schedule flying. Always be ready to take off at the scheduled time.

3. **TARGET INFORMATION.** You will be given the location, elevation and bombing approach heading of the target. You will also be told if any targets on a series are closed.

4. **PRESSURE ALTITUDE.** This is emphasized in briefing so everyone will get the correct pressure altitude and be the same altitude above the target.

5. **INDICATED AIRSPEED.** Given for the safe operation of the airplanes while over the targets as well as to insure an understanding between the pilot and bombardier.

6. **METRO INFORMATION.** You should be given pressure altitude, the temperature at the target, winds aloft and general forecast. This is a helpful aid to your mission and will help you to know what to expect after you are in the air.

7. **BOMBARDIER AND PILOT COORDINATION.** Before mission, have a perfect understanding with your pilot as to the signals that will be used and type of mission to be flown. Remember, team work is essential for a good mission.

B. EQUIPMENT

Check to be sure you have the necessary equipment and that it is in good condition, before each mission. Keep an accurate record of your bombing results on the 12-C.

1. **BOMBARDIER'S KIT.** The kit is your "tool box" for a bombing mission. All of the instruments in a kit are important, so take care of them.

2. **PARACHUTE.** For your safety learn to wear the parachute while working in the airplane. Check your parachute carefully before taking off on a mission.

3. **CAMERA.** Be sure your mission number is recorded on the film before take-off and that there is enough film in camera for the mission.

4. **TACHOMETER.** It enables you to set the proper disc speed in the sight more quickly and accurately.

5. **12-C FORMS.** Don't forget them: they are your "log" of results.

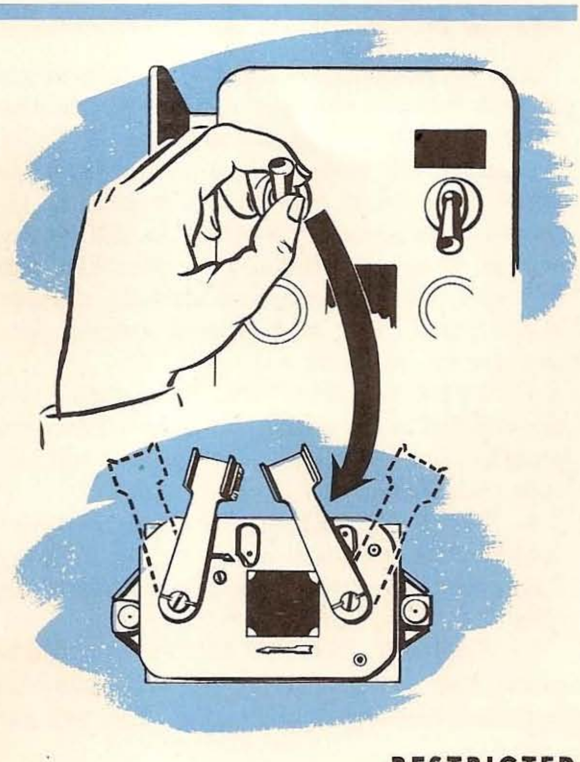
6. **OXYGEN MASK.** If you are going above 10,000 ft. pressure altitude be sure you have your oxygen mask. Check it for proper fit.

7. **ABC TANGENT SCALES.** The ABC is to be used. Be sure you take the tangent scales for the correct bombing altitude.

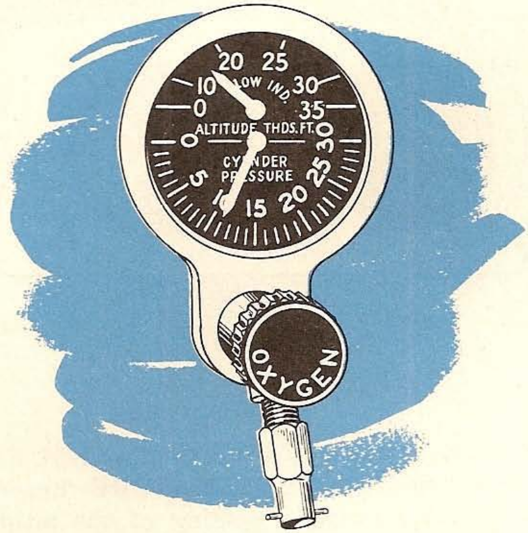
C. PRE-FLIGHT

You must pre-flight all the equipment you will use on the mission. You might say that a pre-flight is insurance of having a good mission. If you find a malfunction in your pre-flight, call a maintenance man; do not try to fix the equipment yourself.

1. **BOMBS, RACKS AND CONTROLS.** Before loading bombs, cock and fire all stations to insure proper release. After loading bombs, inspect them in their respective stations, to see that the arms of the shackles are properly placed in the releases.

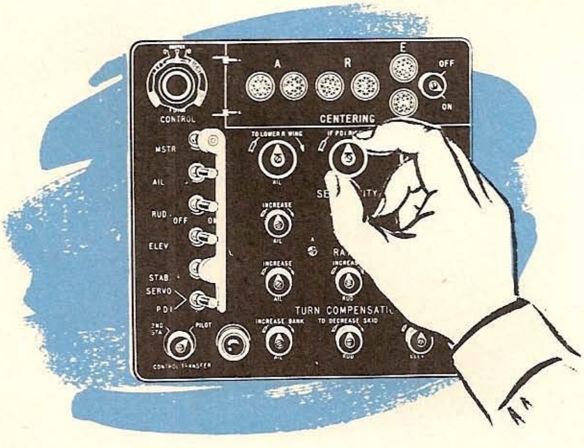


2. **OXYGEN SUPPLY.** Check the oxygen supply at all outlets. Be sure that sufficient pressure is registering in each bottle to last the mission. Remember, too little—too late might be fatal.



3. **AUTOPILOT.** The second bombardier or pilot should pre-flight the C-1 autopilot.

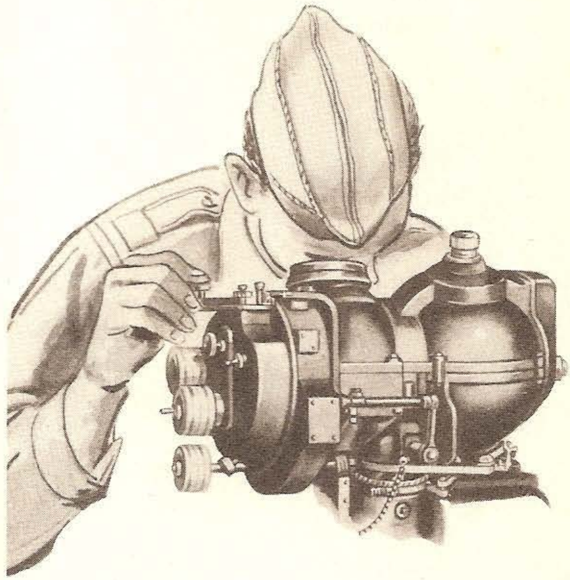
1. Turn autopilot master switch ON.
2. Center turn control.
3. Turn knobs on ACP to "pointers up" position.
4. Turn Servo-PDI switch ON.
5. Disengage bombsight clutch and engage autopilot clutch with PDI on center.
6. Operate airplane controls manually, observing tell-tale lights.



7. Turn aileron, rudder, and elevator engaging switches ON. observing tell-tale lights.
8. Rotate each centering knob, observing controls.
9. Rotate turn control knob, observing controls.
10. Disengage autopilot clutch and displace to each side, observing controls. Engage autopilot clutch.
11. Turn autopilot master switch OFF.

4. **INTERPHONE.** Contact the pilot over the interphone to insure coordination and proper understanding.

5. **BOMBSIGHT PREFLIGHT.**



Installation:

1. Match sighthead and stabilizer.
2. Insert clevis pin and dovetail locking pin.
3. Check for security of cannon plugs on stabilizer.
4. Turn "STAB" switch ON.

Crosstrail mechanism:

5. Check for pre-set trail.
6. Check for dovetail misalignment.
7. Check for tilt of optics.

Rate end:

8. Turn "BS" switch ON.
9. Check knobs on rate end.
10. Check rate motor and optic drive.
11. Check disc speed drum and gear shift.

12. Check for pre-set trail.
13. Check for roller slippage.
14. Check mirror drive cable length.

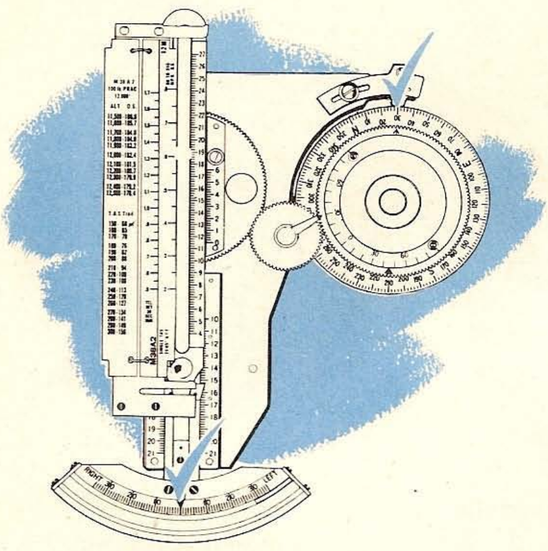
Stabilizer and course knobs:

15. Turn "SERVO" switch ON.
16. Check action of course knobs and PDI.
17. Check torque unit and bombsight clutch.
18. Check autopilot clutch.
19. Check PDI with pilot.

Sight vertical and lighting:

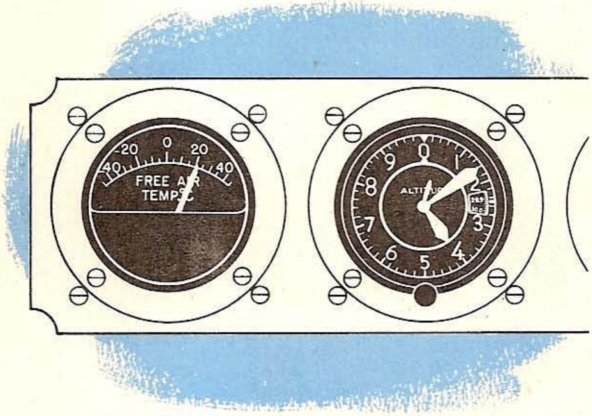
20. Check vertical gyro.
21. Check leveling knobs.
22. Check bubble light.
23. Check crosshair light.

6. **AB COMPUTER.**



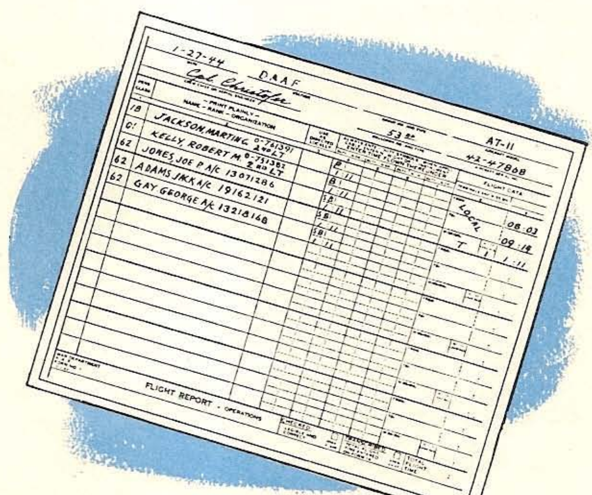
Check installation and zeroing of the computer. Set drift pointer on zero drift, and the lubber lines should be opposite the wind arrow.

7. **INSTRUMENTS.** Set 29.92 on the pressure scale of the altimeter and read runway pressure altitude. After the motors of the airplane have been started, check to see if the free air temperature gage works and read runway temperature. Inspect the compass in the nose. Check all of the instrument calibration cards.



8. **RECORD RUNWAY PRESSURE ALTITUDE AND TEMPERATURE.** Record the pressure altitude reading of the altimeter, with 29.92 set on the pressure scale. Record the reading from free air temperature gage after the motor is running.

9. **FILL OUT FORM 1.** Enter your name, rank, and serial number on Form 1 before take-off.

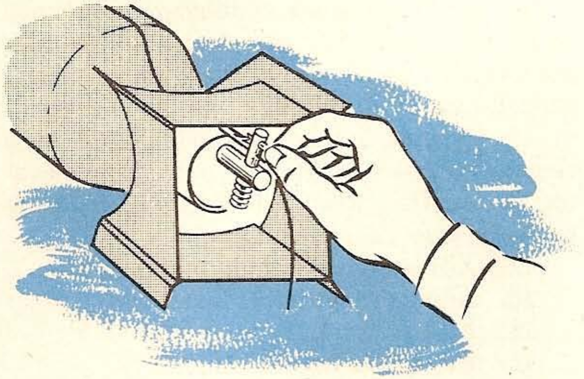


II. *In the Air*

A. DURING CLIMB

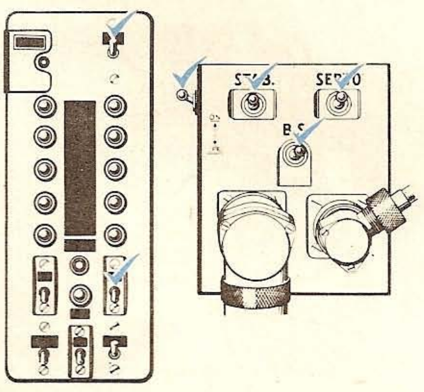
During the climb, you will make your computations for the bombing altitude and prepare yourself for the bombing run. You will also set the necessary data in the sight for the run.

1. **REMOVE ARMING PINS.** Then, when bomb is released, it will be armed.



2. **PUT ON HEADSET AND THROAT MICROPHONE AND ADJUST VOLUME.** Don't fumble with these when putting them on. When speaking into the throat mike, speak in a normal tone of voice.

3. **TURN ALL THE NECESSARY SWITCHES *ON*.**



On the bombardier's control panel, turn ON the bomb circuit and station light switches. Turn ON the "STAB.," "Servo," "PDI," and "BS" switches in the proper sequence.

4. **TURN AUTOPILOT MASTER SWITCH *ON*.** The other bombardier or pilot should turn this switch ON. It supplies current to the flight gyro so it will erect to the vertical.

5. **RECORD TEMPERATURE AT EVERY 1,000 FT.** In order to get an accurate mean temperature, you must have these temperature readings.

6. **PUT ON OXYGEN MASK AND ADJUST SUPPLY.** On day missions oxygen will be used at all times over 10,000 ft. On night missions, start using oxygen from take-off.

7. **COMPUTE BOMBING ALTITUDE.** You must compute accurately for good results, using the C-2, AN or E-6B computer. puter.

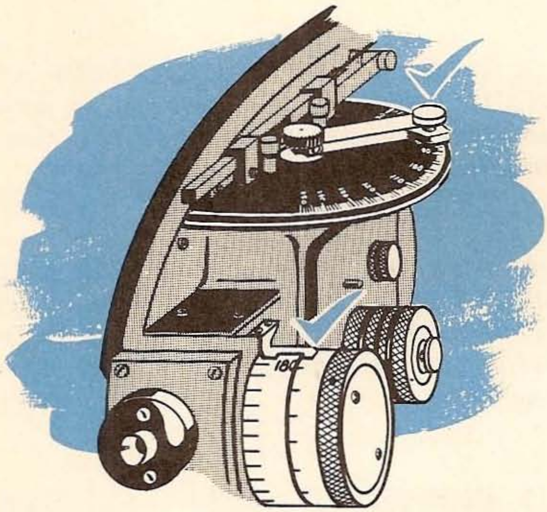
8. **COMPUTE TRUE AIRSPEED.** To solve for the TAS use the E-6B computer.

9. **SET DATA IN SIGHT.** After computing your bombing altitude and true airspeed, use the bombing tables to find the disc speed and trail. Set these into the sight. Check your disc speed with tachometer or stop watch.

B. AT FLIGHT LEVEL

1. **CHECK BOMBING ALTITUDE AND TRUE AIRSPEED.** Check your computations to assure yourself that you haven't made any careless mistakes.

2. **CHECK DATA SET IN SIGHT.** Do this to be sure that you have set the correct disc speed and trail into the sight. It is a good policy to mark the disc speed drum at the proper disc speed setting, so you can detect any change if you accidentally knock it off.



3. **OPEN BOMB BAY DOORS.** When the pilot signals you, raise the bomb bay door switch to open the doors. When doors are open, bomb bay door light will be on.

4. **ENGAGE AND ADJUST THE AUTOPILOT.** The second bombardier or pilot will engage and adjust the autopilot.

1. Center turn control.

2. Turn knobs on ACP to "pointers up" position.

3. Engage autopilot clutch and disengage bombsight clutch.

4. Turn autopilot master switch ON. (Wait 10 minutes before turning other switches ON.)

5. Manually trim airplane for straight and level flight.

6. Turn Servo-PDI switch ON.

7. Turn tell-tale lights switch ON.

8. Center PDI.

9. Adjust aileron centering knob until both aileron tell-tale lights are out. Turn aileron switch ON. Readjust aileron centering knob to level wings.

10. Adjust rudder centering knob until both rudder tell-tale lights are out. Turn rudder switch ON. Readjust elevator centering knob to center PDI.

11. Adjust elevator centering knob until elevator tell-tale lights are out. Turn elevator switch ON. Readjust elevator centering knob for level flight.

12. Adjust centering, if necessary.

13. Adjust sensitivity, if necessary.

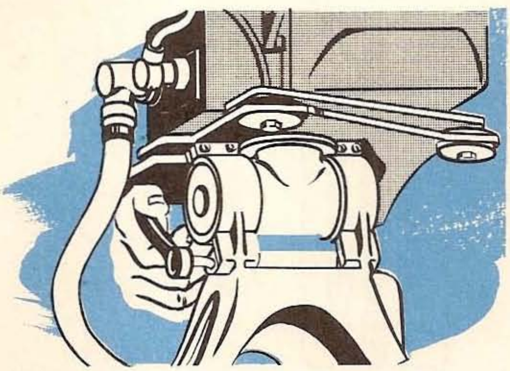
14. Adjust ratio, if necessary.

15. Adjust dashpot, if necessary.

16. Adjust turn compensation, if necessary.

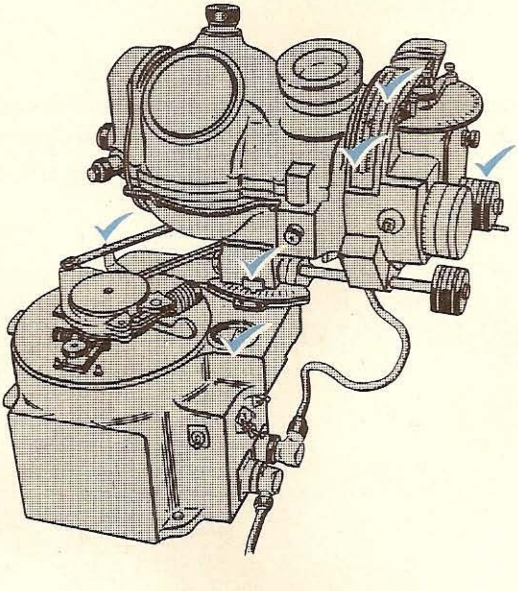
17. Adjust turn control, if necessary.

5. **LEVEL STABILIZER.** A good level eliminates large corrections to level the vertical gyro while on a bombing run.



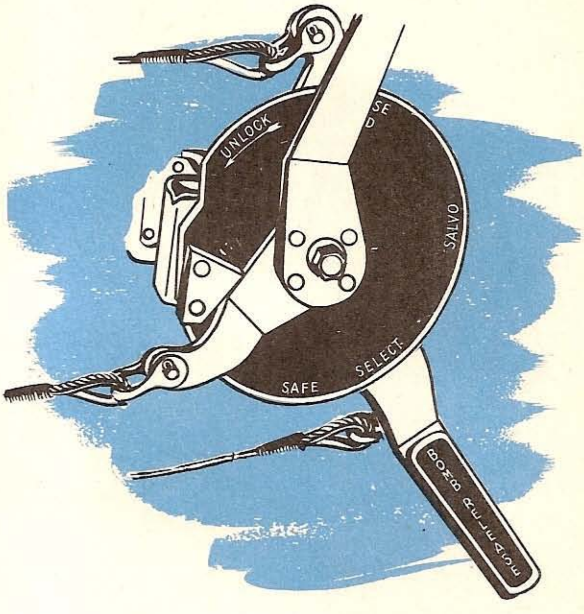
6. **SOLVE FOR AND PRE-SET DRIFT AND DROPPING ANGLE.** You should take a double drift and find the wind. For any heading you can find your drift and groundspeed at the point of the wind arrow. With your groundspeed solved, the values of your dropping angles can be found in the bombing tables. You can also use the AB computer, which will give the drift and dropping angle directly.

7. **PREPARE BOMBSIGHT FOR BOMBING APPROACH.** Center bombsight connecting rod, roll sighting angle index back to 70°, engage mirror drive clutch, and pre-set drift and dropping angle. Also, if you are flying a manual mission, center PDI with the autopilot clutch arm.

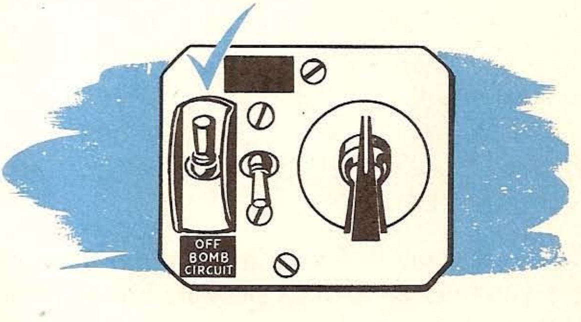


8. **ORIENT YOURSELF IN RELATION TO THE TARGET.** Always observe the terrain you are flying over. If you have located the target, before your run, you will not waste any time in swinging the sight on the target.

9. **PLACE BOMB RELEASE HANDLE TO SELECT POSITION.** This unlocks the releases and allows the bombs to drop armed.



10. **BE SURE INSTRUCTOR'S CUT-OFF SWITCH IS *ON*.** This switch is located on the right hand side of the bombardier's compartment and must be ON in order to release a bomb. It should be left turned ON except when cut off by the instructor to prevent a dangerous or otherwise bad release.

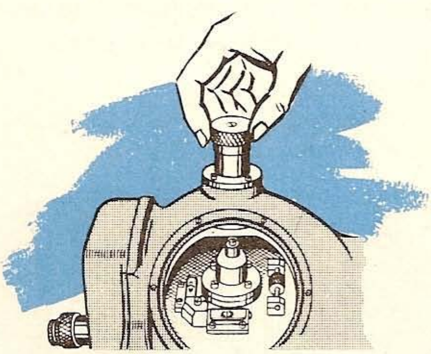


C. BOMBING APPROACH

1. PILOT SIGNALS ON COURSE AND LEVEL.

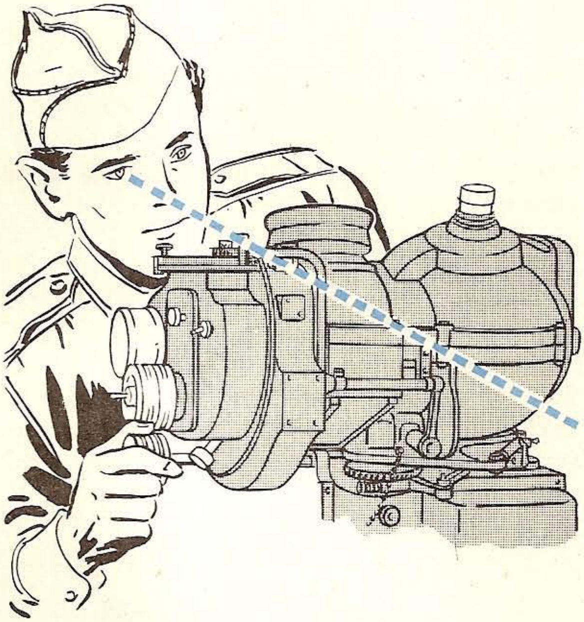
The pilot is ready for you to start the run and the airplane is on the approximate heading to the target.

2. UNCAGE GYRO,

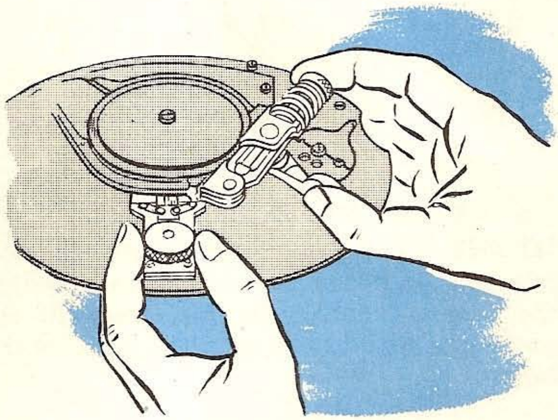


while airplane is level. Once the airplane is level uncage as soon as possible but **be sure it is level.**

3. SWING THE SIGHT ON TARGET. Place the target in the field of vision of the sight, so the fore and aft crosshair will pass through the target. If the field of vision is short of the target—roll the extended vision into the sight. If the field of vision is over the target—use the displacement knob to roll the optics down on the target.



4. ENGAGE BOMBSIGHT CLUTCH AND DISENGAGE AUTOPILOT CLUTCH.

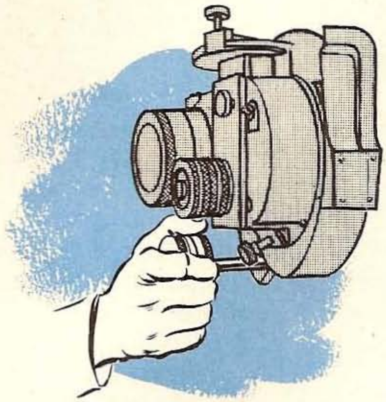


When you engage the bombsight clutch, the sighthead is stabilized by the directional gyro. This allows you to put in the necessary course corrections through the course knobs. Be sure to disengage the autopilot clutch.

5. SIGNAL PILOT.

Answer the pilot's on course and level signal to let him know you received his signal and are ready to direct the airplane on the bombing run.

6. SET UP COURSE.

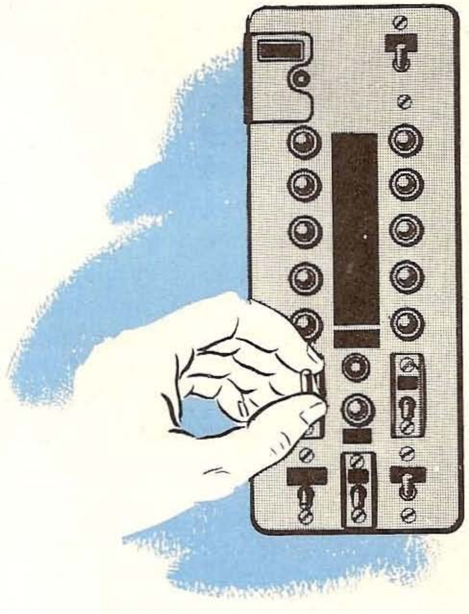


Always set up course first. After swinging on, synchronize for course as soon as possible in order to maintain the proper path into the target. Double grip the course knobs to stop the movement of the fore and aft crosshair. Then put the crosshair back on the center of the target with the turn knob.

7. LEVEL GYRO IF NECESSARY.

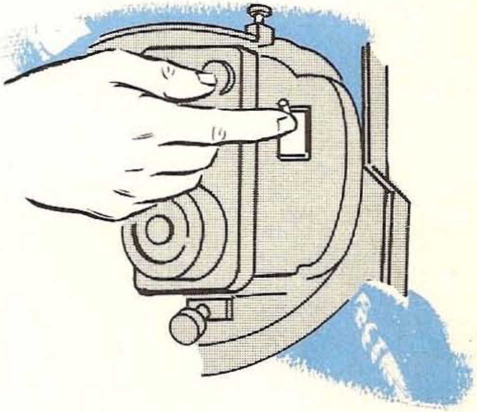
After setting up course, notice your gyro. If it isn't in the vertical, level it by centering the bubbles. Do not attempt to level the gyro if the plane is not flying straight and level.

8. TURN DESIRED RACK SWITCH *ON*.

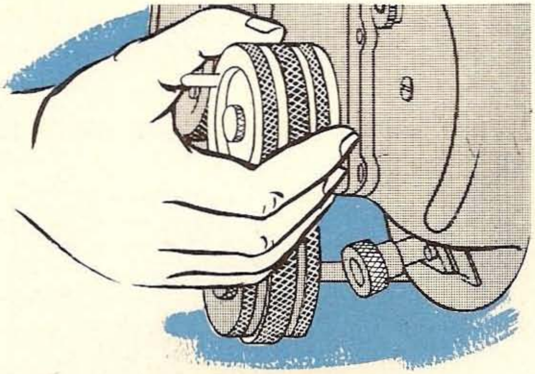


You select the rack from which you want to release the bomb, and raise the corresponding rack switch.

9. TURN RATE MOTOR SWITCH *ON* as lateral crosshair intersects target.

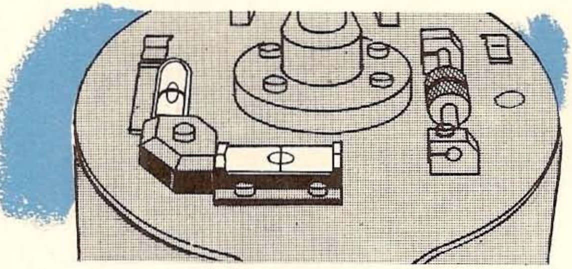


10. SET UP RATE.



With one smooth correction of the rate knob, stop the movement of the lateral crosshair. Then put the crosshair back on the center of the target with the displacement knob.

11. CHECK GYRO LEVEL.

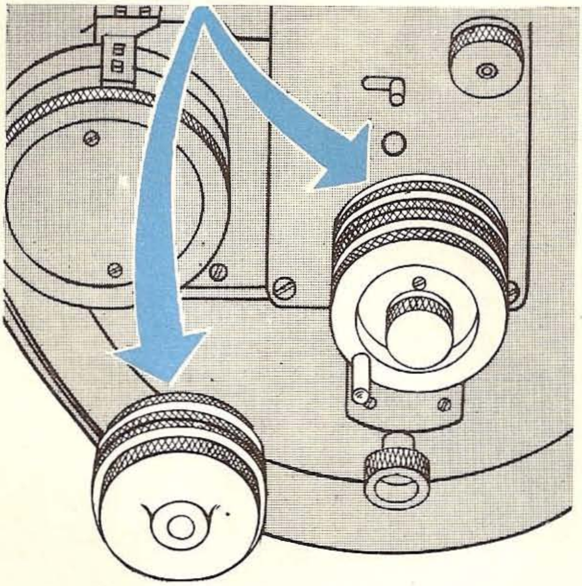


If time permits, you should level it; but if you are too near the release point, looking at the bubbles will teach you to recognize the error caused by improper vertical.

12. HOLD UP RELEASE LEVER.

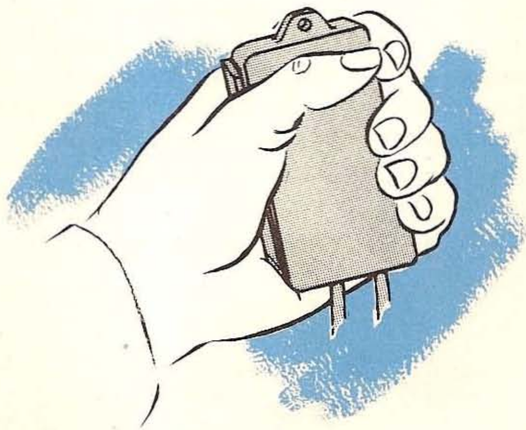
This enables the automatic release points to make an electrical contact, and thus energize the release box.

13. REFINE COURSE AND RATE.



These last-minute corrections are very small. They must be put in with accuracy in order to get a good hit.

14. SIGNAL PILOT WHEN BOMB IS AWAY.



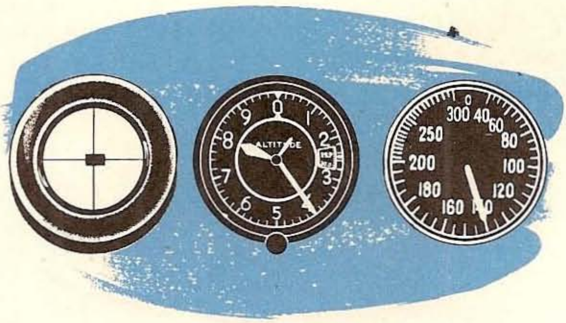
This is to notify the pilot when the bomb is released. On a manual mission, this is a signal to stop following the PDI.

D. AFTER BOMB RELEASE

1. **PUT RELEASE LEVER DOWN.** Do this immediately after the bomb release to insure against an accidental or double release.

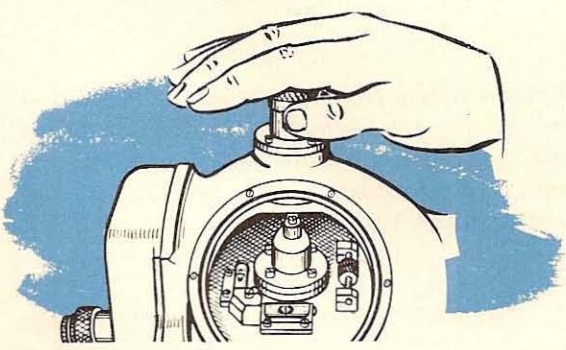
2. **TURN RACK SWITCH *OFF*.** This is also a safety precaution to prevent an accidental release.

3. **CHECK SYNCHRONIZATION, ALTITUDE, AND AIRSPEED.**



These factors enter into "calling your shot" and predicting the impact of the bomb.

4. **CHECK POSITION OF BUBBLES' AND CAGE GYRO.**



The gyro should always be caged at this time to be sure it isn't tumbled when you turn.

5. **ANALYZE BOMB RELEASE (CALL SHOT).** Considering your synchronization, altitude, airspeed, and position of the bubbles, learn to predict the bomb's impact before it hits the ground.

6. **TURN RATE MOTOR SWITCH *OFF*.** Stop the rate motor before the sighting angle index reaches zero. This is done to prevent damaging the mirror drive cable.

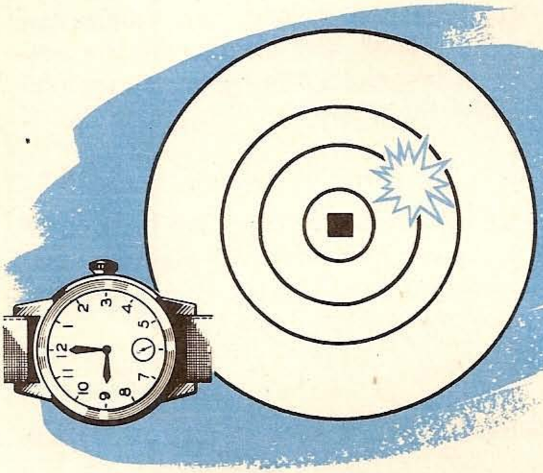
7. **NOTE DRIFT AND COMPASS HEADING.**

You need the drift on the sight and the compass heading of the airplane at the time of release.

8. **WATCH FOR BOMB IMPACT.** Watch for the bomb impact; then compare actual impact with your prediction. How closely can you call your shots?

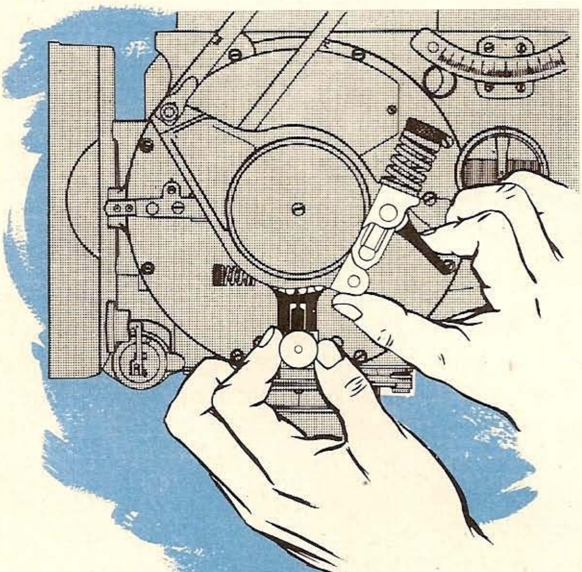
E. AFTER BOMB IMPACT

1. **NOTE TIME AND POINT OF IMPACT.**



Remember the direction and distance of the impact from the center of the target.

2. **ENGAGE AUTOPILOT CLUTCH AND DISENGAGE THE BOMBSIGHT CLUTCH.**



If you're flying on autopilot this will transfer the control of the airplane to the pilot.

3. **SIGNAL PILOT READY TO TURN.** This signal will mean you have caged the gyro, spotted your bomb, prepared your clutches and are ready to turn onto the next run.

4. **NOTE TANGENT OF THE DROPPING ANGLE.** Read the tangent of the dropping angle at the dropping angle index.

5. **RECORD ALL DATA ON 12-C FORM.**

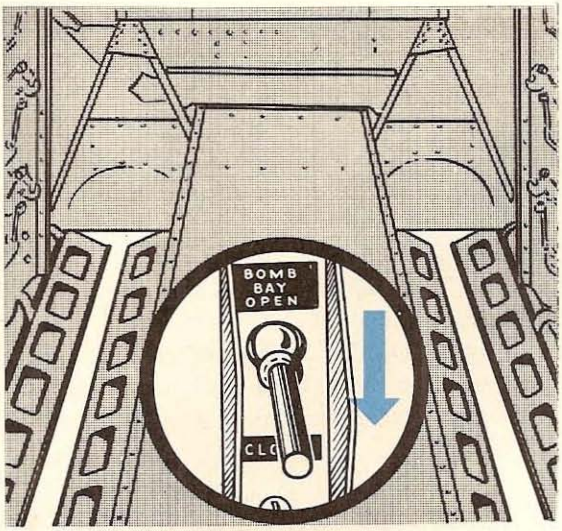
Record drift, compass heading, point and time of impact, tangent of the dropping angle, pressure altitude and indicated airspeed, synchronization and position of the bubbles on the 12-C form.

6. **PREPARE FOR NEXT RUN.** Center the bombsight connecting rod, roll sighting angle index back to 70°, engage mirror drive clutch, and pre-set drift and dropping angle. Also, if you are flying a manual mission, center PDI with the autopilot clutch arm.

F. AFTER LAST BOMB IMPACT

1. **SIGNAL PILOT BOMBING IS COMPLETED.** You do this so the pilot can leave the target series.

2. **CLOSE BOMB BAY DOORS.**



Lower the bomb bay door switch to close the doors. When the doors are closed the bomb bay door light is off.

3. **PLACE BOMB RELEASE HANDLE TO SAFE POSITION.** Placing the arming lever to safe position locks all releases.

4. **TURN BOMBARDIER CONTROL PANEL SWITCHES *OFF*.** Turning OFF all switches opens the circuits and breaks the electrical flow, thus relieving the drain on the generators.

5. **TURN ALL BOMBSIGHT SWITCHES *OFF*.** This prevents all the parts of the sight from starting to run at the same time, when the next user turns the bomb circuit switch ON.

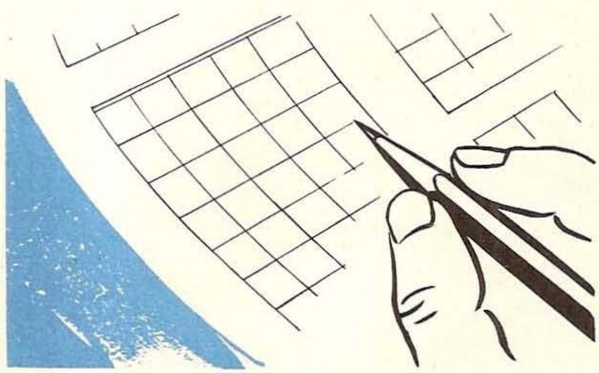
6. **SET TRAIL ARM AT ZERO.** This is done to relieve the tension on the thrust spring at the bottom of the spindle screw.

7. **SET DISC SPEED DRUM AT MINIMUM SETTING.** With the disc speed drum at minimum setting, it will relieve the tension on the disc speed drum springs.

8. **COVER BOMBSIGHT.**

Place the cover over the bombsight in order to protect it from dust.

9. **FILL OUT 12-C FORMS AS COMPLETELY AS POSSIBLE.**



Fill out as much of the forms as possible while in the air, so the time on the ground can be devoted to analyzing the bombs and a critique of the mission.

III. *After Landing*

A. AT AIRPLANE

1. CHECK ENTRY ON FORM 1. After landing check to be sure you have a complete entry in the form 1. This form is a record of your flying time—so don't forget it.

2. FILL OUT REPORT ON ANY MALFUNCTION OF BOMBING EQUIPMENT. Make a report of the malfunction immediately after landing so the fault can be corrected. This will keep the next bombardier from having the same malfunction.

B. TURN IN EQUIPMENT

1. PARACHUTE.
2. CAMERA.
3. TACHOMETER.
4. ABC TANGENT SCALES.
5. BOMBSIGHT TIME. A record of the actual time the bombsight was running is important. This enables the bombsight maintenance men to make the inspections at the proper time.

C. CRITIQUE

1. ANALYZE MISSION WITH INSTRUCTOR. Using the 12-C form and your E-6B computer, you must analyze each bomb that you dropped. Learn how to determine and correct the causes of your error. Listen carefully to what your instructor tells you at this time, for it is here and now that you should learn your mistakes and how to correct them.

2. TURN IN ALL REPORTS AND FORMS. These reports are important to you. Be sure that you fill them in accurately, for each report is a record of **your** bombing.

FIXED ANGLE BOMBING

GENERAL

At low bombing altitudes, such as 500 to 1,500 ft., you will do fixed-angle bombing. This consists of releasing the bomb on a pre-set dropping angle. You must take a double drift to solve for the drift and dropping angle to be pre-set. On the bombing approach, you do not synchronize for rate. Instead, you pre-set your dropping angle and drive the sighting angle manually by turning the displacement knob. You turn this knob at whatever speed is necessary to keep the lateral crosshair on the target.

At the bombing altitude, you set a disc speed of approximately 350 to 400 rpm into the sight. While the disc speed helps, you actually keep the lateral crosshair on the target by turning the displacement knob.

The extended vision is rolled in and locked to give an extra 20° forward vision. This enables you to pick up the target as soon as you are on course. You compensate for this 20° extra forward vision by subtracting 20° from the dropping angle. You then set this corrected dropping angle into the sight.

If the dropping angle is given in degrees, you set the dropping angle index to the degree value of the dropping angle as read on the degree scale. After setting up the dropping angle, roll the sighting angle index to about 60°.

On a fixed-angle bombing run, trail has no effect on the range problem. Therefore, you set trail in the sight only to correct for crosstrail. Nevertheless, be sure to set in trail.

The conduct of a fixed-angle mission is the same as the training qualification mission except at flight level and on the bombing approach.

AT FLIGHT LEVEL

1. CHECK BOMBING ALTITUDE AND TRUE AIRSPEED COMPUTATIONS.

2. CHECK DATA SET IN SIGHT. Check to see that you have 350 to 400 rpm disc speed and the correct trail set into the sight. Also check to see that 20° extended vision is rolled in and locked.

3. OPEN BOMB BAY DOORS.

4. ENGAGE AND ADJUST AUTO-PILOT. (Second bombardier or pilot.)

5. LEVEL STABILIZER.

6. SOLVE FOR AND PRE-SET DRIFT AND DROPPING ANGLE. In taking the double drift, use the bombsight as a drift meter. That is, with a small sighting angle align the fore and aft crosshair with objects on the ground as they pass along it. Then read the drift from the drift scale on the bombsight.

For any heading, you can find your drift and groundspeed at the point of the wind arrow. With your groundspeed solved you can look in the bombing tables and get the value for your dropping angle. These must be solved for accurately in order to have the proper release point.

7. PREPARE BOMBSIGHT FOR BOMBING APPROACH. Pre-set the known drift and dropping angle on the bombsight. Make sure to correct the dropping angle for the 20° extended vision, as 20° extended vision is rolled in and locked.

8. ORIENT YOURSELF IN RELATION TO THE TARGET.

9. PLACE BOMB RELEASE HANDLE TO *SELECT*.

10. BE SURE INSTRUCTOR'S CUT-OFF SWITCH IS *ON*.

NON-SYNCHRONOUS BOMBING APPROACH

1. PILOT SIGNALS ON COURSE AND LEVEL.

2. UNCAGE GYRO, WHILE AIRPLANE IS LEVEL.

3. SWING THE SIGHT ON TARGET.

4. ENGAGE BOMBSIGHT CLUTCH AND DISENGAGE AUTOPILOT CLUTCH.

5. SIGNAL PILOT.

6. SET UP COURSE. Set up good course at the start to insure small corrections at the end of the run.

7. LEVEL GYRO IF NECESSARY.

8. TURN DESIRED RACK SWITCH *ON*.

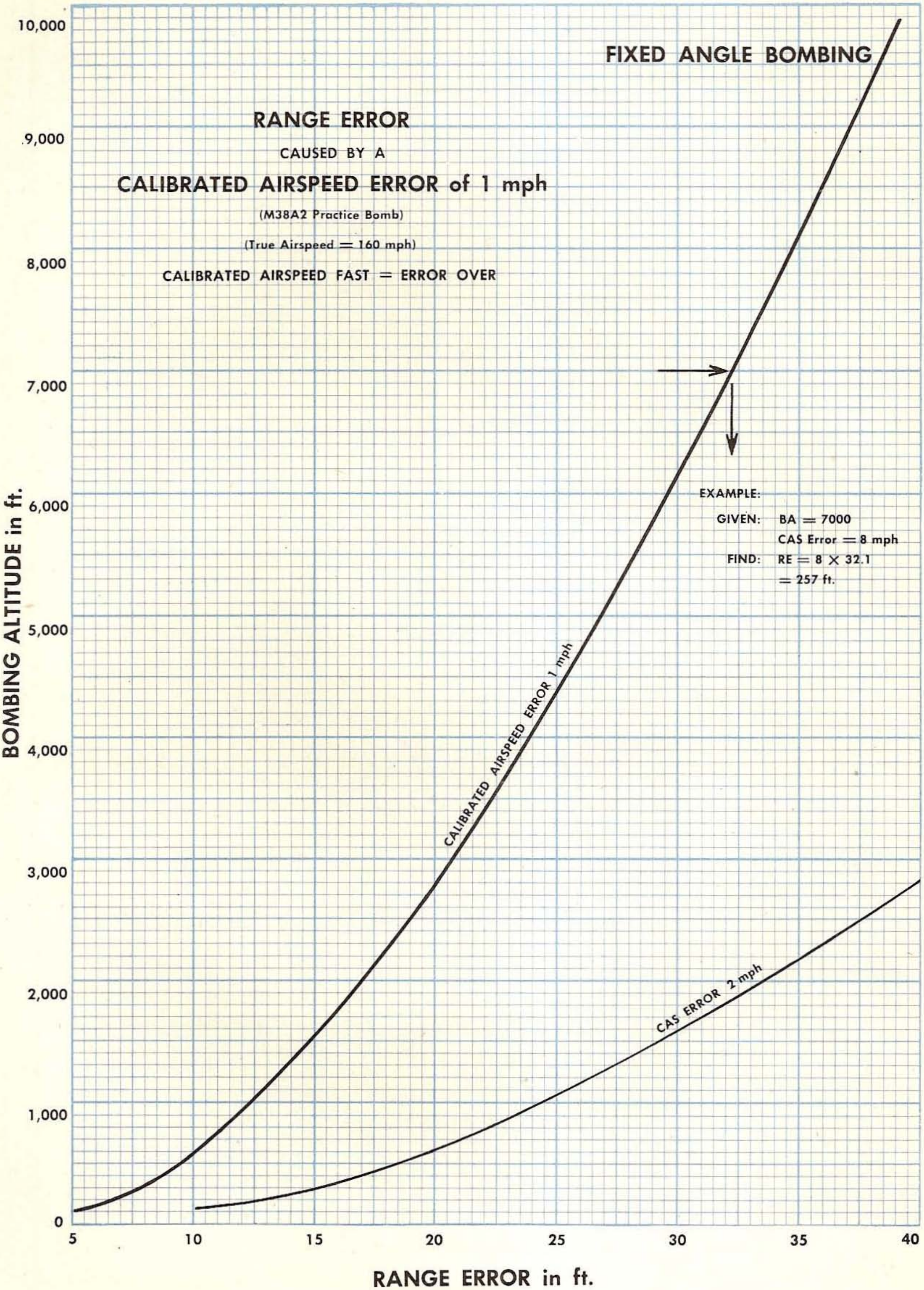
9. TURN RATE MOTOR SWITCH *ON*. You turn the rate motor switch ON, when the lateral crosshair approaches the target.

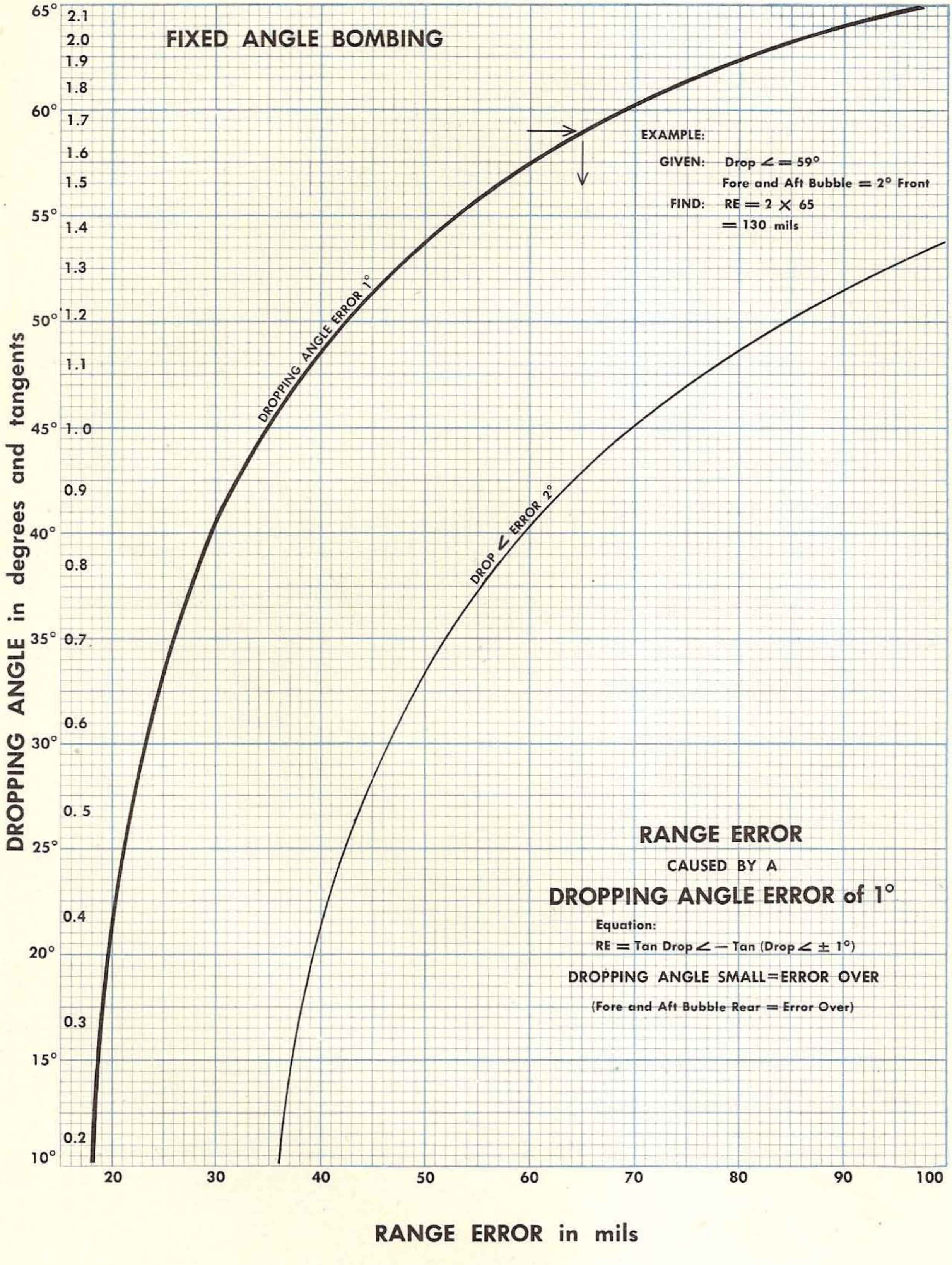
10. KEEP THE LATERAL CROSSHAIR ON TARGET. As you approach the target the lateral crosshair will constantly move off the target. Turn the displacement knob to hold the lateral cross-hair on the target until the bomb is away.

11. HOLD UP THE RELEASE LEVER.

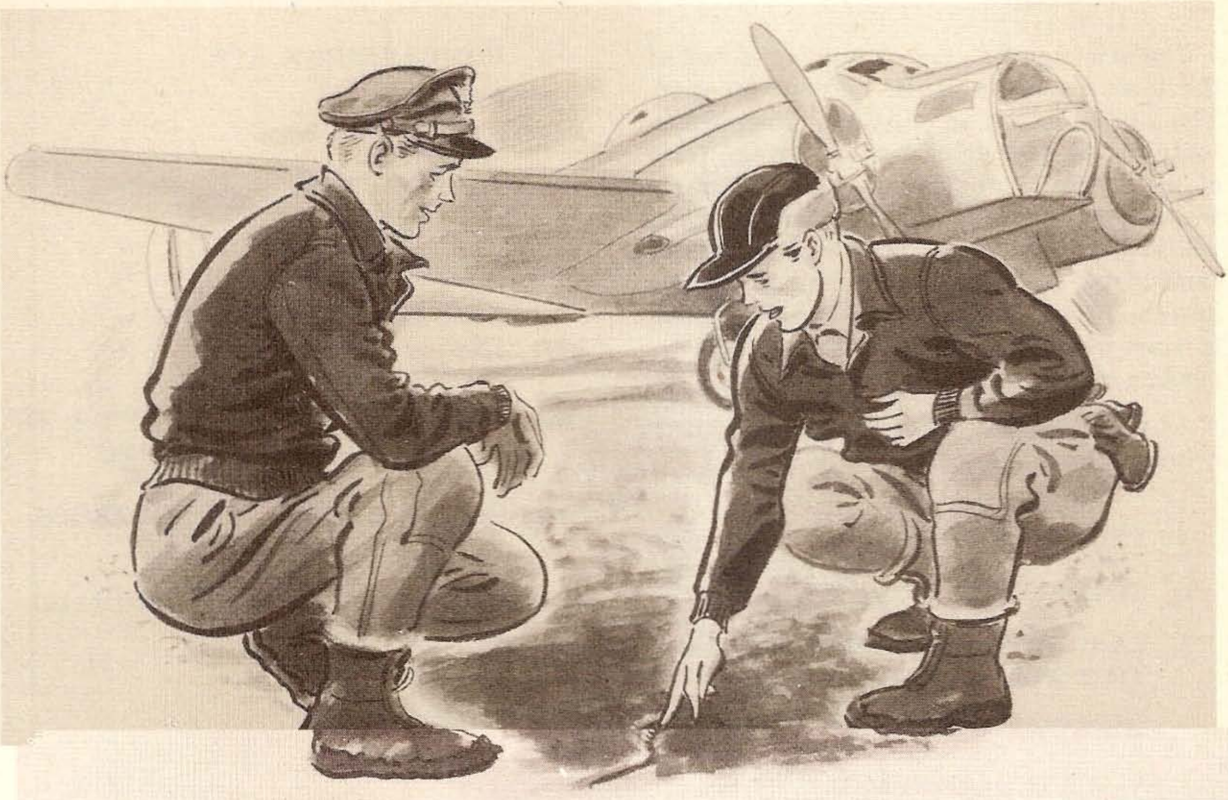
12. REFINE COURSE.

13. SIGNAL PILOT WHEN BOMB IS AWAY.


FIXED ANGLE BOMBING
RANGE ERROR
CAUSED BY A
CALIBRATED AIRSPEED ERROR of 1 mph
(M38A2 Practice Bomb)
(True Airspeed = 160 mph)
CALIBRATED AIRSPEED FAST = ERROR OVER
EXAMPLE:
GIVEN: BA = 7000
CAS Error = 8 mph
FIND: RE = 8 X 32.1
= 257 ft.
CALIBRATED AIRSPEED ERROR 1 mph
CAS ERROR 2 mph
BOMBING ALTITUDE in ft.
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
5
10
15
20
25
30
35
40
RANGE ERROR in ft.


FIXED ANGLE BOMBING
EXAMPLE:
GIVEN: Drop ∠ = 59°
Fore and Aft Bubble = 2° Front
FIND: RE = 2 × 65
= 130 mils
DROPPING ANGLE ERROR 1°
DROP ∠ ERROR 2°
RANGE ERROR
CAUSED BY A
DROPPING ANGLE ERROR of 1°
Equation:
RE = Tan Drop ∠ — Tan (Drop ∠ ± 1°)
DROPPING ANGLE SMALL=ERROR OVER
(Fore and Aft Bubble Rear = Error Over)
DROPPING ANGLE in degrees and tangents
65° 2.1 2.0 1.9 1.8 60° 1.7 1.6 1.5 55° 1.4 1.3 50° 1.2 1.1 45° 1.0 0.9 40° 0.8 35° 0.7 0.6 30° 0. 5 25° 0.4 20° 0.3 15° 0.2 10°
20 30 40 50 60 70 80 90 100
RANGE ERROR in mils

CONDUCT OF A TRAINING COMBAT MISSION



GENERAL

The success of a combat bombing mission depends to a great extent on close cooperation between you and your pilot. Each member of the combat crew must have a thorough knowledge of his own duties as well as the duties of other members of the crew.

You will find there is no standard combat approach, except for the purpose of training. If there were a standardized procedure, the enemy would soon learn of it and take steps to prevent a successful attack. The enemy's opposition and the natural surroundings will determine the approach to be used for that particular theater of operation.

The key to a good mission is the accurate pre-setting of the necessary data. Take advantage of the metro winds and figure the drift and dropping angle on the ground. From this, you will know what to expect after you're in the air.

After you're in the air find the wind by using the E-6B or AB computer.

Evasive action will be practiced on your combat training approaches. These approaches employ certain fundamental evasive techniques. They consist of changing headings by 5° to 15°, varying airspeed, and changing altitude. The anti-aircraft installations and your bombing altitude will determine the length of time you allow for your final straight and level run on the target.

On all combat missions, plan your attack.

I. Preparation

A. BRIEFING

The briefing of a combat mission is one of the most important parts of your mission. You will be issued an objective folder which contains the target information in the form of maps and photographs. You must study these maps and photos to determine how you will identify the target. You may encounter camouflage, so learn the landmarks leading into the target. You will have a definite point to start your approach (initial point) and a heading on which to make the run.

At all times, pay close attention to every detail in the briefing.

1. TYPE OF MISSION.
2. TIME OF TAKE-OFF.
3. TARGET INFORMATION (OBJECTIVE FOLDERS).
4. PRESSURE ALTITUDE.
5. INDICATED AIRSPEED.
6. METRO INFORMATION.
7. BOMBARDIER AND PILOT COORDINATION.

B. EQUIPMENT (Same as on training qualification mission)

1. BOMBARDIER'S KIT.
2. PARACHUTE.
3. CAMERA.
4. TACHOMETER.
5. 12-C FORMS.
6. OXYGEN MASK.
7. ABC TANGENT SCALES.

C. PRE-FLIGHT (Same as on training qualification mission)

1. BOMBS, RACKS AND CONTROLS.
2. OXYGEN SUPPLY.
3. AUTOPILOT (SECOND BOMBARDIER OR PILOT).
4. INTERPHONE.
5. BOMBSIGHT.
6. AB COMPUTER.
7. INSTRUMENTS.
8. RECORD RUNWAY PRESSURE ALTITUDE AND TEMPERATURE.
9. FILL OUT FORM 1.

THOROUGH PREPARATION ASSURES A BETTER MISSION

II. In the Air

A. DURING CLIMB (Same as on training qualification mission)

1. REMOVE ARMING PINS.
2. PUT ON HEAD-SET AND THROAT MIKE.
3. TURN ALL NECESSARY SWITCHES *ON*.
4. TURN AUTOPILOT MASTER SWITCH *ON* (SECOND BOMBARDIER OR PILOT).
5. RECORD TEMPERATURE AT EVERY 1,000 FT.
6. PUT ON OXYGEN MASK AND ADJUST SUPPLY.
7. COMPUTE BOMBING ALTITUDE.
8. COMPUTE TRUE AIRSPEED.
9. SET DATA IN SIGHT (D. S. AND TRAIL).

B. AT FLIGHT LEVEL (Same as on training qualification mission)

1. CHECK BOMBING ALTITUDE AND TRUE AIRSPEED COMPUTATIONS.

2. CHECK DATA SET IN SIGHT (D. S. AND TRAIL).

3. OPEN BOMB BAY DOORS.

4. ENGAGE AND ADJUST AUTOPILOT (SECOND BOMBARDIER OR PILOT).

5. LEVEL STABILIZER.

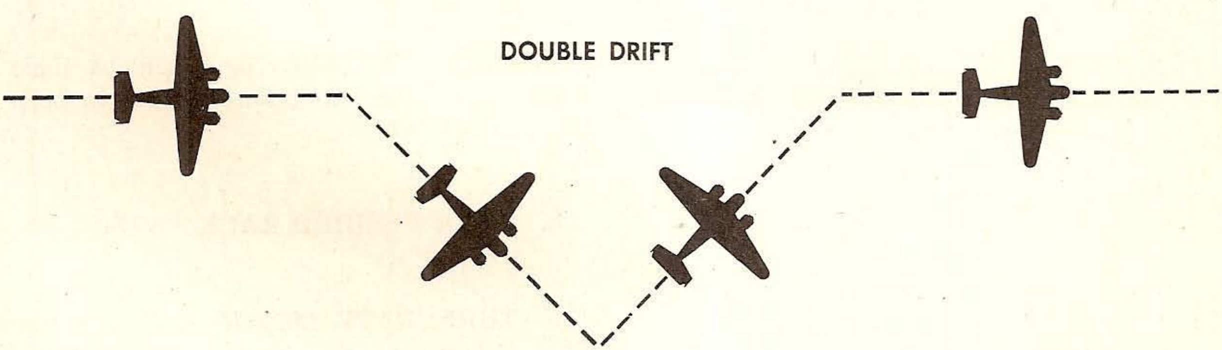
6. SOLVE FOR AND PRE-SET DRIFT AND DROPPING ANGLE. Find your actual wind at bombing altitude by either taking a double drift using the E-6B or a trial run in order to set up AB computer.

7. PREPARE BOMBSIGHT FOR BOMBING APPROACH. Pre-set the known drift and dropping angle for the heading on which you will make the approach.

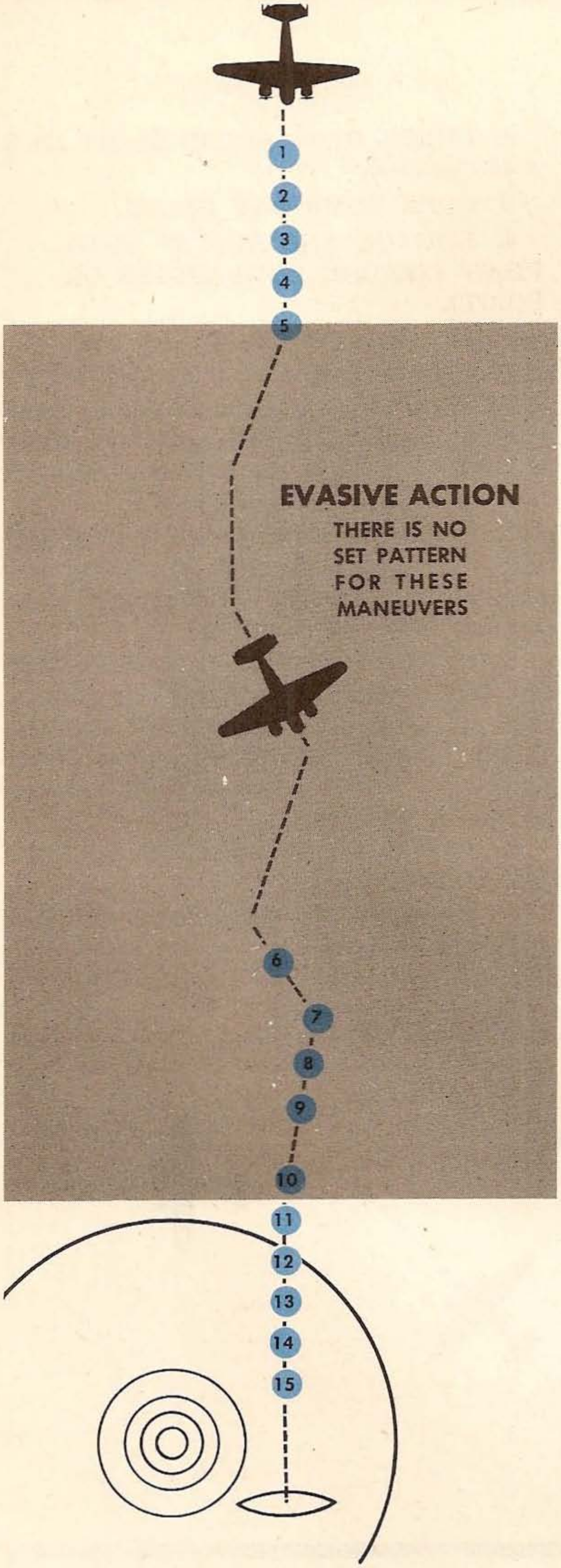
8. ORIENT YOURSELF IN RELATION TO THE TARGET. Knowing your position, you will be able to recognize the predetermined initial point. This will enable you to start your evasive action and plan your approach to the target.

9. PLACE BOMB RELEASE HANDLE TO *SELECT*.

10. BE SURE INSTRUCTOR'S CUT-OFF SWITCH IS *ON*.



C. BOMBING APPROACH



1. **PILOT SIGNALS YOUR SHIP AT THE INITIAL POINT.** The pilot signals you at this point so you may start evasive action. Plan ahead your expected maneuvers into the target.

2. **UNCAGE GYRO.** If the airplane is on autopilot and you are directing its flight, uncage the gyro. If the pilot is doing the evasive action maneuvers leave the gyro caged to prevent the possibility of tumbling it.

3. **DISENGAGE AUTOPILOT CLUTCH.** This is done in order to control the airplane by the autopilot clutch arm for the evasive action maneuvers.

4. **SIGNAL PILOT.** You signal the pilot to tell him that you understand and are starting the approach.

5. **DO EVASIVE ACTION.** On the maneuvers, limit the turns from 5° to 15° and the time straight and level from 10 to 20 secs.

6. **LEVEL GYRO.** Level the gyro on a straight leg of the evasive action prior to the last turn onto the run.

7. **PICK UP TARGET.** Begin to limit turns of the evasive action in order to keep the target in view.

8. **TURN DESIRED RACK SWITCH *ON*.**

9. **TURN RATE MOTOR SWITCH *ON*.** This is done as the lateral crosshair approaches the target so you can judge the time you have left and you can start your bombing run at the proper time.

10. **PRE-SET DRIFT AND ENGAGE BOMBSIGHT CLUTCH.** When the sighting angle index drives to the position at which you should start the bombing run, pre-set the pre-determined drift for your heading and engage the bombsight clutch.

11. **TURN ON TO TARGET AND REFINE COURSE.** This is done by sighting over the trail rack and turning the turn knob until it is aligned with the target. You should have only small adjustments to make on the course synchronization.

12. **PUT LATERAL CROSSHAIR ON TARGET AND REFINE RATE.** You should have only small adjustments to make on the rate synchronization.

13. **HOLD UP THE RELEASE LEVER.**

14. **REFINE COURSE AND RATE.**

15. **SIGNAL PILOT WHEN *BOMB IS AWAY*.** This is done, in combat, so the pilot can turn and get out of the target area immediately.

D. AFTER BOMB RELEASE

(Same as on training qualification mission)

1. PUT RELEASE LEVER DOWN.
2. TURN RACK SWITCH *OFF*.
3. CHECK SYNCHRONIZATION, ALTITUDE AND AIRSPEED.
4. CHECK POSITION OF BUBBLES AND CAGE GYRO.
5. ANALYZE BOMB RELEASE (CALL SHOT).
6. TURN RATE MOTOR SWITCH *OFF*.
7. NOTE DRIFT AND COMPASS HEADING.
8. WATCH FOR BOMB IMPACT.

E. AFTER BOMB IMPACT

(Same as on training qualification mission)

1. NOTE TIME AND POINT OF IMPACT.
2. ENGAGE AUTOPILOT CLUTCH AND DISENGAGE BOMBSIGHT CLUTCH.
3. SIGNAL PILOT *READY TO TURN*.
4. NOTE TANGENT OF DROPPING ANGLE.
5. RECORD ALL DATA ON 12-C FORM.
6. PREPARE FOR NEXT RUN.

F. AFTER LAST BOMB IMPACT

(Same as on training qualification mission)

1. SIGNAL PILOT *BOMBING IS COMPLETED*.
2. CLOSE BOMB BAY DOORS.
3. PLACE BOMB RELEASE HANDLE TO *SAFE* POSITION.
4. TURN BOMBARDIER'S CONTROL PANEL SWITCHES *OFF*.
5. TURN BOMBSIGHT SWITCHES *OFF*.
6. SET TRAIL ARM AT ZERO.
7. SET DISC SPEED DRUM AT MINIMUM SETTING.
8. COVER BOMBSIGHT.
9. FILL OUT 12-C FORMS AS COMPLETELY AS POSSIBLE.

III. After Landing

A. AT AIRPLANE

(Same as on training qualification mission)

1. CHECK ENTRY IN FORM 1.
2. FILL OUT REPORT ON ANY MALFUNCTION OF BOMBING EQUIPMENT.

B. TURN IN EQUIPMENT

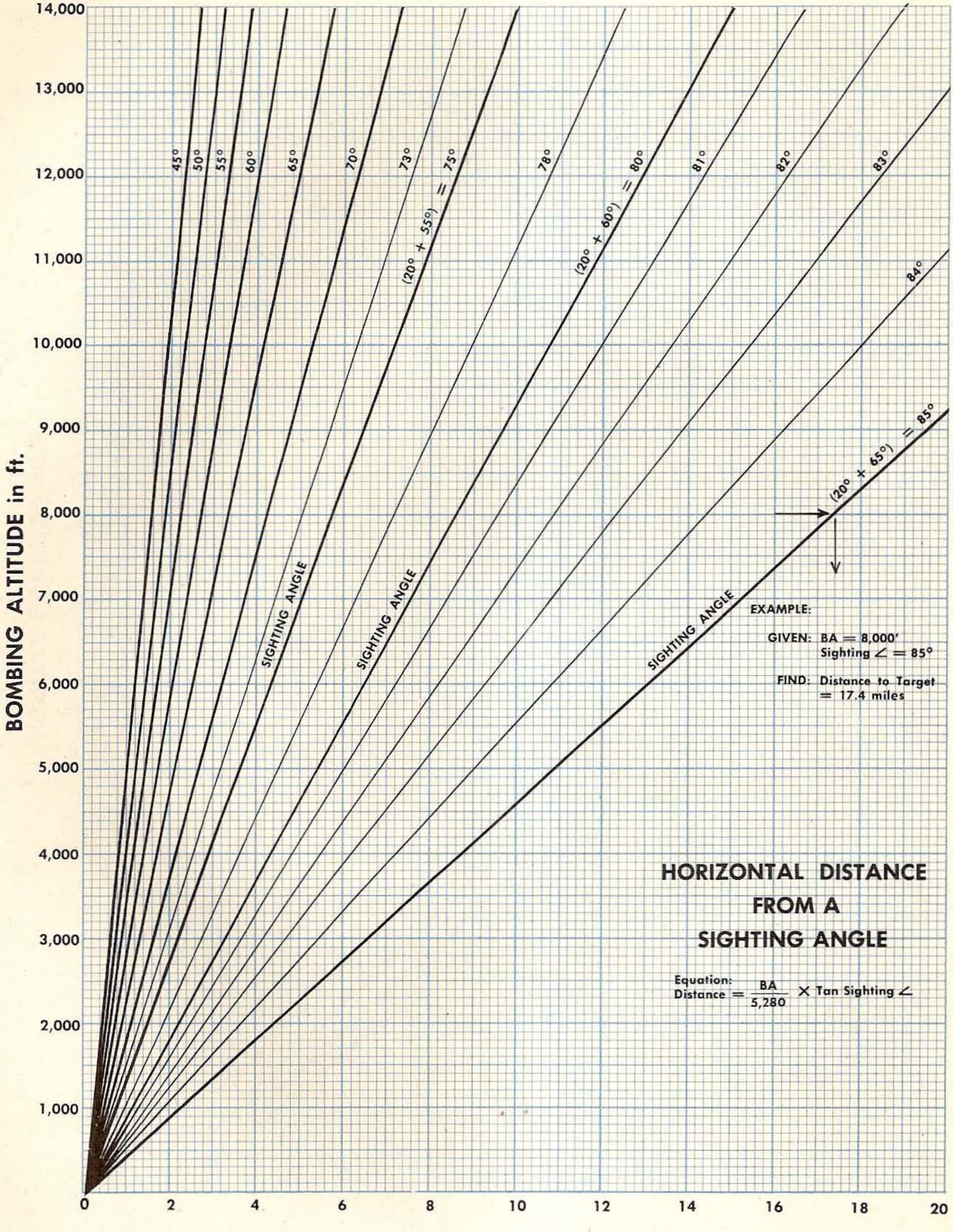
(Same as on training qualification mission)

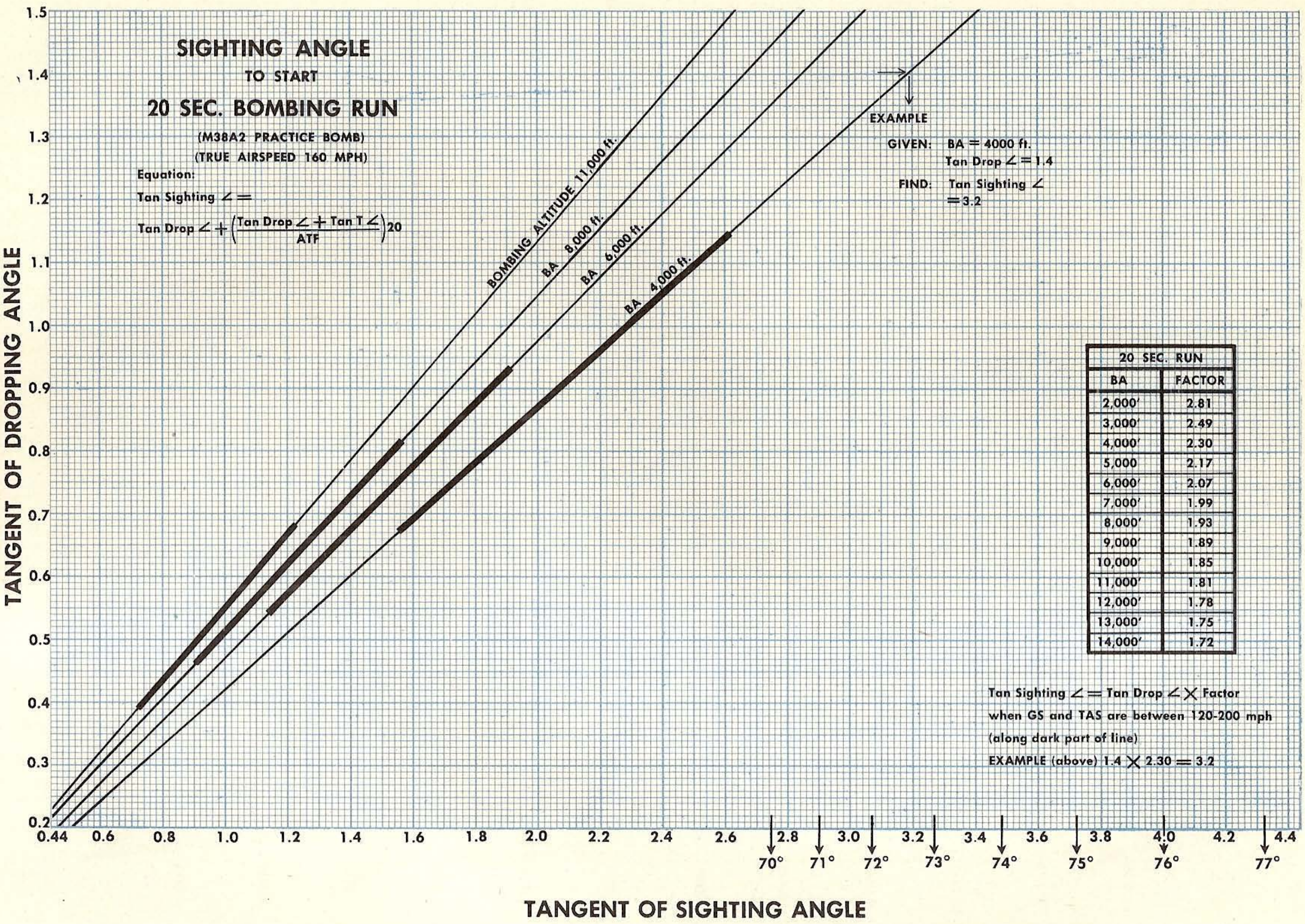
1. PARACHUTE.
2. CAMERA.
3. TACHOMETER.
4. ABC TANGENT SCALES.
5. BOMBSIGHT TIME.

C. CRITIQUE

(Same as on training qualification mission)

1. ANALYZE MISSION WITH INSTRUCTOR.
2. TURN IN ALL REPORTS AND FORMS.


HORIZONTAL DISTANCE FROM A SIGHTING ANGLE
Equation: Distance = BA / 5,280 × Tan Sighting ∠
EXAMPLE:
GIVEN: BA = 8,000′ Sighting ∠ = 85°
FIND: Distance to Target = 17.4 miles
BOMBING ALTITUDE in ft.
HORIZONTAL DISTANCE in miles
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2
4
6
8
10
12
14
16
18
20
45°
50°
55°
60°
65°
70°
73°
(20° + 55°) = 75°
78°
(20° + 60°) = 80°
81°
82°
83°
84°
(20° + 65°) = 85°
SIGHTING ANGLE
SIGHTING ANGLE
SIGHTING ANGLE



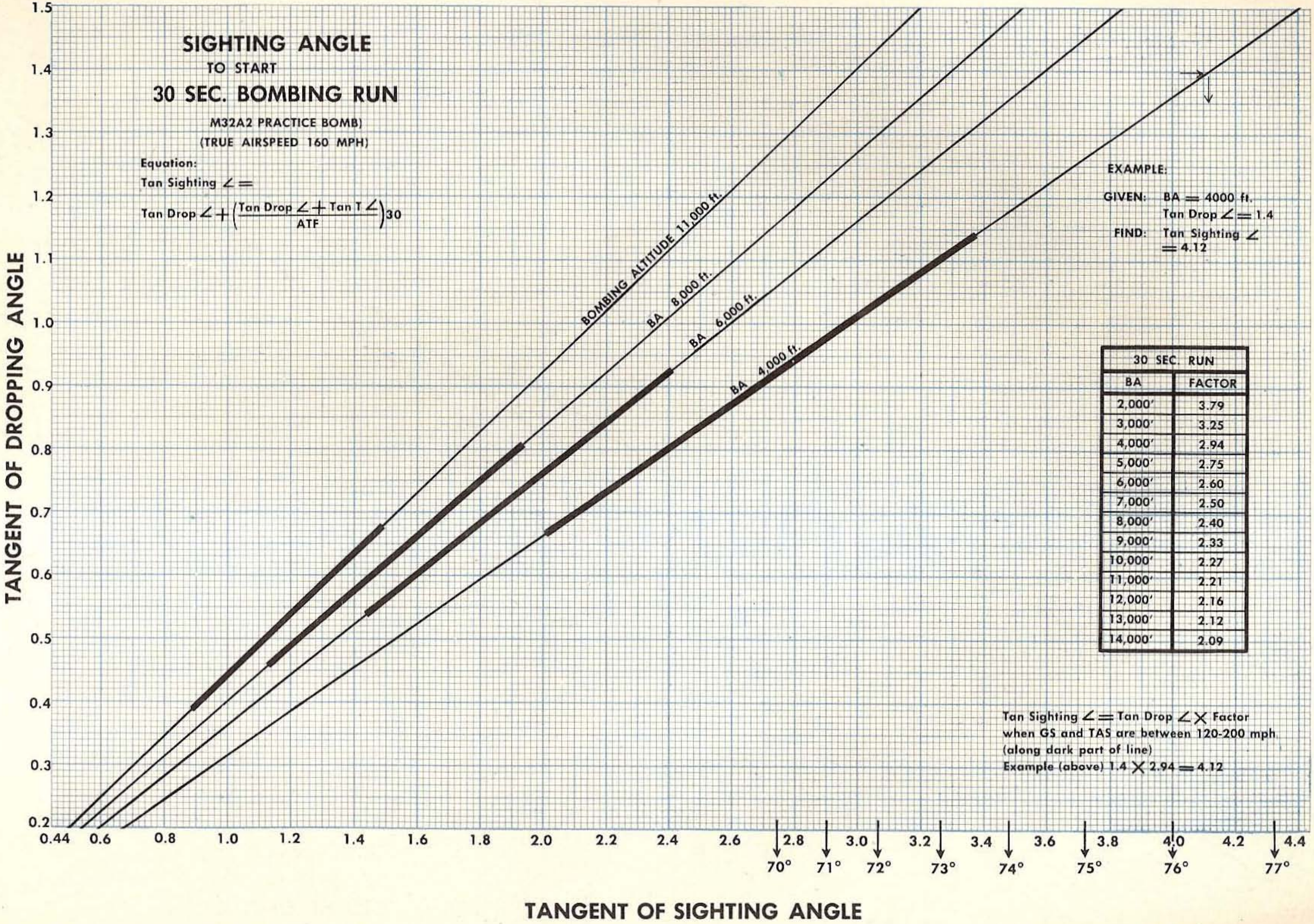
20 SEC. RUN	
BA	FACTOR
2,000′	2.81
3,000′	2.49
4,000′	2.30
5,000	2.17
6,000′	2.07
7,000′	1.99
8,000′	1.93
9,000′	1.89
10,000′	1.85
11,000′	1.81
12,000′	1.78
13,000′	1.75
14,000′	1.72

SIGHTING ANGLE
TO START
30 SEC. BOMBING RUN

M32A2 PRACTICE BOMB)
(TRUE AIRSPEED 160 MPH)

Equation:
Tan Sighting ∠ =

$$\text{Tan Drop}\angle + \left(\frac{\text{Tan Drop}\angle + \text{Tan T}\angle}{\text{ATF}}\right)30$$



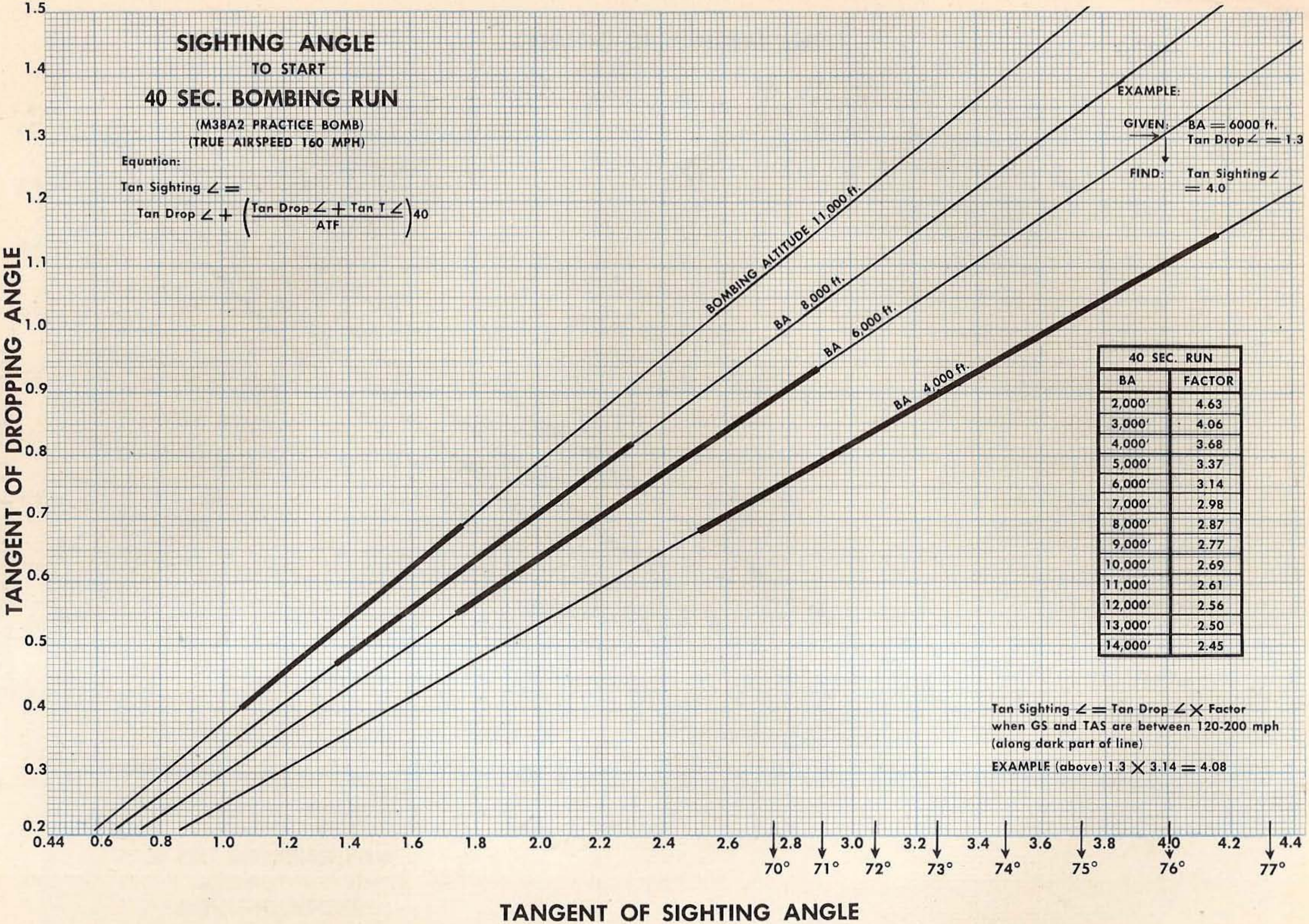
EXAMPLE:

GIVEN: BA = 4000 ft.
Tan Drop ∠ = 1.4

FIND: Tan Sighting ∠
= 4.12

30 SEC. RUN	
BA	FACTOR
2,000′	3.79
3,000′	3.25
4,000′	2.94
5,000′	2.75
6,000′	2.60
7,000′	2.50
8,000′	2.40
9,000′	2.33
10,000′	2.27
11,000′	2.21
12,000′	2.16
13,000′	2.12
14,000′	2.09

Tan Sighting ∠ = Tan Drop ∠ × Factor
when GS and TAS are between 120-200 mph
(along dark part of line)
Example (above) 1.4 × 2.94 = 4.12



40 SEC. RUN	
BA	FACTOR
2,000′	4.63
3,000′	4.06
4,000′	3.68
5,000′	3.37
6,000′	3.14
7,000′	2.98
8,000′	2.87
9,000′	2.77
10,000′	2.69
11,000′	2.61
12,000′	2.56
13,000′	2.50
14,000′	2.45

CONSTANTS AND CONVERSION FACTORS

5300—The disc speed constant for the M-Series Bombsights.

7773—The constant used in solving for groundspeed in mph, $\left(\frac{5300 \times 88}{60}\right)$

18—The number of mils used in determining bubble error of one degree.

88/60—Factor used to change mph to ft/sec. You multiply mph by 88/60 to find ft/sec.

1.15—Factor used to convert knots to mph. You multiply knots by 1.15 to find mph.

EQUATIONS

$$WR = GS\ (ft/sec) \times ATF$$

$$AR = WR - T$$

$$\text{Tan WR}\angle = \frac{WR}{BA}$$

$$\text{Tan AR}\angle = \frac{AR}{BA} = \text{Tan Drop}\angle$$

$$\text{Tan T}\angle = \frac{\text{T (in ft.)}}{BA} = \frac{\text{T (in mils)}}{1{,}000}$$

$$\text{Trail (in ft.)} = \text{T (in mils)}\ \frac{BA}{1{,}000}$$

$$DS = \frac{5{,}300}{ATF}$$

$$\text{GS (ft./sec.)} = \frac{DS \times BA \times \text{Tan WR}\angle}{5300}$$

$$\text{GS (mph)} = \frac{DS \times BA \times \text{Tan WR}\angle}{7773}$$

$$CT = T \times \text{Sin drift angle}$$

$$RCCT = T\ (1 - \text{Cos drift angle})$$

$$\frac{\text{DS Error}}{DS} = \frac{\text{Range Error (in mils)}}{\text{Tan WR}\angle \times 1{,}000}$$

$$\text{Tan Sighting}\angle = \text{Tan Drop}\angle + \left(\frac{\text{Tan WR}\angle}{ATF}\right)\text{Time of Run}$$

Glossary of Terms

Actual time of fall (ATF)—The time lapse between the release and impact of the bomb.

Actual range (AR)—See Range, actual.

Actual range angle (AR∠)—See Angle, actual range.

Airspeed compression error—See Error, airspeed compression.

Airspeed, calibrated (CAS)—The reading of the airspeed indicator, corrected for instrumental and installation errors.

Airspeed, indicated (IAS)—The reading of the airspeed indicator.

Airspeed, true (TAS)—The true speed of the airplane relative to the air.

Altitude, bombing (BA)—The actual height of the airplane above the target.

Altitude, calibrated (CA)—The reading of the altimeter corrected for instrumental and installation errors.

Altitude, flight level pressure (FLPA)—The pressure measurement in feet that the airplane is above the standard datum plane.

Altitude, indicated (IA)—The reading of the altimeter.

Altitude, mean pressure (MPA)—The average between the target pressure altitude and the flight level pressure altitude.

Altitude, pressure (PA)—The reading of the altimeter corrected for instrumental and installation errors when 29.92 is set on the pressure scale. The pressure measurement in feet above the standard datum plane.

Altitude, pressure above target (PA above T)—The pressure measurement in feet of the column of air between the airplane and the target.

Altitude, pressure variation (PA Var.)—The pressure measurement in feet between sea level and the standard datum plane.

Altitude, runway pressure (RPA) — The pressure measurement in feet that the runway is above the standard datum plane.

Altitude, target pressure (TPA)—The pressure measurement in feet that the target is above the standard datum plane.

Altitude, true (TA)—The actual height of the airplane above sea level.

Angle, actual range (AR∠)—The angle which subtends the actual range of bomb.

Angle, drift—The angle between the true heading and the true course.

Angle, drift correction—The angle added to or subtracted from the airplane's true course to obtain true heading.

Angle, dropping (Drop ∠)—The angle between the line of sight and the vertical reference at the instant the bomb is released.

Angle, range (R∠)—The angle between the line of sight and the true vertical. At the instant of release, this angle differs from the dropping angle by the amount the vertical reference is out of the true vertical.

Angle, sighting—The angle between the line of sight and the vertical reference at any instant.

Angle, tangent of dropping (Tan drop ∠)—Actual range divided by bombing altitude.

Angle, tangent of trail (Tan T ∠)—Trail in feet divided by bombing altitude.

Angle, tangent of whole range (Tan WR ∠)—Whole range divided by bombing altitude.

Angle, trail (T ∠)—The angle which subtends trail on the ground.

Angle, whole range (WR∠)—The angle which subtends whole range.

Apparent precession—See Precession, apparent.

Area target—See Target, area.

Axis, pitch (lateral)—An imaginary line running laterally through the center of gravity of the airplane, parallel to a straight line through both wing tips. Hence, the axis about which the airplane pitches.

Axis, roll (longitudinal)—An imaginary line running fore and aft through the center of gravity of the airplane, parallel to the axis of the propeller or thrust line. Hence, the axis about which the airplane rolls.

Axis, yaw (vertical)—An imaginary line running vertically through the center of gravity of the airplane, at right angles to the pitch and roll axes. Hence, the axis about which the airplane turns or yaws.

Barometric pressure (Corrected to sea level conditions) (BP Corr.)—See Target barometric pressure.

Bombing altitude (BA)—See Altitude, bombing.

Bombing approach—The flight of the bombing airplane or formation from the beginning of attack upon a specific target until the beginning of the straight bombing run.

Bombing, fixed angle (Non-synchronous)—That method of bombing where the drift angle and dropping angle are pre-determined and set into the sighting mechanism. Sometimes called low altitude bombing.

Bombing, synchronous—That method of bombing where the bombsight is used to determine and set up the drift angle and dropping angle by synchronizing. Sometimes called high altitude bombing.

Bombing run—The brief period of flight of the bombing airplane or formation immediately preceding bomb release.

Bombing, train—The release of two or more bombs in succession from the same airplane, with a single sighting operation, and with the desired interval in feet between successive bombs.

Calibrated airspeed (CAS)—See Airspeed, calibrated.

Calibrated altitude (CA)—See Altitude, calibrated.

Circular error (CE)—See Error, circular.

Collision course—The true course made good by the airplane when passing directly over the target.

Compass heading (CH)—See Heading, compass.

Compression error, airspeed—See Error, airspeed compression.

Course synchronization—The process of adjusting the course knobs of the bombsight and directing the airplane so that the fore and aft crosshair remains centered on the desired object as the airplane flies toward it. If crosshair is moving off to the right the synchronization is off to the right.

Course, true (TC)—The direction of flight over the surface of the earth, expressed as an angle with respect to true north.

Crosstrail (CT)—The distance upwind that the airplane must fly in order for a bomb to hit the target.

Deflection error (DE)—See Error, deflection.

Deviation (Dev.)—The angle between a line to magnetic north and a line passing through a compass needle.

Disc speed (DS)—The speed in rpm at which the disc rotates in the M-Series bombsight. The time factor, arrived at by dividing ATF into 5,300.

Drift angle—See Angle, drift.

Drift correction angle—See Angle, drift correction.

Dropping angle (Drop ∠)—See Angle, dropping.

Error, airspeed compression (Temperature)—The increase in the indication of the free air temperature gage caused by air compression and friction on the case around the sensitive element.

Error, circular (CE)—The radial straight line distance of the bomb impact to the center of the target.

Error, deflection (DE)—The distance of the bomb impact right or left of the target's center.

Error, installation—The error in the airplane instrument due to the location and installation of its units.

Error, instrument—The error inherent in the instrument itself and arising in the manufacture of the instrument.

Error, range (RE)—The distance of bomb impact over or short of target center.

Extended vision—The increase in the sighting angle available with M-Series bombsights when you rotate the extended vision knob. (20° in the M-7 and M-9).

Fixed target—See Target, fixed.

Fixed angle bombing—See Bombing, fixed angle.

Flight level pressure altitude (FLPA)—See Altitude, flight level pressure.

Flight level temperature (FL Temp.)—See Temperature, flight level.

Groundspeed (GS)—Actual speed relative to the earth's surface.

Heading, compass (CH)—The magnetic heading with deviation applied.

Heading, magnetic (MH)—The true heading with variation applied.

Heading, true (TH)—The direction of the longitudinal axis of the airplane, expressed as an angle with respect to true north.

Indicated airspeed—See Airspeed, indicated.

Indicated altitude—See Altitude, indicated.

Induced precession—See Precession, induced.

Initial point (IP)—The point on the ground over which you will start your bombing approach.

Installation error—See Error, installation.

Instrument error—See Error, instrument.

Lateral axis—See Axis, pitch.

Line of sight—The imaginary straight line from the bombsight optics to a point on the ground lying under the intersection of the crosshairs.

Longitudinal axis—See axis, roll.

Magnetic heading (MH)—See Heading, magnetic.

Magnetic north (MN)—See North, magnetic.

Maneuvering target—See Target, maneuvering.

Mean pressure altitude (MPA)—See Altitude, mean pressure.

Mean temperature—See Temperature, mean.

Mil (m̸)—An angle whose tangent is 0.001. It subtends a distance on the ground equal to 1/1,000 of the bombing altitude.

Moving target—See Target, moving.

Non-synchronous bombing — See Bombing, fixed angle.

North, true (TN)—The direction to the north pole from any given point on the earth's surface.

North, magnetic (MN)—The direction of the magnetic north pole from any given point on the earth's surface.

Pitch axis—See Axis, pitch.

Precession, apparent—The movement of the earth in relation to the gyro.

Precession, induced—The movement of the gyro in relation to the earth caused by applying an external force to the gyro.

Preflight inspection—A test of the functioning efficiency of equipment, such as the bombsight, before the take-off on any bombing mission.

Pre-set trail—The trail that remains set into the sight when the trail arm is on zero.

Pressure altitude (PA)—See Altitude, pressure.

Pressure altitude above target (PA above T)—See Altitude, pressure above target.

Pressure altitude variation (PA Var.)—See Altitude, pressure variation.

Point target—See Target, point.

Range, actual (AR)—The horizontal distance traveled by the bomb during ATF.

Range angle (R ∠)—See Angle, range.

Range component of crosstrail (RCCT)—The error over which results when there is a crosswind, because the bombsight measures trail along the course rather than the heading.

Range error (RE)—See Error, range.

Range synchronization—The process of adjusting the rate knobs of the bombsight so that the lateral crosshair remains centered on the desired object as the airplane flies toward it.

Thus you solve for groundspeed. If the crosshair is moving off to the rear the synchronization is said to be fast.

Range, whole (WR)—The horizontal distance traveled by the airplane during ATF.

Release point—The point in space where the bomb is released from the airplane.

Roll axis—See Axis, roll.

Runway pressure altitude (RPA)—See Altitude, runway pressure.

Sighting angle—See Angle, sighting.

Speed of Closure—The speed at which the distance between two objects is closed.

Standard datum plane (SDP)—The level where the barometric pressure is exactly 29.92.

Standard lapse rate—A temperature decrease of 2°C for each 1,000 ft. increase in altitude.

Synchronization (course-range)—See Course or range synchronization.

Synchronous bombing—See Bombing, synchronous.

Tangent of dropping angle (Tan Drop ∠)—See Angle, tangent of dropping.

Tangent of trail angle (Tan T ∠)—See Angle, tangent of trail.

Tangent of whole range angle (Tan WR ∠)—See Angle, tangent of whole range.

Target, area—A target which requires a distribution of bombs of the proper size throughout the area in which the definite vulnerable points lie.

Target, fixed—A target which has no motion relative to the earth.

Target, maneuvering—A target which moves with accelerated motion (changing speed or direction or both).

Target, moving—A target which moves with constant speed and direction.

Target, point—A target which, to be destroyed, requires either a direct hit by a bomb of the proper size or a hit within a limited distance therefrom.

Target barometric pressure (corrected to sea level conditions) (TBP Corr.)—The weight of the column of air above the target measured in inches of mercury and corrected to sea level conditions.

Target pressure altitude (TPA)—See Altitude, target pressure.

Target temperature (T Temp.)—See Temperature, target.

Temperature, flight level (FL Temp.)—The free air temperature in degrees centigrade that exists at flight level.

Temperature, mean—The average between the target temperature and the flight level temperature.

Temperature, target (T Temp.)—The free air temperature in degrees centigrade that exists at the target.

Trail—The horizontal distance that the bomb lags behind the airplane because of air resistance.

Trail angle (T ∠)—See Angle, trail.

Train bombing—See Bombing, train.

Trajectory—The arched path of the bomb through the air.

True airspeed (TAS)—See Airspeed, true.

True altitude (TA)—See Altitude, true.

True course (TC)—See Course, true.

True heading (TH)—See Heading, true.

True north (TN)—See North, true.

Uncage—To unlock the gyro from the sight case by use of the caging knob.

Variation (Var.)—The angle between lines to true north and magnetic north.

Vector—A straight line which proceeds in a given direction, and whose length shows distance traveled in a given time.

Vertical axis—See Axis, yaw.

Whole range (WR)—See Range, whole.

Whole range angle (WR ∠)—See Angle, whole range.

Wind—A moving air mass designated by the direction from which it comes.

Yaw axis—See Axis, yaw.

THE GUGLER LITHO. CO.
MILWAUKEE, WIS., SEPT. 1944, 16M

Notes