MA-8 20 Jan 1944

NAVIGATIONAL USES OF THE NORDEN BOMBSIGHT

In the not too distant past, there grew up among the commissioned personnel of the Army Air Forces an intense feeling of rivalry over the relative merits of their respective positions. Out of this rivalry sprang such terms as "chauffeur", when referring to a pilot; "high-altitude bookkeeper", the name for the navigator; and the bombardier was someone possessed of a morbid propensity towards dropping things.

Combat experience, as well as a clearer understanding of individual duties, has done a great deal towards breaking down whatever prejudices had been built up. It was no longer "ten men in a ship". Rather, it became one ship with one crew. Multiply that by all the ships and all the crews operating as units of our far-flung Air Force and you begin to realize the extent of the problem that was faced, met, and solved.

Even more recently, it became evident that the War Department had gone even a step further. If the duties of individual crew members were such that one's began only as the other's was completed - was it not more feasible to combine both jobs? Thus was born the Bombardier-Navigator, an integral part of every combat crew. In our medium bombardment ships there is only one man. In some of our heavy bombardment aircraft there are two such qualified men - each qualified to do either or both duties if called upon.

Yet there are still some of our bombardment aircraft that carry a navigator and a bombardier. Each of these men is rated only in his particular specialty.

It is for these men - specifically, it is for those navigators - that this paper is directed.

Your crew member has an instrument designed to blast any designated target to hell. By virtue of its design, it contains features that can be of inestimable value to you in your position as navigator. Learn those features. Be adept in their use - so that your function as a part of smooth running teams may be performed well.

Learn the features of the BOMBSIGHT.

Understand what the BOMBSIGHT can do for you.

Use this knowledge and this understanding.

Use it as a check on your own instruments.

Use it if, and when, your own instruments fail you.

Don't pass it off as a gadget that drops things, because its advantages to you are limitless.

To list a few of the things that can be accomplished with the use of a sight:

1. Read drift.

2. Determine ground speed.

3. Calibrate Air Speed Meter.

4. Swing compass.

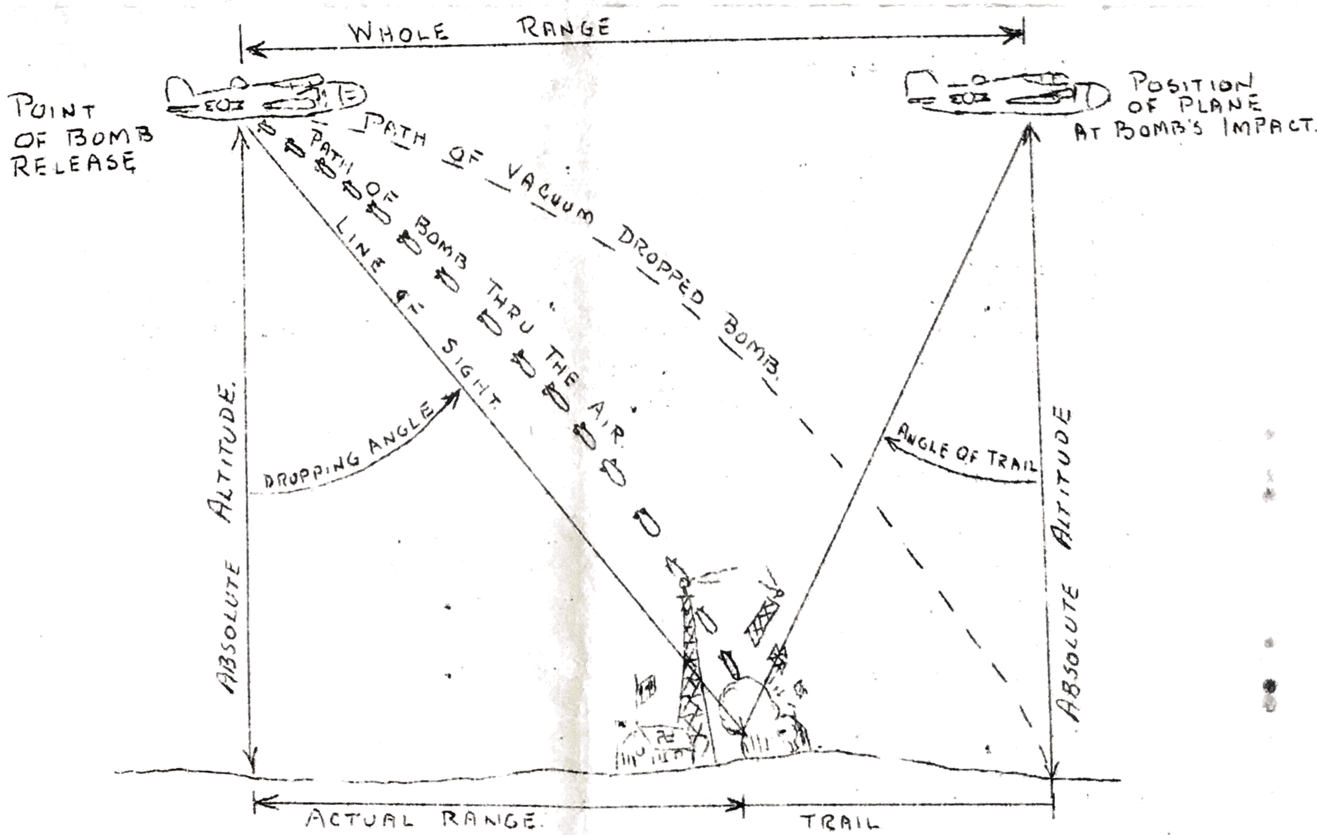
5. Check precession on gyro.

6. Determine relative bearings (this feature is limited).

Let us then look into the matter with a wholesome respect for a precision instrument, since the navigator, as you have all come to realize, is only as good as any of his instruments.

BOMBING THEORY

No attempt will be made here to go too deeply into the theory of the bombsight. We will, however, take up some necessary definitions and diagrams in order that we understand just what the bombsight actually does for us.



If we were to consider conditions in a vacuum, a bomb released from any altitude would hit the ground at a point directly beneath the airplane. As regards the time of fall - from any designated altitude a bomb dropped from rest or dropped from a moving body, will take the same time to reach the ground. (A feather will fall as quickly as a steel ball.)

However, if we were to consider conditions outside a vacuum - where the bomb is falling through air, it would lag behind the ship upon impact. This distance on the ground is called trail. A bomb falling through air will take longer to hit if dropped from a moving body, than it would if it were dropped from rest. This is due to friction mostly and the fact that the bomb is passing through more atmosphere. Bombing tables and the bombsight itself take care of this factor.

Let us consider then just the two aspects of the bombing problem. The bombing problem can be summed up by saying that it consists of determining at what point in the air a bomb should be released in order to get a hit on the target. For any one heading, there is only one spot in the air at which a bomb can be released and hit the target for any given altitude, air speed, kind of bomb and ground speed. If we can accurately find that spot, a hit can be secured. To find that spot, the problem must be broken down into a range problem and a course problem.

The range problem consists of determining how near the target a plane should be before the bomb is released. It is accomplished through use of the horizontal (or rate) cross hair. For the bombsight to solve accurately this bombing problem, it is necessary that the plane be flying level at the instant of release. If the plane is in a climb at the instant of release, the bomb will fall over the target. If the plane is in a glide at the instant of release, the bomb will fall short of the target. This is true in synchronous bombing. The reverse is true in fixed angle bombing.

The course problem consists of determining the course to be flown in cases where the wind direction and the heading of the airplane are at an angle to each other. The vertical (or course) hair is used to solve this phase of the bombing problem. In determining the correction for wind, if we were to overcorrect, our bomb would fall over and upwind; if we were to undercorrect, or not correct enough, our bomb would fall short and down wind.

The error in range (falling over and short) is a result of the error in course. Therefore, as far as actual procedure in bombing is concerned, bombardiers kill their course first and then synchronize for rate.

Mention has been made earlier of both synchronous and fixed angle bombing. Fixed angle bombing is used for altitudes below 2000 feet absolute because the relative speeds or the apparent rate of approach of the target is too fast for both the sight and the bombardier. Synchronous bombing is used at all altitudes above 2000 feet.

In synchronous bombing by synchronizing the rate hair upon an object on the ground, the sight is determining a ground speed and a dropping angle. In fixed angle bombing you work the problem in reverse and determine a ground speed (usually by double drift) and consult the tables to find the dropping angle which is pre-set into the sight.

USING THE SIGHT TO READ DRIFT

1. Using the Bombsight as a Driftmeter

In using the sight as a driftmeter it is practical and more accurate to use the sight with the bombsight running and the bombsight gyro uncaged. Optics will be set on any convenient sighting angle and telescope clutch will be engaged to hold optics at desired sighting angle. To determine drift on course on any heading desired, the navigator will manually swing the sight with course knobs and observe the fore and aft cross hair through optics. When the sight is indicating the drift present, objects on the ground will track the fore and aft hair or parallel it. When this condition occurs, drift is killed with the bombsight and can be read directly off the drift scale. Drift is read as L or R, not Drift Correction. Drift by this method can be determined either with the bombsight caged or uncaged. However, in rough air a more accurate drift can be determined with bombsight gyro uncaged so the optics will be stabilized.

The bombsight has two gyros built into it. A vertical gyro to take care of PITCH and ROLL and a horizontal gyro to take care of yaw. It should be mentioned here that a vertical gyro has its spin axis in the vertical plane and a horizontal gyro has its spin axis in the horizontal plane. However, the wheel of the vertical gyro spins in the horizontal plane while the wheel of the horizontal gyro spins in the vertical plane.

If drift is taken with the gyro caged, it is not necessary to have the bombsight running.

2. Drift by Synchronization

Another method of determining drift is by synchronization or killing drift by use of the course knobs. In this method, the pilot follows the PDI or Pilot Direction Indicator. The PDI is zeroed with the left hand. You then uncage the bombsight gyro and swing the sight on any convenient object in view, observing through the optics, and setting the fore and aft hair on the object. Then clutch in the directional clutch (this connects the bombsight to the stabilizer and gives the bombsight stabilization in azimuth) and release the secondary clutch.

Note the direction the fore and aft hair is moving off the object and correct accordingly by double gripping the course knobs, trying to kill apparent motion. As corrections are put in, they are relayed to the pilot through the PDI, and he corrects accordingly, crabbing the ship into the wind. When apparent motion of fore and aft hair is stopped, drift is killed and cross hair may be placed back on the object with the outside knob. If the hair stays on the object, the drift is killed and may be read on the drift scale.

This latter method, drift by synchronization, is perhaps the better of the two methods. In the first place it allows for greater accuracy in determining the drift because of the refinements that can be applied to the reading. Then too, if this procedure is followed, it is not then necessary to call up the pilot and correct for the amount of drift because by following the PDI during the drift reading procedure he has done just that - corrected it as you were cranking it in.

GROUND SPEED BY BOMBSIGHT

The determination of ground speed is another function performed by the bombsight. The procedure in determining it is as simple as that of reading drift.

In this operation, we are using the rate (or horizontal) hair of the sight. It is necessary only to synchronize this hair with some object on the ground. When the hair and the object on the ground remain in coincidence, we have set into the sight a certain dropping angle. This angle is read from the sight opposite the left index. With this dropping angle, we enter our tables and read off the corresponding ground speed. (The table may be found on the last page of this report.) Before synchronization is attempted, all switches on the sight are turned on and sight is allowed to warm up. Disc speed is set into sight by dividing the navigational constant 1,239,200 by the absolute altitude.

In order to understand what makes such a seemingly simple operation possible, let us again refer to our original diagrams used to illustrate the theory of bombing.

In the diagram:

1. Whole Range was defined as the actual distance the plane travels from the point of release until the bomb hits the ground.

2. Actual time of fall is the time in seconds that it would take for a bomb to hit from any specified altitude.

Using then a simple Rate, Time and Distance formula:

$$\text{Ground Speed} = \frac{\text{Whole Range}}{\text{A T F}}$$

Let us then substitute into this formula, values that we know or can determine quickly:

1. Whole range is equal to altitude X tangent of dropping.

2. A T F may be computed in many ways:

   a. On the basis of the gear ratios set into the B.S. mechanism, if we were to divide the disc speed (RPM of the disc) into the navigational constant 5300, we would get our A T F.

   $$\text{A T F} = \frac{5300}{\text{DS}}$$

   Using this method, DS is determined from tables where the entering arguments are absolute altitude and TAS.

b. There are specially designed tables (for each type and weight of bomb) which give the actual time of fall in seconds. The entering arguments in this table are Absolute Altitude and TAS.

c. In case one does not have A T F tables and he wishes to figure out his disc speed to preset in the sight, the same results can be gotten using the navigational constant, 1,239,200, and dividing it by the absolute altitude in order to determine actual time of fall.

Let us then go back to our formula and see what we have derived thus far.

$$\text{Ground Speed} = \frac{\text{Abs. Alt.} \times \text{tangent of dropping}}{\text{ATF} \left\{ \begin{array}{l} \text{Time in} \\ \text{secs. from} \quad \text{or } \frac{5300}{DS} \\ \text{tables} \end{array} \right\}} \times 1.4667$$

The 1.4667 is put into the formula only as a conversion factor since our answer without it would come out in feet per second. 1.4667 is used as the conversion factor from feet per second to miles per hour.

That is the formula upon which is based the attached table. So, for any dropping angle set on the sight by synchronizing the rate hair, we can read off a corresponding G/S.

CALIBRATION OF THE AIRSPEED METER

If calibrating the Air Speed Meter with the bombsight, it is not necessary to have a measured course, since ground speed can be determined without a timepiece. What is needed is a straight road of known surveyed altitude. The theory is still the same. A run with the wind and one against the wind for every 10 or 15 miles difference in air speed through the desired range.

As soon as lateral hair comes on the road with extended vision out and bubbles leveled, synchronize for rate and continue synchronization to the vertical for extreme accuracy. Read the dropping angle; refer to the table; and record the G/S.

Also record the pressure altitude, average temperature, and the average indicated air speed held for that run. (Remember the average indicated air speed near the end of the run is the most important for that is what final synchronization was for.)

COMPASS SWINGING

The bombsight has been used successfully in compass swinging missions in conjunction with the gyro. Especially good use has been made of this instrument when swinging over the runways. Let us set up a specific problem and definite conditions in order that we might understand the procedure.

Let us say a particular air base has three runways numbered 18 and 36, 3 and 21, 10 and 28. These three runways allow us six headings that we can swing on where the bearing of the road, or in this instance, runway is definitely known. The bombsight is used in conjunction with the PDI to fly the ship directly from the runway. When the fore and aft hair of the sight is tracking the edge of the runway, then the magnetic heading of the ship is equal to the magnetic bearing of the runway. A comparison of this value with our compass heading will give us our deviation correction. Let us assume then that these are the values we determined:

MH	DC	CH
180	+1	181
360	-1	359
30	+2	32
210	-1	209
100	+4	104
280	-3	277

We now have six points of our graph and we wish to determine the intermediary ones. Let us then go back and fly over runway 3. With the bombsight running and the PDI engaged, correct the heading of the ship until fore and aft hair is again tracking the edge of the runway. At this point your compass should be reading 32. Then turn off on intermediate headings of 45, 60, 75, 90, making gentle turns not over a 20 degree bank and determine the deviation on these headings by a comparison of the directional gyro and your compass. We are now ready to come back to the heading of 100 for which we had previously determined a deviation.

If there were to be no precession in our gyro and it was giving us correct readings, then the difference between our gyro and our compass would give us a D.C. of plus four. Let us assume though that as we flew up runway 10 (making certain that our magnetic heading was 100 degrees), the difference between our D. gryo and our compass was 8 degrees. This would show 4 degrees of precession on the gyro which would have to be applied proportionately to all headings between 30 and 100 degrees.

RELATIVE BEARINGS

Relative bearings are limited by the azimuth ring which extends only 20 degrees to either side of the longitudinal axis of the ship.

REFERENCES

TM 1-250 - Precision Bombing Practice
TM 1-510 - Synchronizing
TM 1-251 - Handbook for Bombardiers
Aviation Ordnance Pamphlets No. 649, 650.

All specific information listed above as regards reading drift and determination of G/S concerns itself with the Norden sight.

For information on the Sperry sight, Instruction No-14-8035B, dated November 1942, published by Sperry Gyroscope Company, should be consulted.