ION SERIES NO. 18

ALTIMETERS. . .

How Their Readings are Affected by Temperature and Other Factors

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WEATHER BUREAU

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ALTIMETERS. . .

Altimeters have been used in airplanes since the very early days of aviation. From a relatively simple device whose accuracy sometimes left much to be desired, the barometric-type aircraft altimeter has been developed into a precision instrument that is vital to aircraft operations.

The principal use of the barometric altimeter is to give an indicated height above some reference point, usually sea level.

One may wonder "Why discuss altimeters in a series of articles on aviation weather?" The reason is that the heights shown by the barometric altimeter are determined from the air pressure, but the air pressure changes as a result of certain weather phenomena. Knowledge of ways in which altimeter readings are affected by weather conditions will help the airman to interpret intelligently what the altimeter tells him. To better understand what

Courtesy Kollsman Instrument Corporation

FIG. 1 - A TYPICAL ALTIMETER FOR AIRCRAFT.

the barometric altimeter can do, and its limitations, let us review briefly how it works.

Figure 1 shows the basic instrument, familiar to all pilots. Inside the instrument is a pressure-sensitive metal capsule from which the air has been removed and the opening sealed. This sealed metal capsule is made so it expands when the air pressure decreases and contracts when the pressure increases. This small movement is transmitted and multiplied through a linkage and gear train system which actuates the indicators on the dial.

AT ANY PARTICULAR POINT ON THE GROUND OR ALOFT, THE AIR PRESSURE DEPENDS PRINCIPALLY ON THE WEIGHT OF THE AIR ABOVE IT. IT IS THIS PRESSURE AT THE INSTRUMENT, AND THE ALTIMETER SETTING, THAT DETERMINES THE INDICATED ALTITUDE.

All barometric altimeters are calibrated with reference to an established standard relating pressure to altitude. This standard is known as the U. S. Standard Atmosphere. It assumes the sea level pressure to be 29.92 inches of mercury, and the sea level temperature 59° F. Also, it is based on a uniform rate of decrease of temperature with height of approximately 3 1/2° F per thousand feet from sea level to the stratosphere. This relationship is shown in Figure 2.

When in flight, the barometric altimeter reads correctly only when the instrument is adjusted to the prevailing local altimeter setting and the air column between the airplane and the ground satisfies the conditions set for the U. S. Standard Atmosphere. Consequently, the instrument indicates true heights.

How Pressure Changes Affect the Altimeter

Any surface weather map shows wide differences in the pressure over the country. Keeping in mind that the altimeter responds only to pressure changes, we can see from Figure 3 that these pressure changes have an important effect on the altimeter. In this illustration, we have an aircraft flying from Tampa, Florida, to

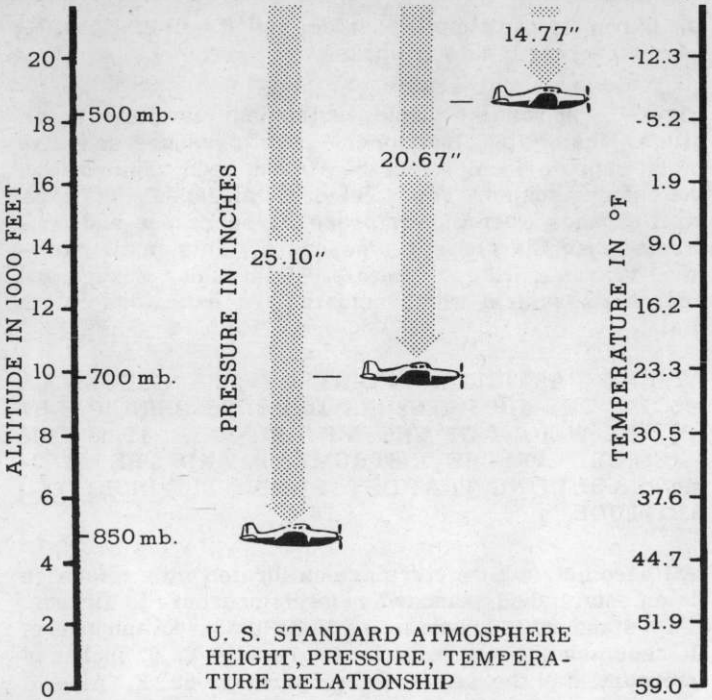

FIG. 2 - SOME FEATURES OF THE U. S. STANDARD ATMOSPHERE. NOTE UNIFORM CHANGE OF TEMPERATURE WITH HEIGHT AS SHOWN ON RIGHT MARGIN. AT 18,000 FEET, AIR PRESSURE IS APPROXIMATELY HALF THE SEA LEVEL PRESSURE.

Mobile, Alabama with the altimeter remaining set to 29.92 inches, (the altimeter setting at Tampa at departure). In this case, the altimeter setting decreases as the flight progresses. Although the pilot flies at an indicated altitude of 500 feet all the way, his true altitude of 500 feet at Tampa decreases to only about 200 feet on reaching the Mobile area. In some weather situations, the pressure changes over a similar distance may be even greater than in this example.

Obviously, if the altimeter is to show as accurately as possible the heights above sea level, there must be some way to compensate for these pressure changes. This compensation is accomplished through the "altimeter

setting" system. The pilot can obtain the current value for the altimeter setting from ground stations by radio. The usual practice is to obtain the altimeter setting on passing successive CAA Communications Stations, and to re-set the instrument accordingly. In Figure 1, the altimeter is set to 29.92.

How Temperature Changes Affect the Altimeter Reading

We have said that the air pressure at any particular point depends on the weight of the air directly above it. We know that warm air is lighter (less dense) than cold air, but the altimeter does not consider these temperature changes. It senses only that the pressure on it has decreased, and changes its indicated altitude accordingly.

In flight, a correctly set altimeter will read too high when the mean temperature of the air column below it is colder than the U. S. Standard Atmosphere.

Similarly, the altimeter will read too low when the mean temperature of the air column below it is warmer than the specified standard.

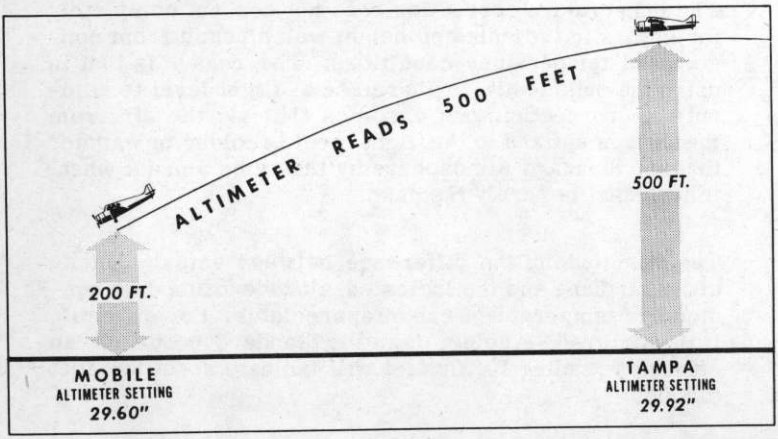

FIG. 3 - THE TRUE HEIGHT OF THE AIRPLANE CHANGES WHEN THE SURFACE PRESSURE CHANGES IF THE PILOT FLIES AT A CONSTANT INDICATED ALTITUDE AND DOES NOT RE-SET HIS ALTIMETER.

For purposes of landing and maintaining vertical distance from other aircraft flying assigned altitudes, we do not correct for the effect of temperature on the altitude reading. In the case of landing, the altitude error introduced by non-standard temperatures diminishes to practically zero during the descent and landing. For vertical separation of aircraft flying at assigned altitudes, all aircraft in a given area will be using the same altimeter setting and any errors introduced by non-standard temperatures will affect all the aircraft alike.

However, when the pilot must determine, if on a certain flight, how much clearance he will have between his assigned pressure altitude and a mountain ridge, he must take temperature into account. To do this he computes a correction to his indicated altitude. A practical rule is to reduce the indicated altitude by 1% for each 5° F that the actual temperature at flight level is below the Standard temperature for the indicated altitude. Similarly, he increases indicated altitude by 1% for each 5° F that the actual temperature is above the Standard. (These corrections can be most easily applied by referring to the correction scales provided for this purpose on most air navigation computers.)

The temperature correction does not account completely for errors in the indicated height which result from non-standard temperature conditions. The reason is that in using the outside air temperature at flight level to compute the correction, one assumes that all the air from the surface upward to the flight level is colder or warmer than the Standard Atmosphere by the same amount when, in fact, that is rarely the case.

The magnitude of the difference between actual altitude of the airplane and the indicated altitude caused by non-standard temperatures can be appreciable. For example, if the air is 40° F colder than the Standard condition, an altimeter reading 10,000 feet will indicate about 800 feet too high.

Effects of Other Weather Conditions on Altimeter Indications

Within and in the immediate vicinity of thunderstorms

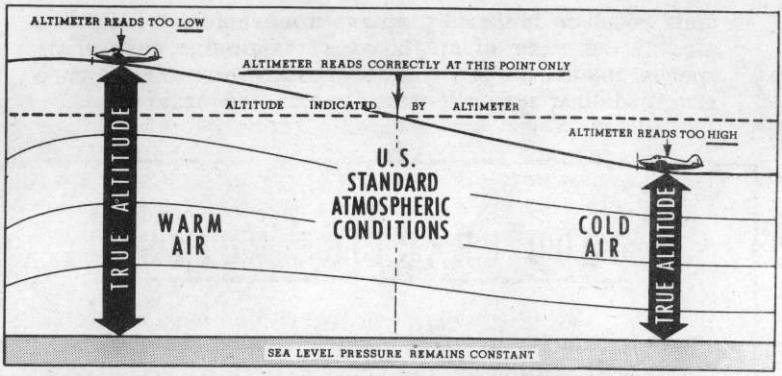

FIG. 4 - THE ALTIMETER READING IS TOO HIGH WHEN THE AIR IS COLDER, AND TOO LOW WHEN THE AIR IS WARMER THAN THE U. S. STANDARD ATMOSPHERE.

localized and brief pressure changes occur which affect the altimeter reading and can not be allowed for with the altimeter setting system. These conditions can cause indicated altitudes to be in error by at least several hundred feet.

Mountain waves, a condition in which air spills rapidly over the crest of a mountain ridge and down the slope, only to be forced upward again to complete one or more wave-like motions, cause localized but very important changes in air pressure. There are reliable reports of altimeters on aircraft flying in standing waves reading more than 1,000 feet too high. (See Aviation Series Article No. 5.) Even when standing waves do not form, strong winds blowing over mountain ridges or peaks can induce local reductions in pressure which will cause the altimeter to read too high. Pressure in neighboring valleys will also be caused to fall by this phenomenon.

Other Effects

Besides the differences that result from non-standard atmospheric conditions and certain phenomena, there are basic instrumental and installation errors that cannot be completely eliminated. For example, the altimeter must be vented to a "static" pressure which approaches the true outside air pressure at flight level. This static pressure is seldom obtained exactly because of the ef-

fects resulting from the airplane's movement through the air. In the case of airplanes of sonic or near-sonic speeds, the errors in altimeter reading often are of such magnitude that special corrections are necessary.

GOOD PRACTICE RULES

1. Set altimeter to latest reported value just before takeoff. (If the instrument is calibrated properly, the indicated altitude while on the ground should be within 50 feet of the field elevation.)

2. Remember that when in flight the altimeter shows heights based on standard atmospheric conditions, not actual height above sea level.

3. When considering terrain clearance, correct indicated altitude for non-standard temperatures.

4. When flying in mountainous areas, allow greater than normal terrain clearance if standing wave conditions are suspected, or thunderstorms or strong winds aloft exist.

This is the concluding article of this Aviation Series articles on weather. Previous issues are now available in booklet form from the Superintendent of Documents, Washington 25, D. C., at 5 cents per copy. The complete series will be available from the Superintendent of Documents as a set of 18 booklets soon after July 1, 1956, at 75 cents per set.

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