Taking the Mystery Out of Air Data Systems

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Got a problem with the air data system or an air data display on a helicopter? Call the avionics guy; he knows all about that stuff. That's a familiar remark heard around many hangars these days. Some A&P mechanics have had formal training on air data systems, but most have not and are a bit uncomfortable working on them. In this article, I want to take some of the mystery out of what an air data system is comprised of, what the parameters associated with the system are and what they are used for.

In the more complex helicopter systems we might find an air data computer. In most helicopters, we would in all probability just find an air data sensor. A computer is not required as the helicopter's flight envelope is not very high or fast compared to a business or commercial jet aircraft. Air Data Systems are built for a specific airframe that flies in a specific flight envelope. You would not build an air data system for a Sikorsky S-92 and then use it as is in a Airbus H AS-350. Other systems such as radios are more generic in nature in that you could use the same radio in a variety of aircraft without any problems.

An Air Data System in any form includes sensing, computation and display. Useful air data parameters can only be measured indirectly. The basic properties of barometric pressure and temperature are measured, and from these all other parameters are calculated.

Familiar examples of helicopter air data parameters are:

- Barometric Altitude (ALT)
- Indicated Airspeed (IAS)
- Vertical Speed (VS)
- Static Air Temperature (SAT)
- Total Air Temperature (TAT)
- True Airspeed (TAS)

Pitot-Static System

For any air data system to work, the aircraft needs a Pitot-static system. In small single pilot helicopters there is one Pitot-static system. In larger aircraft with a pilot and co-pilot, there are typically two independent Pitot-static systems, one for the pilot's side and one for the co-pilot's side instrumentation.

The Pitot-static system is divided into three parts, the impact pressure chamber and line (Pitot), the static pressure chamber and line, and a heating element to prevent icing from occurring. This is shown in figure 1.

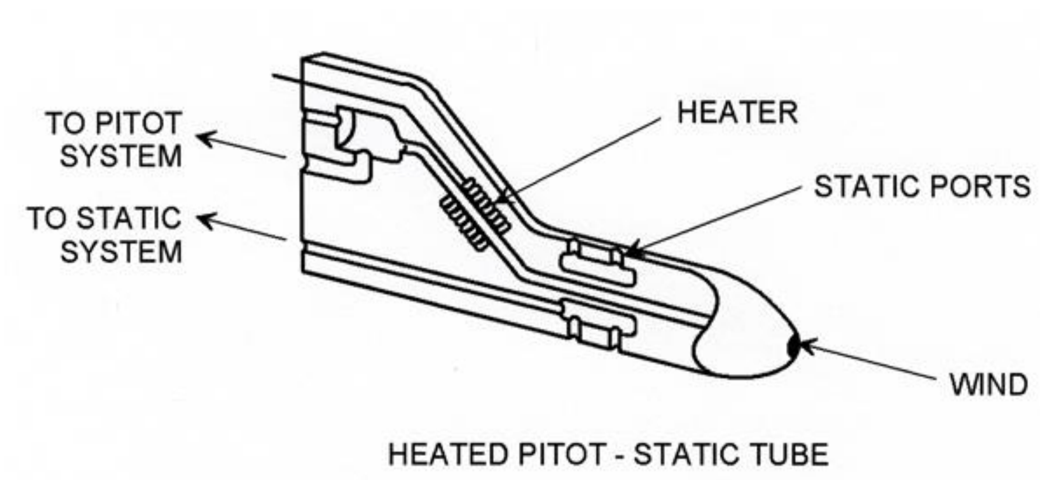


Figure 1

The Pitot chamber receives the impact pressure of the air as the aircraft moves. The static chamber is vented to the free undisturbed air (no ram effect) through small holes on the top and bottom of the tube. For the most accurate operation, the Pitot-static tube should be parallel to the longitudinal axis of the aircraft.

Static pressure can also be sensed by a pair of openings to the outside of the aircraft, connected to the sensor by pneumatic plumbing. These openings are usually in the form of holes that are flush with the aircraft skin. Temperature sensing involves a probe extending into the air stream, which will change its electrical resistance as the temperature of the air changes. An example is shown in figure 2.

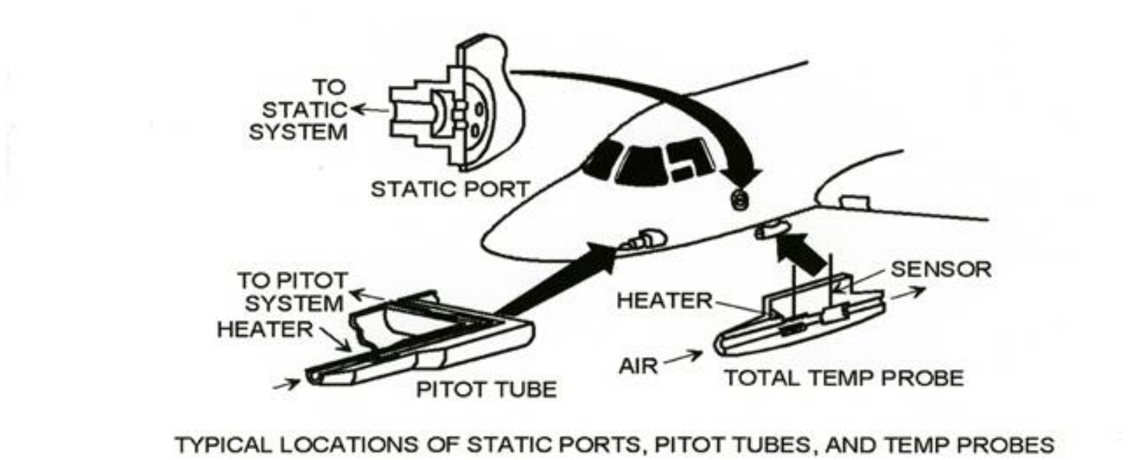


Figure 2

Pressure

From talking about the Pitot-static system, we now know that there are two kinds of pressure that the air data system must sense, *static* or atmospheric pressure and *Pitot* pressure. Static or atmospheric pressure is the force exerted by the weight of the atmosphere above a unit area, undisturbed by the aircraft but varying with general atmospheric changes and altitude. Atmospheric pressure is measured by an aneroid or mercury barometer. A mercury barometer consists of an upright glass tube containing mercury. The tube is sealed at the top, open at the bottom and stands in an open dish of mercury.

The column of mercury in the glass tube adjusts itself so that its weight is equal to the weight (pressure) exerted by the atmosphere on the free surface of the mercury in the dish.

The height of the column of mercury at any instant is directly proportional to the atmospheric pressure. Since the weight of the atmosphere is concentrated near the earth's surface and decreases as we go higher, static pressure is said to be a nonlinear, inverse function of altitude.

On an average day near sea level, atmospheric pressure will support a column of mercury approximately 29.92 inches in height. This means of measuring atmospheric pressure gives rise to the practice of expressing atmospheric pressure in inches of mercury instead of pounds per square inch. In meteorology, the "millibar" is used as the unit of pressure and 29.92 inches of mercury equals 1013 millibars. Millibars have since been replaced by the term Hectopascals (Hpa).

Pitot pressure provides impact air pressure; that is the pressure of the airstream against the aircraft as it flies through the air. In flight, pitot pressure is higher than static pressure due to the ram effect of the aircraft in motion. This Pitot-static differential, often called dynamic pressure, is sensed by connecting both Pitot and static lines to the sensors.

Altitude Data

There are four barometric altitude terms that we use. They are:

Indicated Altitude – is the altitude the pilot reads on his barometric altimeter. This is the altitude above sea level subject to the errors caused by nonstandard atmospheric conditions.

True Altitude – is the true height of the aircraft above sea level. The accepted procedure for computing true altitude is to combine pressure altitude and outside air temperature at a given flight level.

Pressure Altitude – is the altitude in the standard atmosphere corresponding to the pressure sensed at flight level.

Density Altitude – is the vertical distance above sea level in the standard atmosphere at which a given air density is to be found.

Airspeed Data

There are three types of airspeed that we associate with helicopters. They are:

Indicated Airspeed (IAS) – is the airspeed that is indicated on the instrument, uncorrected for instrument and position error, compressibility effects and variations in air density.

Calibrated Airspeed (CAS) – is the result of correcting IAS for instrument error and position error, which is also known as installation error.

Instrument error is normally small and will be ignored for our discussion. Position errors are due to the detection of dynamic and static pressures by the Pitot-static system. The airflow around the aircraft will cause the pressure sensed by the static ports to vary, as compared to the true ambient pressure some distance away from the aircraft.

Since changes in angle of attack or configuration (gear or sling load) affect the airflow, it is very hard to find a static port location that is ideal under all operating conditions. When the aircraft is at high angles of attack, the Pitot tube is not parallel to the airflow. In this position, the ram effect is reduced and this results in a lower IAS reading. The errors in the airspeed system are determined during flight test and are recorded on a chart in the aircraft's flight manual.

True Airspeed (TAS) – is the result of correcting CAS for compressibility and the density of the air at flight level. TAS can be computed if the pressure altitude and outside air temperature are known. When we speak of TAS, we are in reality relating the speed of the aircraft to the specific air mass through which it is passing.

High speed fixed wing aircraft also use Equivalent Airspeed and Mach, but we are not concerned with those parameters in helicopters so we will not discuss them here.

Temperature

Outside Air Temperature (OAT) affects aircraft performance in several ways. During takeoff, it affects the amount of thrust available from the engines and available lift due to air density. At cruise, fuel consumption is affected and OAT is required to compute True Airspeed (TAS).

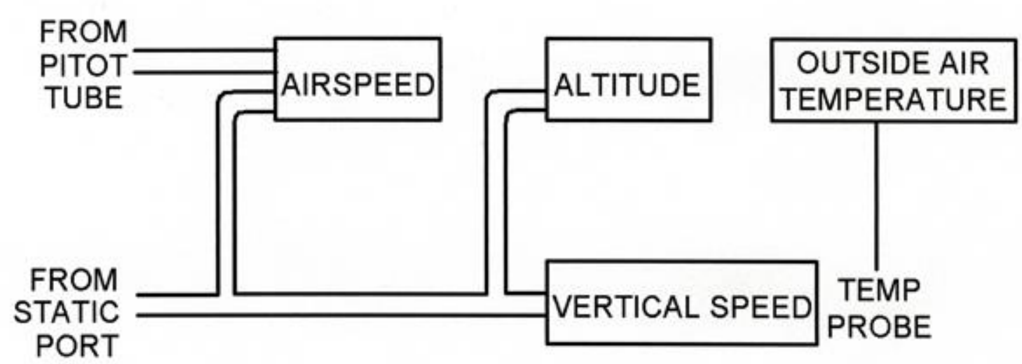
In poor weather, Static Air Temperature (SAT) indicates the potential for icing to occur, while Total Air Temperature (TAT) will indicate the likelihood that icing is occurring and the need to de-ice or change flight level.

The measurement of temperature from a moving aircraft is usually accomplished by means of a platinum wire probe, or thermometer projected into the air stream. The platinum element changes its electrical resistance in a very predictable fashion with changes in temperature. This change in resistance is converted into an electrical signal that is proportional to total air temperature.

Static Source Error and Correction (SSEC)

As we have stated earlier, static pressure is the absolute pressure of the undisturbed air mass surrounding the aircraft in flight. Typical static sensing systems are built as flush openings in the side of the aircraft or as a protruding probe. The airflow past the static port will cause the pressure in the static system to be different from the undisturbed air. At low speeds, this effect is usually small enough that it can be ignored, but at jet speeds it is significant and only a carefully designed system will be satisfactory. Since SSEC is usually associated with a Mach number and high speed flight, we will not discuss it here.

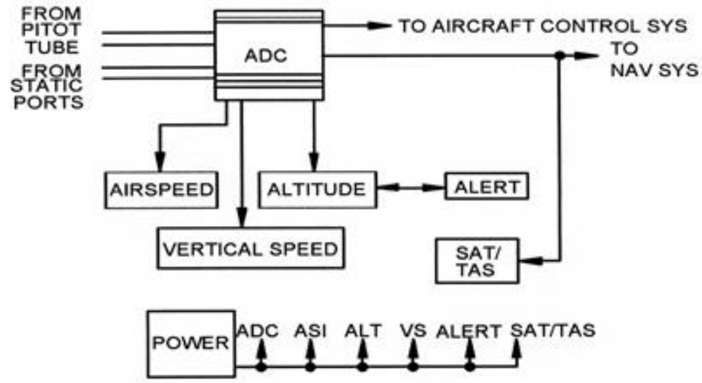
The following diagrams are shown to give you a representation of what air data parameters are used for a particular air data display. Notice in figure 3, that only airspeed uses both Pitot and static inputs, while altitude and vertical speed only use static input only.



Typical Pitot-Static Port Data

Figure 3

In a system that employs an air data computer, such as that shown in figure 4, the Pitot and static inputs go to the computer and the computer derives an electrical output based on the pressure inputs.



Typical Air Data Computer System

Figure 4

Hopefully this short article has helped clarify the differences in basic air data terminology and explains why some air data parameters are not used in helicopters, but are used in fixed wing aircraft. If you want to learn more, ask your supervisor to send you to an OEM school on your air data equipment. If not, then go ahead and call for the avionics guy.