

Bush Cat

by SkyReach



TECHNICAL GUIDANCE MATERIAL

AIRSPEED INDICATOR CALIBRATION

This document explains the process of calibration of the airspeed indicator to generate curves to convert indicated airspeed (IAS) to calibrated airspeed (CAS) and has been compiled as reference material only.

Technical Guidance Material

BushCat

NOSE-WHEEL AND TAIL-DRAGGER
FITTED WITH ROTAX 912UL/ULS ENGINE

APPROVED QRH PART NUMBER:	BCTG-NT-001-000
AIRCRAFT TYPE:	CHEETAH – BUSHCAT*
DATE OF ISSUE:	18 th JUNE 2018

**Refer to the POH for more information on aircraft type.*

For BushCat Nose Wheel and Tail Dragger LSA

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Abbreviations and Symbols

ASI: Airspeed Indicator

CAS: Calibrated airspeed

EFIS: Electronic Flight Information System

IAS: Indicated airspeed

ISA: International Standard Atmosphere

E_{ins} : Instrument error

E_{pos} : Position error

V_{qc} : Simulated calibrated airspeed

1. BACKGROUND

The aerodynamic forces acting on an aircraft are directly dependent on the *dynamic pressure* encountered by the aircraft. In essence, the dynamic pressure is that portion of the total pressure in the atmosphere that acts on the aircraft due to its movement through the air. The calibrated airspeed (CAS) is directly representative of the dynamic pressure acting on the aircraft regardless of altitude, wind, temperature etc. Thus, at a given CAS, the aerodynamic forces acting on the aircraft are constant, regardless of altitude, temperature etc. This conveniently means that the stall CAS for a given aircraft weight and configuration will be much the same within the flight envelope of a typical light aircraft, regardless of the environmental conditions. The pitot-static system installed in the aircraft attempts to display CAS to the pilot but is subject to numerous errors.

In order to determine the relationship between indicated airspeed (IAS) and calibrated airspeed (CAS) it is necessary to account for the most significant errors present in the pitot-static system. These errors are *instrument error* and *position error*.

- Instrument error: The error present in the reading of the instrument due to manufacturing imperfections and wear and tear. This can vary vastly depending on the make, age and condition of the instrument.
- Position error: The error present in the reading due to the system sensing pressures that are not truly representative of what the aircraft is encountering. These errors come from the *position* on the aircraft at which the total and static pressures are sensed and can be affected by the pressure distribution around the aircraft, the propeller slipstream etc. Up to the time of writing, the standard pitot-static system installed in the Cheetah/BushCat made use of a pitot tube to sense total pressure, while the instruments themselves (ASI and altimeter) were left to sense static pressure within the cabin.

This Technical Guidance Material aims to assist the owner/operator in generating the **approximate** relationships between IAS and CAS for their aircraft. Information is entered into the accompanying Excel spreadsheet and the calibration graphs will automatically be generated for your system. You can then print these graphs for reference. These relationships are subject to potential errors present in the tests used to obtain them, but

have been shown to be representative of reality (within about 1.5mph in their applicable range) when applied to another aircraft in the fleet.

Note that if any changes have been made to the cabin, doors or pitot-tube of the aircraft, these will affect the validity of this method.

2. DETERMINATION OF INSTRUMENT ERROR FOR YOUR ASI

The procedure to determine the instrument error present for your ASI is a relatively simple one but must be done carefully and accurately. It requires 2 people to accomplish and involves applying a pressure to the pitot tube to simulate a calibrated airspeed. This will generate a certain indicated airspeed on the instrument. This is done for multiple values all the way up and down the speed scale while recording the pressures corresponding to each indicated airspeed. Upscale and downscale readings are taken as, for example, the needle of the ASI may lag behind the movement of the pressure capsule due to mechanical free play in the linkages. This could mean that the indicated airspeed for a given calibrated airspeed in flight could vary depending on the movement of the linkages in the instrument before reaching that airspeed, and so it is important to determine the magnitude of this effect.

Equipment:

- Calibrated differential manometer.
- Means to apply a pressure to the pitot tube (such as a small syringe).
- Rubber/silicone tubing of roughly 4mm internal diameter.
- T-piece connector to connect the syringe and manometer to the pitot tube.
- Tie-wraps.

Method:

1. Connect one end of the differential manometer to the t-piece connector using a length of rubber tubing. Secure a syringe to a free leg of the t-piece connector with another piece of rubber tube.
2. Zero the reading on the manometer. If there is no zeroing function, note the zero-IAS pressure reading as an entry in Column 1 for an IAS of zero.

- Carefully attach the last end of the t-piece connector to the pitot tube itself with a third length of rubber tubing. When attaching the arrangement to the pitot tube, ensure that the plunger of the syringe is inserted and on its lower stop. Use tie-wraps to secure each connection.



Figure 1 Arrangement of instrument calibration system

- Have someone sit in the cabin viewing the ASI as the pilot would in flight. The second person must then slowly apply pressure to the syringe until the needle on the ASI reads the closest round value (usually about 20 to 25mph for analogue instruments). The person in the cabin calls when the desired value has been reached (record this in Column 1 of Appendix A, or the spreadsheet provided).
- Hold the syringe steady (the friction on the plunger should be sufficient for you to let it go). Let the pressure value stabilise.
 - Note that leaks will be evident by a steadily decreasing pressure value on the differential manometer. If the leak rate exceeds approximately 5-10 Pascals per second, it is likely that the pitot line itself has a leak and will have to be changed.
 - If the desired airspeed value on the ASI is overshoot (for example, the needle indicates 22mph, rather than the desired 20), the pressure on

the system must be reduced to about 5mph **below** the intended value (15mph for the example given), before pressure is reapplied to obtain the correct value.

6. Record the reading on the differential manometer in Column 2 of the sheet provided in the Appendix A.
7. Gradually apply pressure to the syringe to obtain the next speed value on the ASI and repeat the process. Go up in 5mph increments until at least 90mph. A 5ml syringe should be just sufficient to obtain the pressure required for this.
8. Once the highest speed has been obtained, gradually reduce pressure on the syringe until the next round number below it has been obtained.
9. Continue back down the speed scale taking pressure readings at the same values that you took going up the speed scale (completing Column 3, but from bottom to top).
 - i. Note again that if the desired airspeed value on the ASI is overshoot while reducing pressure (for example, the needle indicates 83mph, rather than the desired 85), the pressure on the system must be increased to about 5mph **above** the intended value (90mph for the example given), before pressure is slowly reduced again to obtain the correct value.
 - ii. Once the applied pressure has been reduced to zero (plunger of syringe is completely removed from cylinder) note the zero reading on the manometer again in the zero IAS row.

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3. GENERATING THE IAS-CAS RELATIONSHIP FOR YOUR AIRCRAFT

Now that the pressure measurements are complete, Columns 1 to 3 of the sheet should be populated with values. This section details the calculation of Columns 4 to 19 in order to generate the relationship for your aircraft. This section requires some calculation and can be done manually with a pocket calculator, **or using the spreadsheet provided.**

1. **Columns 4 and 5:** Convert each measured upscale and downscale pressure to the CAS that it corresponds to (denoted as V_{qc}) using the formula below. If there was a zero IAS pressure reading during the calibration, *subtract* this from the measured pressure (as per the formula). Note that this assumes that your ASI has been designed for sea level in the International Standard Atmosphere (ISA). If the difference between V_{qc} for the upscale and downscale values is less than 1mph (as it should be for an EFIS type system), average the two values for each IAS and use those averages for the remainder of the calculations (rather than continuing the calculations for both upscale and downscale columns). **Note that pressure values must be in Pascals for this formula to apply.**

$$V_{qc} = 2.8583\sqrt{(\text{Measured Pressure} - \text{Zero IAS pressure})} \text{ in mph} \quad (1)$$

2. **Columns 6 and 7:** The instrument error (E_{ins}) is then calculated for each measured pressure as follows.

$$E_{ins} = IAS - V_{qc} \quad (2)$$

3. **Columns 8 to 11:** Rainbow SkyReach has conducted in-flight calibrations to estimate the position error present for a factory-built aircraft. Equations to calculate the position error for both descent and level flight are given below. Note that these equations are only applicable for values of V_{qc} between 50mph and 75mph, but serve as good estimates at speeds below 50mph.

$$\text{Descent: } E_{pos} = 0.3189 \times V_{qc} - 17.805 \quad (3)$$

$$\text{Level: } E_{pos} = 0.3182 \times V_{qc} - 15.455 \quad (4)$$

4. **Columns 12 to 15:** The final step is to estimate what the indicated airspeed in flight would be for the CAS that was simulated by applying a pressure to the pitot tube. This done using the following formula.

$$IAS = V_{qc} + E_{ins} + E_{pos} \quad (5)$$

5. A plot of IAS (Columns 12 to 15) on the x-axis, versus V_{qc} (Columns 4 and 5) on the y-axis, can now be produced for both upscale and downscale calibrations. This is the approximate IAS-CAS relationship for your aircraft. This method has been applied to other aircraft with different ASIs and has been shown to yield results that agree to within 1.5mph of flight determined calibrations.

- i. Note: If the difference between your upscale and downscale readings is large, this implies that a given indicated airspeed on your ASI could correspond to a range of CAS values.

6. **Columns 16 to 19:** If the difference between upscale and downscale readings is relatively small, the average of the upscale and downscale IAS values can be plotted against the average of the upscale and downscale values of V_{qc} . This can be done for both descent and level flight.

- i. Note that the readings in flight can vary about this calculated average. If, for example, the difference between upscale and downscale IAS in Columns 12 and 13 is 2mph, then in flight the actual IAS obtained for a given CAS can vary by 1mph either side of this average.

Once the total calibration procedure is complete you should end up with 3 graphs depicting important information relating to the calibration. A sample set of data were used to present examples of these graphs.

Figure 2 shows the instrument error present for a sample ASI. For this aircraft, the spread between upscale and downscale readings was about 5mph on average. Negative values represent an *overread* error. Thus, for this example aircraft, the ASI would overread by between 0.5 and 6.5 mph when it is indicating 40mph (and so the real value, excluding any position error, would be between 40.5mph and 46.5mph).

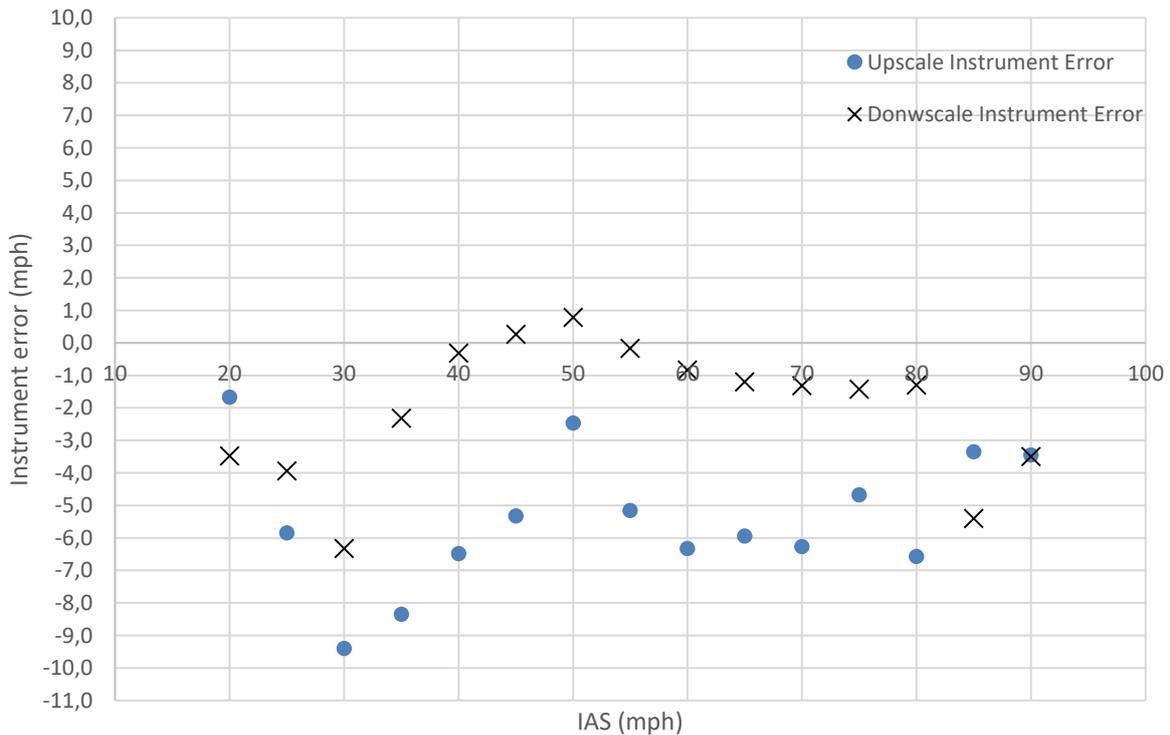


Figure 2 IAS instrument error sample

Figure 3 below shows the final output that is of concern to the operator. It represents the total relationship between IAS and CAS for the upscale and downscale readings, as well as the average of the two. For a given CAS, the IAS shown by the instrument could lie anywhere between the boundaries marked by the crosses and the dots. It must be noted that the position error applied to the data to generate these curves was itself subject to errors associated with the inflight calibration conducted. Thus, these relationships are **approximate only**, but have been shown to be representative of reality.

More accurate relationships can be determined using flight test methods that are beyond the scope of this text.

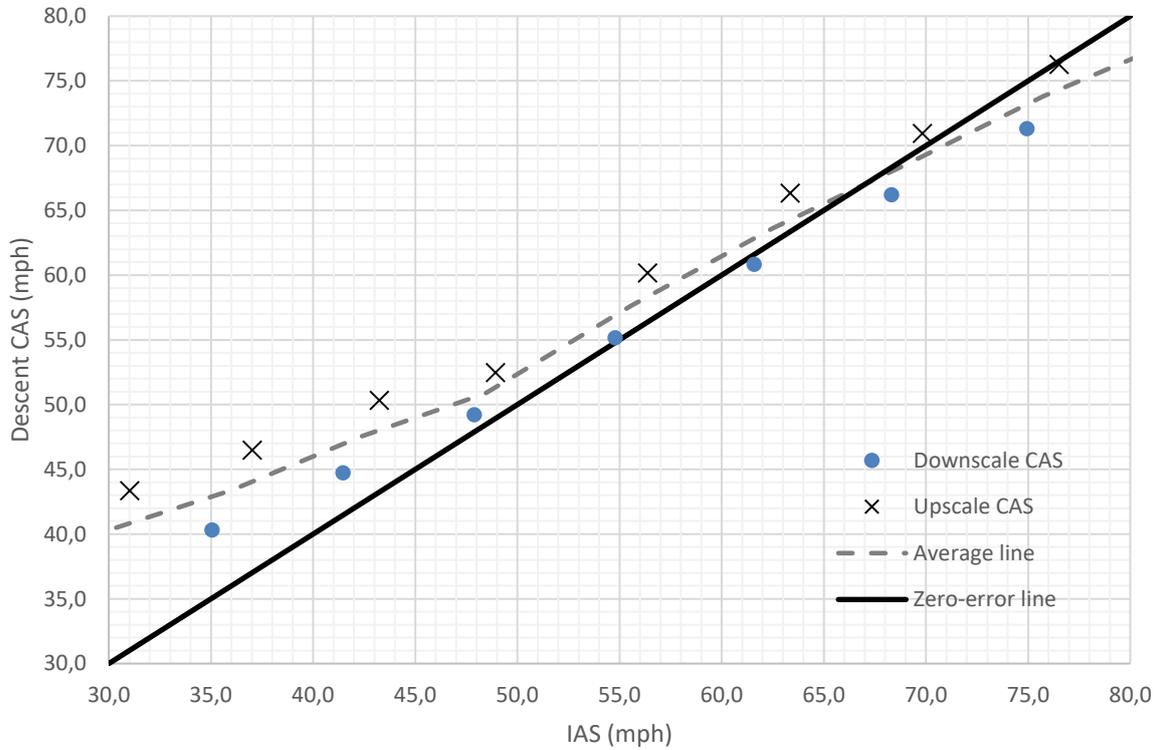


Figure 3 Sample relationship between IAS and CAS for power off descent

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4. CORRECT ALIGNMENT OF THE PITOT TUBE

The flight determined position error data were captured with the pitot tube aligned in the position as shown in the Figures below. The angular alignment of the pitot tube mounting bracket can be adjusted to obtain the correct position.

Looking directly down the tube from the front, align the tube with the zip on the bottom surface of the wing, as shown below.

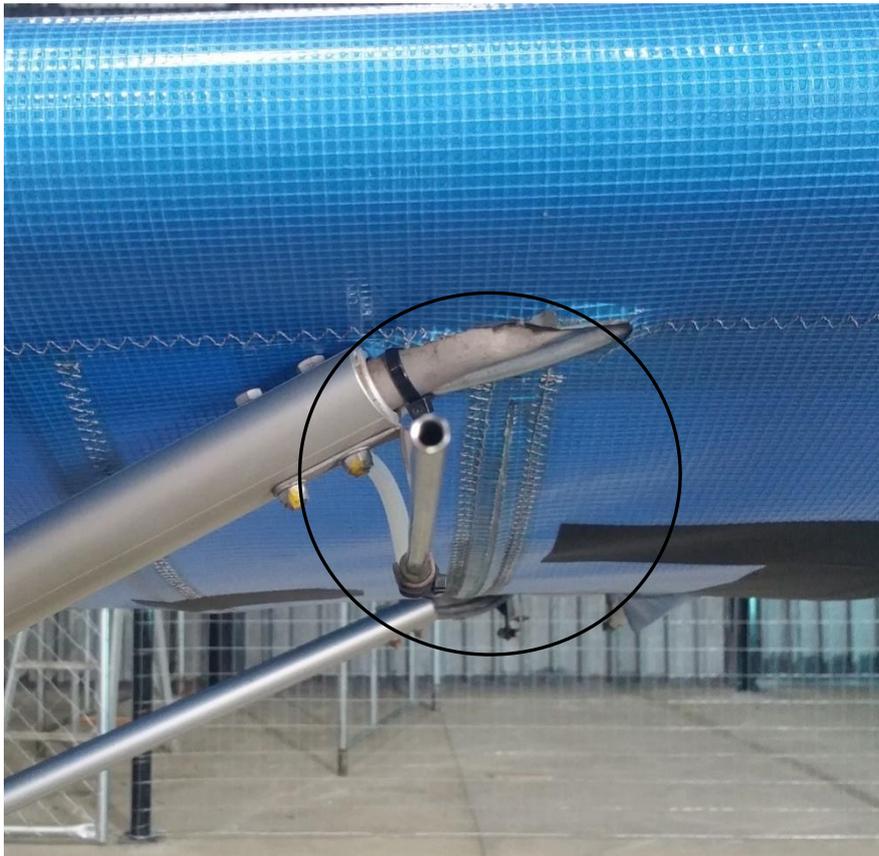


Figure 4 Longitudinal alignment of pitot tube

Looking at the pitot tube from the outboard side, align it with the horizontal jury strut sitting between the two main struts of the wing, as shown by the dashed red lines in Figure 5 below. These checks can be incorporated in the pre-flight check to ensure correct alignment before each flight. Care should be taken when removing and replacing the pitot cover during operational flying to keep prevent misaligning the pitot tube.



Figure 5 Vertical alignment of pitot tube

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