8mm Pitot-static tube, ESP series

Installation and Maintenance Manual

8mmESP V1.0

www.basicairdata.eu

10/05/2014

FOREWORD

Basicairdata comes on the web as a free and open resource for DIY telemetry instrumentation users and makers. The initial motive that fueled this endeavor was the need for dedicated instrumentation which generally is not commonly available or is very costly for the standards of the DIY market. A great feedback sustains the site growth and the continuous instrumentation revisions and development.

Every care has been taken during each development step, yet if for some reason you have doubts or problems arise, feel free to send us an email.

Basic Air Data Team

AVAILABLE DOCUMENTATION AND CONTACT INFORMATION

Every information published on this manual is available, free of charge on the BasicAirData website at

http://www.basicairdata.eu

Since this document was written as a quick-reference manual, only a selected subset of information is collected inside of it.

You can contact the BasicAirData team at

http://www.basicairdata.eu/social.html

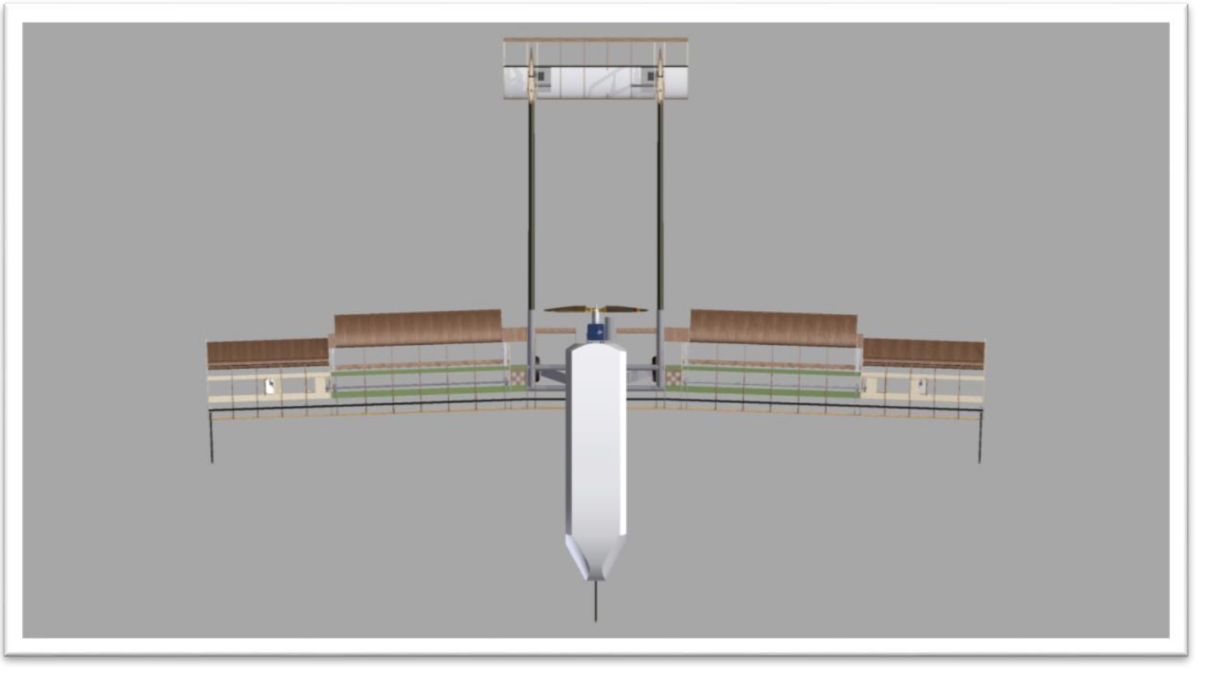

Figure 1: Air frame equipped with three airspeed probes, on the nosecone and the wingtips

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INTRODUCTION

The measurement of the airplane velocity, relative to the air-mass around it, is a common task on an instrumented aircraft. With airspeed data, it is possible to evaluate the aircraft dynamics and the aerodynamic performance; it is a fundamental measurement for system identification and control procedures.

Figure 2: 8 mm Pitot tube on a commercial air frame

Our probes are designed to be mounted on scale models. Use on manned aircraft is not certified and inadvisable. Be aware of your country legal restrictions regarding RC aircraft and relative devices. Always place safety first. It should be crystal clear to you that this probe is designed and tested to fly in the subsonic speed range and at a small altitude above the ground. Also, keep in mind that your probe performance and accuracy is directly linked to the pressure sensor you are using and the air data processing units that translate the sensed quantities into useful data. This installation manual describes the main issues that can impact airspeed probe operation, reliability and performance. Usually, the installation position affects the accuracy of static pressure, whereas total pressure is only slightly affected. Even in a good installation position, the static pressure can differ by many percentage points from the actual value.

Because the probe length affects the quality of the measurements, for a given installation position, suggestions on probe length calculation are provided.

From now on, we will assume that you have already built a Basic Air Data 8 mm airspeed probe. Information on construction and assembly can be found at this URL:

http://www.basicairdata.eu/flanged-pitot.html.

At the same URL, you can also find 3D models for the airspeed probe and probe flange.

The probe schematics are also available in Appendix B.

If you are an expert user, please refer to the "Quick Installation" and "Technical Data" sections for a quick installation procedure.

INSTALLATION OVERVIEW

For best performance, your airspeed probe must be properly installed. This brief guide describes some well-known procedures for installation and maintenance of airspeed sensors. The airspeed measurement instrument is composed by two main subsystems; the primary one is the 8 mm probe that you've already built and the secondary is everything else: from the pressure sensor to the calculation algorithms. As the type and availability of the required hardware are diverse we will try not to depend on a specific product solution.

At first, we will describe alternative mounting positions, then we will introduce probe-specific characteristics and performance. Ideally, the airspeed probe should be really long to minimize the static error, if it weren't for mechanical limitations

If problems arise during installation or use of the equipment, please feel free to contact us.

GENERAL INSTALLATION LAYOUT

There are three widely used probe installation layouts. Here follows a brief description of each setup. The probe can be installed essentially anywhere, but the advantage of a standard mounting point is the possibility to use available experimental data and bibliography. On the contrary, if a non-standard installation position is chosen, the corresponding position error needs to be calibrated. Refer to the "Pneumatic Connection" paragraph for detailed pneumatic connection instructions. For detailed mechanical information on mounting points refer to the "Mechanical Setup" paragraph.

WING TIP/ LEADING EDGE LAYOUT

The probe is mounted on the leading edge of the wing. It is necessary to keep it out of the propeller wake and far from the fuselage. In Figure 3 you can see an airspeed probe mounted on the wing tip.

This type of installation is suitable for tractor propeller configurations. Its main drawback is a higher wiring and tubing complexity and the fact that roll dynamics affect the measurements. After probe placement, it is also necessary to add weight on the opposite wing to balance the unit on the roll axis.

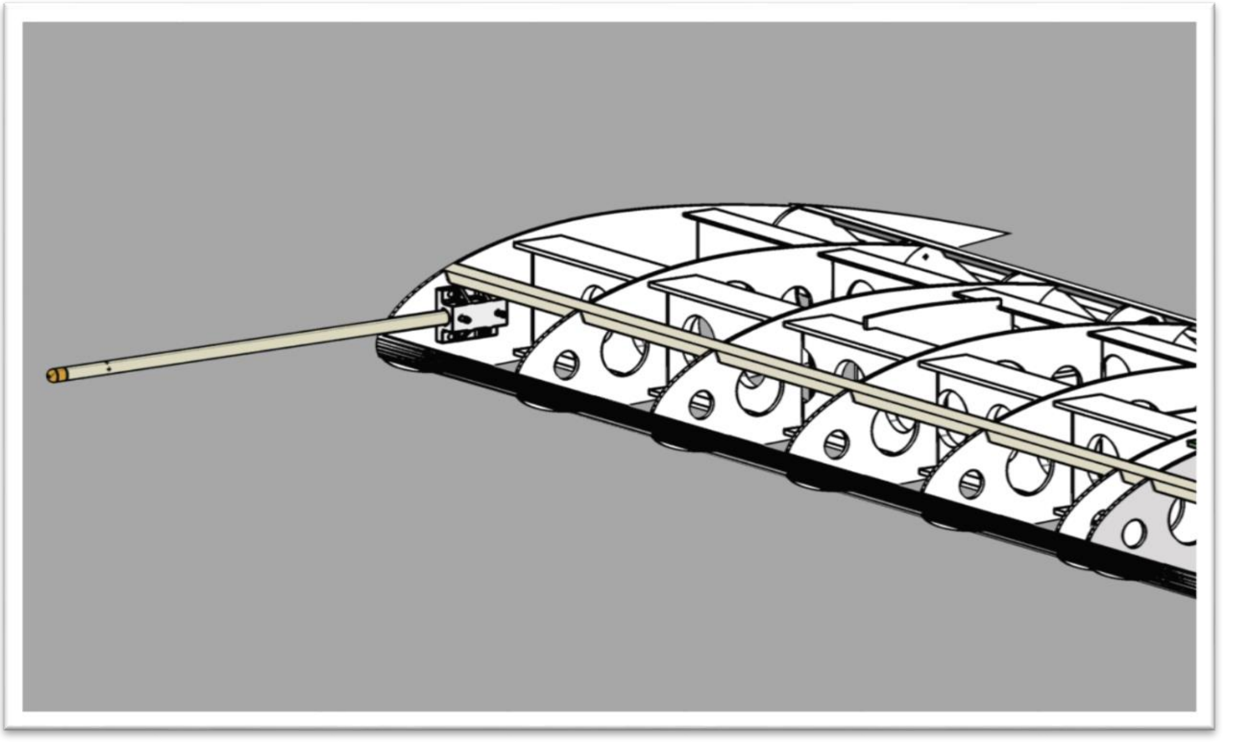


Figure 3: Wing tip installation, with barbed ports inside the wing

To achieve maximum probe dynamic performance, the pressure lines from the probe to the pressure sensor should be as short as possible. Then, sensor output can be routed through electrical wires to the fuselage. The longer the probe the better the measurement quality. You can read an introductory article with relative references at the following link:

http://www.basicairdata.eu/wing-tip-pitot-placement.html

Given the wing chord, c, and the profile thickness at the installation wing section, t, then the probe length protruding from the wing, *l,* should be chosen equal to *max(10t;1c)*. For example, if our wing has a symmetric NACA 0012 airfoil and a chord of 20cm, we get *t=2,4cm* and *l≥max(24cm;20cm)*; so *l* should be greater or equal to 24cm.

In another example, if we use a profile with *c=20cm* and *t=1,5cm* then *l≥max(15cm;20cm)*=20cm. At this probe length, the static pressure accuracy should be around 2% of the dynamic pressure.

Keep in mind the relation between accuracy and coefficient of lift. For high lift airfoils at high AoA, the error should be expected to be higher than what is reported in the references.

Refer to the "Mechanical Setup" section to size the mounting base.

For a precise evaluation of uncertainty, airframe specific considerations should be taken. It is possible that in many circumstances the uncertainty is overestimated, due to the crudeness of the assumptions.

Nose Mount

In this configuration, roll dynamics affect much less the probe performance, the probe is located inside nearly undisturbed air flow for a wide attitude range and sensor wiring is easy. Usually it is required to fit an internal dedicated mounting bracket to fix the probe in place.

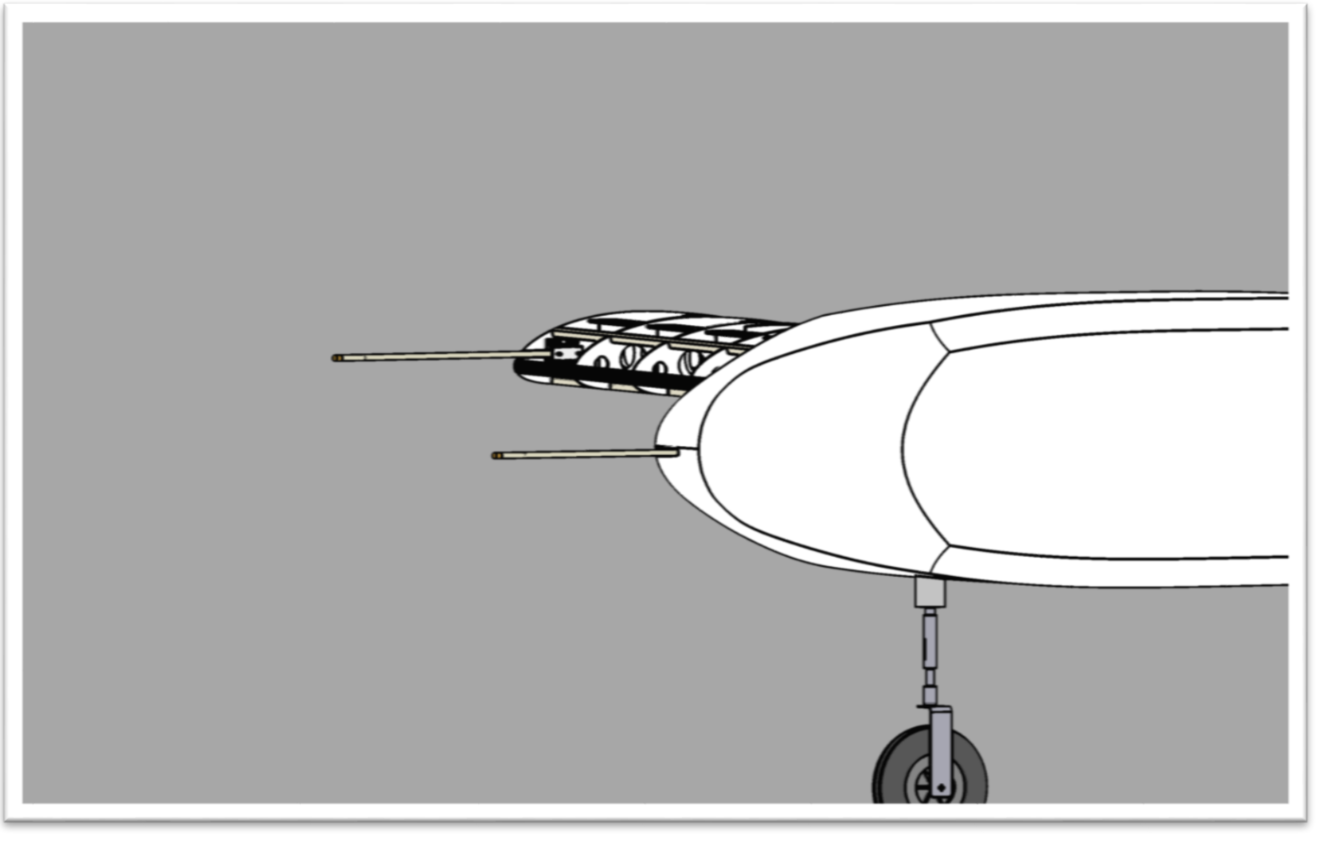


Figure 4: Nose mounted probe

It is advisable to select a probe length, in front of the fuselage, greater than 1.3 times the maximum fuselage diameter or 1,5 the hydraulic diameter. Have a look at this article for calculation details.

http://www.basicairdata.eu/nose-cone-pitot-installation.html

The suggestions for wing tip installation are still valid for the nose installation: the longer the probe the better the measurements.

UNDER WING/ ON WING STRUT

It is easy to install the probe on the wing struts but the routing of flexible tubing and wire can be messy and flimsy. The roll dynamics can strongly affect the measurement.

Figure 5: Under Wing installation on biplane wing strut

This installation is adequate for total pressure measurement only. To obtain the differential pressure reading, the static pressure can be sampled from a static port on the fuselage.

If the Pitot-static probe is mounted under the wing but protrudes beyond the leading edge of the wing, it is possible to treat this case as a leading edge mounting installation.

MECHANICAL SETUP

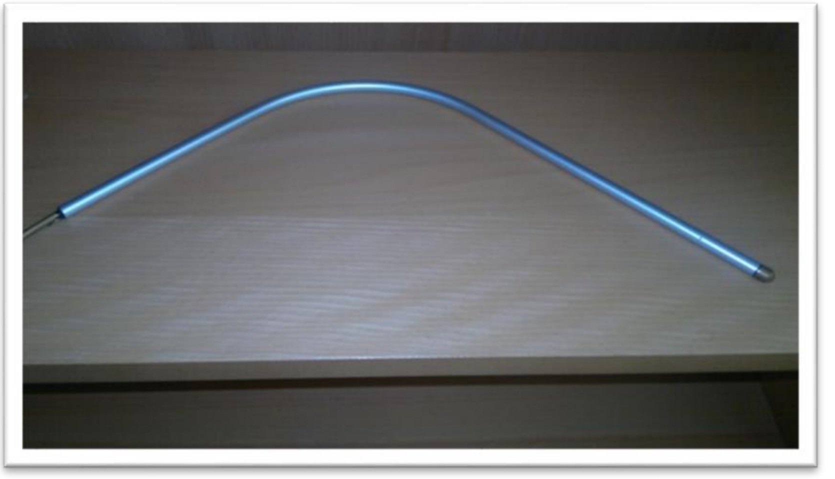


Figure 6: Aluminum BasicAirData 8mm airspeed probe, L shaped for under wing mounting model 8mmESP00LAL

There are two main types of BasicAirData Pitot-static probes. The first one is without a flange, as those depicted in figure 6, and the second is with a flange as in figure 7. Since variants of the basic flange are available, it is possible to accommodate for different installation requirements.

Figure 7: Carbon fiber 8mm model :8mmESPF4CF

Both systems are relevant and operational and it is up to you to choose what type fits your application best. Important factors to take into account while choosing are the overall dimensions of the equipment and how easily it will lend itself to use and mounting.

Regardless of the mounting options you make, please keep in mind the following guidelines:

- The Main axis of the probe must be aligned with the longitudinal axis of the airframe as per figure 4.
- Specify the maximum load factor (in Gs) and probe dimension for your application and check the joint strength and stiffness requirements, with the aid of the tables 2 and 3 in the "Technical Data" section.
- Be careful not to damage or alter structural parts of the aircraft during installation.

The mounting options for the probe are not restrictive: any custom configuration can be used, as long as it can withstand the aforementioned strain. In some cases, epoxy glue has been proven good enough to hold the probe in place.

Many methods have been used in order to mount a probe without a flange, with a clamp being the most common. It is readily available and easy to customize. Two examples are shown in the following figure.

Figure 8: Hydraulic pipe clamps, useful for probe mounting

The airspeed probe with flange model requires different preparation. Check "Technical Data" instructions on adequately-sized support plates, in order to ensure that your structure can cope with the corresponding G-load.

Print the drill pattern that you will find in Appendix C, mark the hole position with a pencil, drill 3.2 mm holes in your airframe where the flange will be mounted, place the flange and tighten the bolts.

PNEUMATIC CONNECTION

On the rear part of the probe or on the flange, you will find the two pneumatic connections; we call them the signal lines.

Refer to the supplied assembly drawings: for the flanged model, the rear nipple is the total pressure port, the forward nipple is the static pressure port. For the non-flanged model, you should label the pressure ports during the assembly phase.

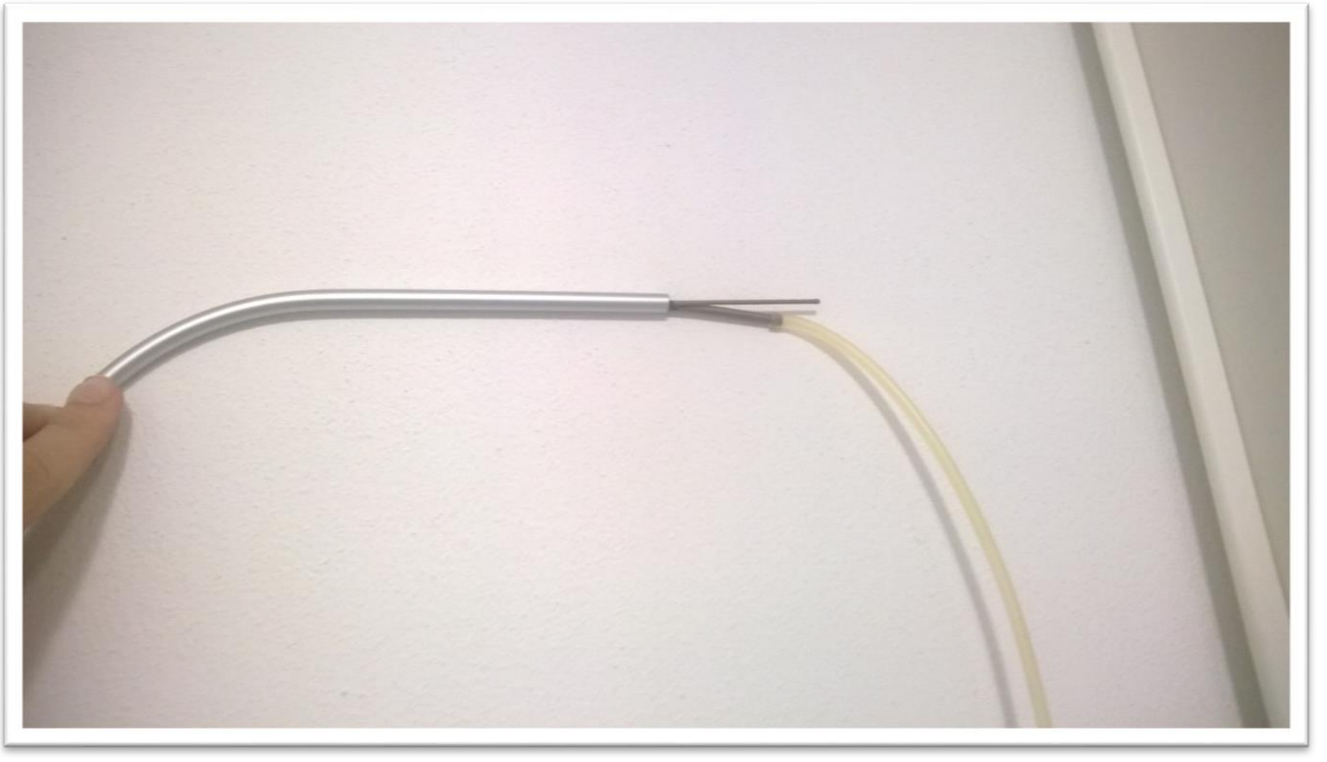


Figure 9: Pressure tapping on a non-flanged, L-Shaped pitot

Blowing through the center hole of the probe, the air will escape trough the total pressure port; the other pressure port is the static one.

You can decide whether you will connect one absolute pressure sensor to each signal line, or you will treat the lines as a dual signal port and connect them to a differential pressure sensor. General connection schemes can be found in the "General Instrumentation Layout" section.

Be very careful not to bend the metal pressure lines of the probe, as the metal can suddenly crack. If that happens, repair works or component replacement may be needed.

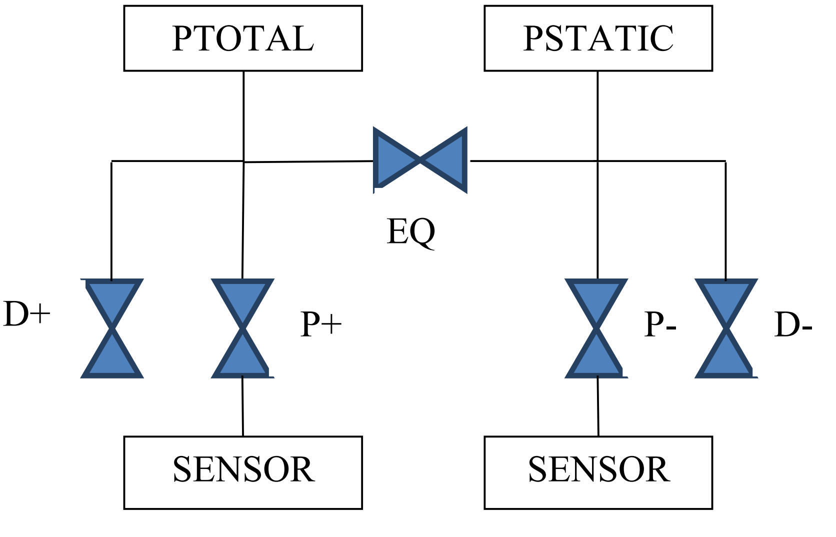
It is common for the first part of the tubing, about one centimeter, to be made out of tygon or silicone tubing. After that section, the tube is coupled with a rigid section of tubing. That arrangement does not hinder performance and ensures good vibration decoupling between the probe, the sensor and the tubing. See below how you can practically realize different types of transition joints.

Figure 10: Example triple transition joint, from 2mm OD silicon tube to brass 3mm OD tube, then to 4mm OD silicone tube and 3mm OD rigid plastic tube. Consider using cable ties to secure the joints.

The overall pneumatic tubing should be as short and stiff as possible. Metal and nylon are appropriate materials. The lines should be free of obstructions and held in place during the flight. Do not allow the lines to move and bend freely.

In many cases, for example when low G-forces and low vibrations are expected, the use of silicone tube of high thickness can be acceptable. However, in the general case, silicon tubing can deform under oscillatory forces, which can lead to unwanted pressure changes. In order to avoid this fault, use instead a pressure line made of rigid plastic material or metal, for example brass. Many manufacturers of compressed air fittings have in their catalogs plastic tubes with outside diameter of 3-4 mm, often used in RC models for retractable landing gears.

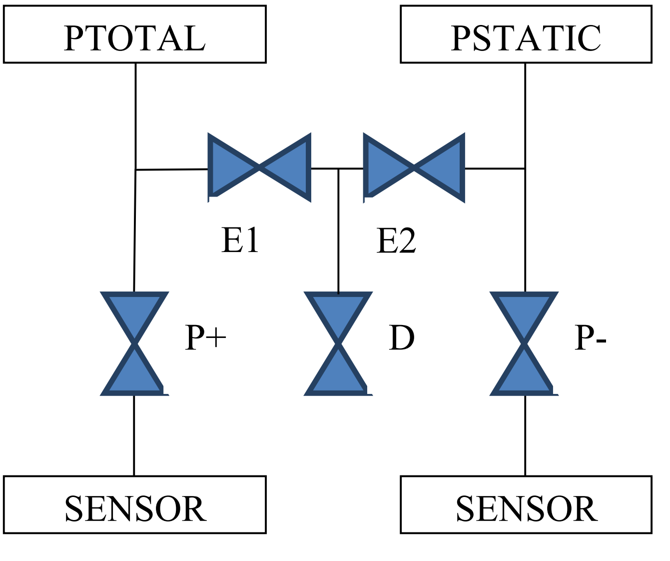
The main cause of probe malfunction is the presence of condensate in the signal lines. To purge the lines you need some hardware on the signal lines. We now present a conceptual connection scheme for a probe that can be purged as described in "Maintenance" section. This configuration can be used on large models or where extreme performance and reliability is required. This is the same configuration that should be used in Pitot-static test equipment.



VALVE ID	FUNCTION/NORMAL STATUS
P+	Total pressure isolation valve / OPEN
P-	Static pressure isolation valve / OPEN
EQ	Bypass/equalize valve / CLOSED
D+	Total pressure drain valve / CLOSED
D-	Static pressure drain valve / CLOSED

Figure 11: Five valves connected to the instrumentation

Take a look at the five-ways manifold scheme in Figure 11. The main advantage of this configuration is the ability to purge the signal lines without the risk of damaging pressure transducers. The circuit is also capable of withstanding some condensate in the drain lines without loss of performance. Now check the configuration depicted in Figure 12. It provides the same functionalities as the previous configuration, but has only one, common exit line for drained liquid.



VALVE ID	FUNCTION/NORMAL STATUS
P+	Total pressure isolation valve / OPEN
P-	Static pressure isolation valve / OPEN
E1/2	Bypass/equalize valve / BOTH CLOSED
D	Drain valve / CLOSED

Figure 12: Five valves alternative connection scheme

Pressure lines are interrupted by manual valves. It is possible to replace the drain valve(s) with a plugged tube section and of course it is also possible to use any kind of miniaturized solenoid valve to do the same task. Whichever arrangement you use, be sure to route the whole drain tubing below other pneumatic circuit components.

To ensure maximum accuracy, at least during low AoA flight paths, be sure that pressure transducers input ports have the same piezometric height (the same distance from a horizontal ground reference plane). This kind of error can be compensated with attitude data from an inertial unit or similar alternatives.

ELECTRONIC SETUP

Complimentary hardware and software is required, in order to integrate the airspeed probe to your application, but this is up to the end user. You can refer to

http://www.basicairdata.eu/pitot-integration.html

for a complete software/hardware open suite that can be used with 8mm airspeedprobes.

PRELIMINARY TESTS

After the equipment has been installed on board, it is recommended to proceed to a full calibration. In the following links, there is a suggested procedure for the calibration.

http://www.basicairdata.eu/introduction-to-sensor-testing.html

http://www.basicairdata.eu/pitot-probe-test-equipment.html

Even if you haven't dedicated test equipment for the airspeed probe, you can do some basic tests with a simple DIY U-tube manometer as described here, in total a pressure port test:

http://www.basicairdata.eu/pitot-firmware.html

MAINTENANCE AND USE

The airspeed probe is virtually maintenance-free, no part should be replaced due to aging problems. However, it is fundamental to maintain pressure lines free from cuts, abrasions and obstructions. Pressure lines are often made of nylon or other plastic material so if they are bended or strained they are prone to cracking. They must be inspected on a regular basis for signs of wear, sun exposure or overheating. If any sign of aging or damage is found then immediately proceed to replacement of the pressure lines.

Working on the configuration of Figure 11, to ensure that the pneumatic circuit is dry, you can follow the procedure below:

1. *Open EQ valve*
2. *Close P+ and P-*
3. *Open D+ and D-. If condensate is present, it will pour out along the drain line. Leave the valves in this position for at least 5 minutes.*
4. *Close EQ valve*
5. *Open P+,P- valves*
6. *Close D+ and D-*

Never blow air directly into the pressure ports!

If you suspect that water is trapped inside the probe, place the probe in a vertical position and use the same draining procedure.

The basic 8mm pitot is not designed for continuous use in icy conditions, so verify carefully that the airspeed sensor is properly working prior to takeoff. The simplest qualitative test consists of blowing from a distance against the total pressure port and test that sensor is reading a non-zero variable speed.

When the airframe is either at the field or in storage, to avoid probe clogging by foreign bodies or insects, always use a probe cover.

An example probe cover can be found in the following link:

http://www.basicairdata.eu/pitot-cover.html

A simple cotton fabric ribbon works well as a probe cover as well.

Figure 13: A Cover for an airspeed probe

GENERAL INSTRUMENTATION LAYOUT

An airspeed probe is often used along with other air data instruments and sometimes these instruments will share pressure lines. The following figure depicts as a common connection diagram.

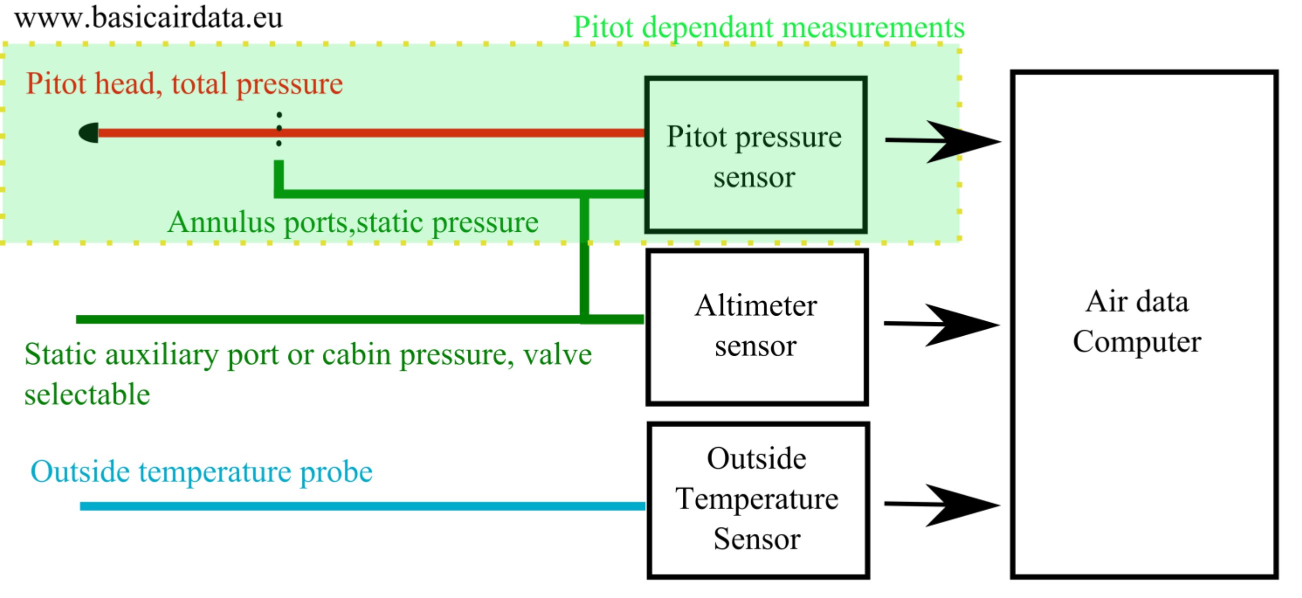


Figure 14: Air data instruments integration scheme

Fuselage auxiliary static vents are not required for basic operations, neither the use of the cabin pressure as an emergency static source. The layout highlights the fact that if air data is routed to a central air data computer then it is possible to have better compensated measurements based on all the sensors installed on the airframe. The use of outside temperature and its integration with barometric data and total pressure data make it possible to obtain good true air speed (TAS) measurements. TAS is calculated taking air density into account. Using air temperature and pressure, it is possible to calculate air density and plug it in the TAS calculations. An example algorithm for the air density calculation can be found here:

http://www.basicairdata.eu/calculation-routines.html

QUICK INSTALLATION

After reading the "General Installation Layout" section, select one out of three probe installation options. Then, look it up in the table below and obtain the minimum airspeed probe length, outside of the airframe, *l*.

Definitions of lengths are depicted on figure 15

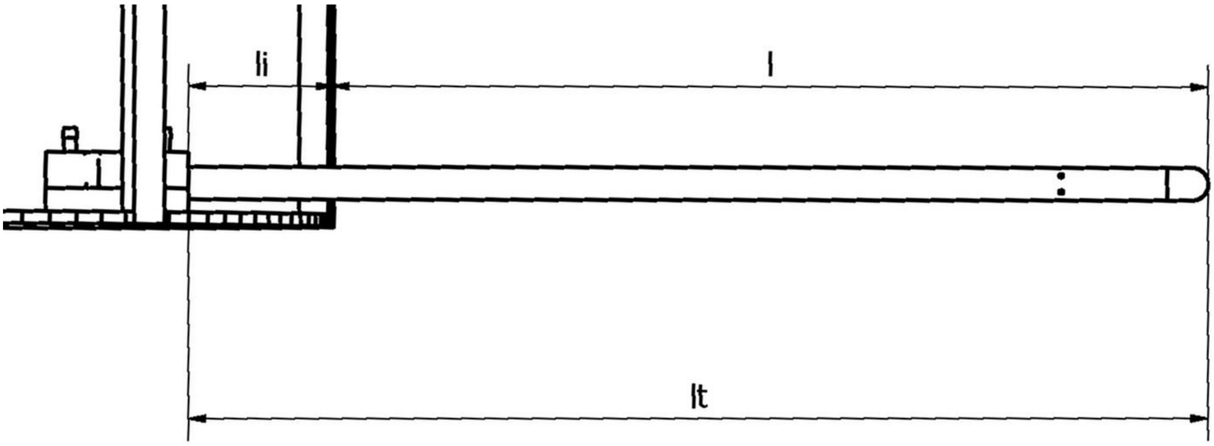


Figure 15: lt, l and li graphically defined

Wing tip installation	Nose installation	Wings struts/ Under wing
Measure: *t:* maximum wing thickness (m) *c*: wing local chord (m) Select: *l=10t* or *1=c*, whichever is larger	Measure: *D:* maximum fuselage diameter in meters $l = 1{,}3D$	If installation position is similar to wing tip installation then use wing tip distance. Otherwise avoid installation or use only underwing total pressure measurement.

Table 1: Required probe length in relation to installation position

Calculate the total length of the probe *lt* as the sum of *l* and *li*. The latter is the length of the probe inside of the wing or inside of the fuselage. *li* is the length measured from the outside of the airframe to the mounting flange. In the case of a non-flanged probe select *lt* as at least 35 mm. This provides a minimum probe length to clamp the probe on the airframe.

After obtaining the total length value, proceed to the “Technical Data” section.

TECHNICAL DATA

The probe unit is not heavy enough to impact the host airframe, but for some situations, such as light and fast airframes, some recommendations on probe support sizing are due. A probe of up to 300mm can withstand heavy G loads and airspeeds.

From the user point of view, it is useful to know how one should size the probe mount to withstand the loads induced by the probe. For greatest accuracy, different sizing for every different mounting layout should be specified, but as this is not practical, a reference mount is used in the following tables. This reference mount is a simple flat surface of given dimensions and thickness. As sizing depends also on G load, or maximum allowed acceleration, the sizing will depend also on that parameter.

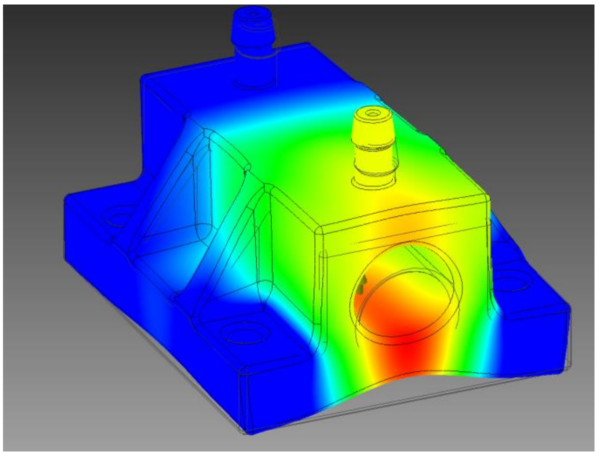


Figure 16: Flange FEM, maximum deformation in red

To save the user from the burden of subsequent calculations, some parameters have been fixed during the sizing process.

All the test cases consider a maximum force on each single screw of 40N with screwing moment should never exceeding 1Nm. Forces and moments where tested along all three coordinate axes. The next table is populated with the sizing results.

Mount dimensions	Material	Recommended Minimum Thickness
55mmx45mm	Plywood	3 mm
55mmx45mm	Plastic ABS	3 mm
55mmx45mm	Balsa	Not advised
55mmx45mm	Carbon fiber	2 mm
55mmx45mm	Glass fiber	2 mm

Table 2: Support sizing

With the provided sizing for the mounting base, the airspeed probe tube is rated for the G load reported on Table 3 below. Standard sizing is marked with green. Rows marked in red require special attention, as explained below.

Case No	lt, length [mm]	Total unit weight [g]	Maximum G load with two screws	Main tube material	Pitot head material	Advised V_{NE} [m/s]	Static deflection [degrees]
1	150	18	45	Carbon fiber	Printed plastic	100	0.05
2	200	22	30	Carbon fiber	Printed plastic	100	0.07
3	250	26	22	Carbon fiber	Printed plastic	100	0.10
4	300	30	17	Carbon fiber	Printed plastic	55	0.12
5	350	33	13	Carbon fiber	Printed plastic	55	0.14
6	400	37	10	Carbon fiber	Printed plastic	N/A	0.15
7	450	41	9	Carbon fiber	Printed plastic	N/A	0.19
8	500	45	7	Carbon fiber	Printed plastic	N/A	0.19
9	150	23	34	Alluminium	Brass	100	0.13
10	200	28	22	Alluminium	Brass	100	0.16
11	250	33	16	Alluminium	Brass	55	0.21
12	300	38	12	Alluminium	Brass	52	0.25
13	350	42	10	Alluminium	Brass	N/A	0.31
14	400	47	7	Alluminium	Brass	N/A	0.31
15	450	52	6	Alluminium	Brass	N/A	0.36
16	500	57	4	Alluminium	Brass	N/A	0.32

Table 3: Probe rating as a function of total length

Cases in red require detailed and application specific information to verify the design. The reported values on Table 3 should not be considered very accurate, due to the variability of the 3D printing and epoxy gluing processes and the tolerances of the materials used.

In Table 3 you will also find weight and static deflection information. It is safe to interpolate the table vales but not to extrapolate them. The “Never Exceed Velocity” (V_{NE}) has been related according to probe resonance frequency.

In the V_{NE} column, in rows 1, 2, 3, 9 and 10, the value has been artificially lowered to 100 m/s; analytical/simulated value for the material is actually higher.

Rows 7, 8, 14, 15 and 16 refer to long probes, use of which should be examined carefully and separately.

For the longer probe sizes speed-related problems may arise and it is advisable not to use the flanged connection at these lengths.

Regarding the screw tightening torque, a value of 0,25Nm is suggested, for all the cases of table 3. Use a standard washer on both the nut side and one on the bolt head side.

If your sizing is not listed or if you have any doubt, fell free to come in contact with BasicAirData members.

REFERENCE LIST

The same references found on the BasicAirData site also valid for this manual. You can find detailed reference lists in the site articles.

APPENDIX A

PROBE CODES

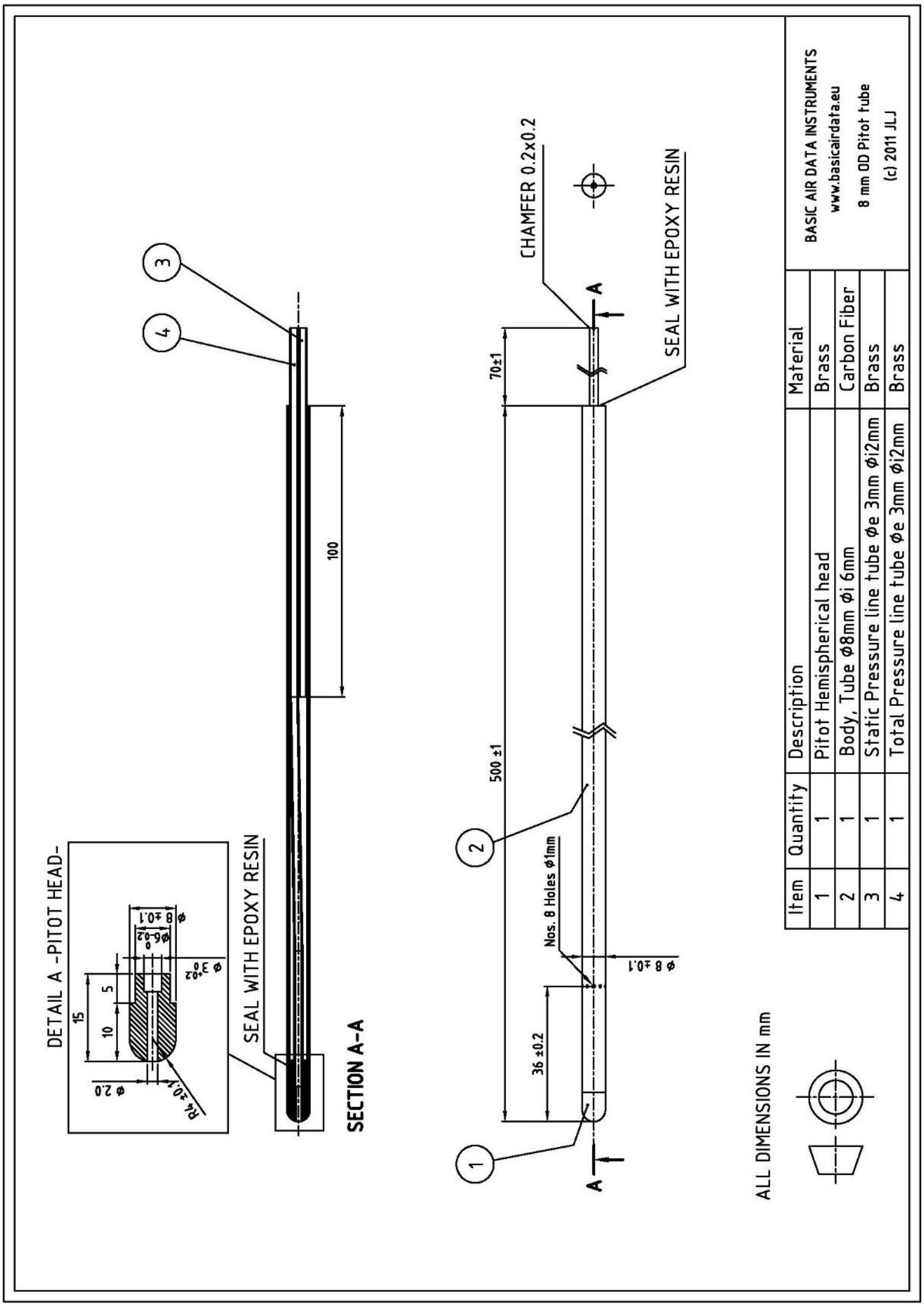
To communicate in an efficient way, we introduce an airspeed probe code system. The last three digits of the code represent the length in mm.

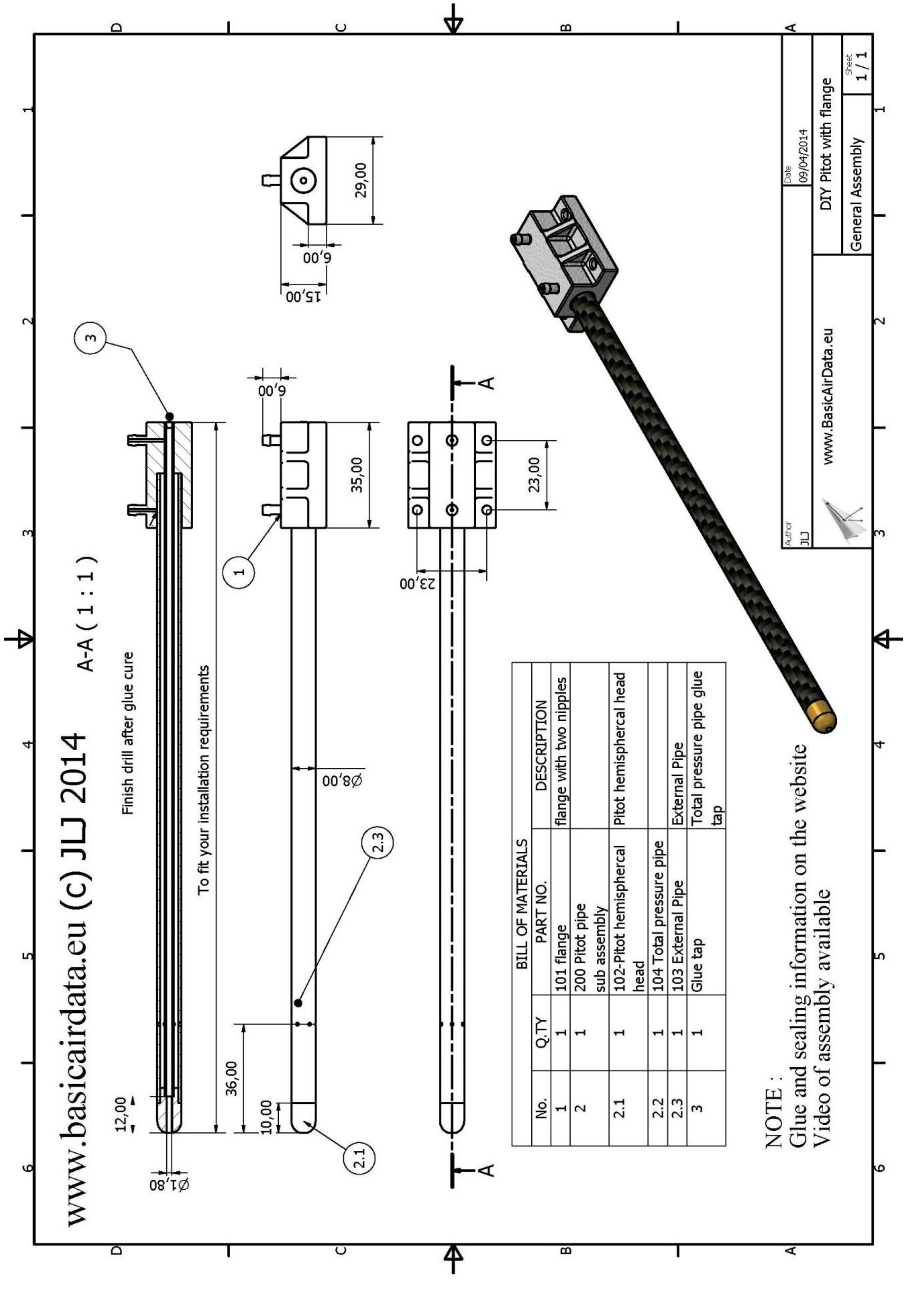
FLANGE	Static Holes #	Shape	Pipe Material	lt ??? mm	Code
Yes	2	Straight	Carbon Fiber	??? mm	8mmESPF2SCF???
Yes	4	Straight	Carbon Fiber	??? mm	8mmESPF4SCF???
Yes	2	Straight	Carbon Fiber	??? mm	8mmESPF2SCF???
Yes	4	Straight	Carbon Fiber	??? mm	8mmESPF4SCF???
No	0	L-Shaped	Carbon Fiber	??? mm	8mmESP00LCF???
Yes	2	Straight	Aluminum	??? mm	8mmESPF2SAL???
Yes	4	Straight	Aluminum	??? mm	8mmESPF4SAL???
Yes	2	Straight	Aluminum	??? mm	8mmESPF2SAL???
Yes	4	Straight	Aluminum	??? mm	8mmESPF4SAL???
No	0	L-Shaped	Aluminum	??? mm	8mmESP00LAL???

Table A.1:Probe coding system

APPENDIX B

PROBE DRAWINGS, ESP SERIES NON-FLANGED AND FLANGED MODELS





BILL OF MATERIALS

No.	Q.TY	PART NO.	DESCRIPTION
1	1	101 flange	flange with two nipples
2	1	200 Pitot pipe sub assembly	
2.1	1	102-Pitot hemisphercal head	Pitot hemisphercal head
2.2	1	104 Total pressure pipe	
2.3	1	103 External Pipe	External Pipe
3	1	Glue tap	Total pressure pipe glue tap

APPENDIX C

DRILL PATTERN

Print this page without scaling. You will get a drill pattern for use with the probe flange. If you are printing with a laser printer on glossy paper, you can iron the drawing directly on wood. Just print the drill pattern, put the drawing side against the wood surface and then press with a hot iron for a minute. The drawing will transfer to the wood.

The flange footprint is 29 mm x 35 mm. Check the printed image dimensions with a ruler before ironing.