

# TRANSONDAS: A NEW DEVICE TO MEASUREMENT OF FLOW

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*Abstract: This work shows the transonda that is a device destined to measure the flow in pipe lines under pressure and in natural or artificial channels. This instrument is being developed in the Hydromechanical Laboratory for Small Hydro Power Plants – LHPCH – of the Engineering Federal School of Itajubá – EFEI – in partnership with Markare Devices Electronics Co. This paper shows the transondas patented models, the results of researches of the preliminary version and the results of the tested prototype in the wind tunnel of the referred laboratory.*

*Keywords: Transonda, flowmeter, pressure sensor.*

## 1 INTRODUCTION

There are several methods and devices suitable for the measure of flow in pressurized pipes and in open channels. The main devices are the captors of Plandtl, Pitot, Darcy, Darcy-Cooler and Recknagel types and propiler flowmeter. The current level of technological development of the pressure sensors and of the data acquisition and treatment systems has encouraged the developement of a device that facilitates the determination of draining speed through the data acquisition of the stagnation and static pressures in real time.

This paper shows the transondas patented models, the results of researches of the preliminary version and the results of the tested prototype in the wind tunnel.

## 2 THE SPECIFICS SOFTWARES

The specifics softwares promoted a true technical revolution in the procedures, treatments and analyses of the results of the measures, mainly in the field of the Mechanics of the Fluids. However, the evolution of the pressure captors is little, many of them has maintained unaffected for several decades, as, for example, the Pitot and Prandtl tubes.

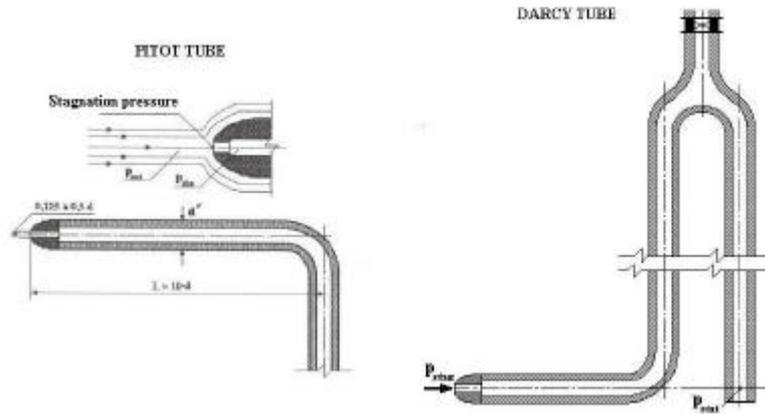
The quality, reliability, prices and dimensions of pressure captors has been motivating the development of technological researches for integration of systems, that, in this specific case, includes the software and the pressure captors. This automation process is happening, for example, in the field now occupied by the propiler flowmeters and by other probe types. These new devices are technically competitive, offering advantages in the calibration, installation, operation, handle, execution time of the measure, control of results, error, reliability and others.

These considerations conducted the authors of the Energy Group – GEN – of the Federal School of Engineering of Itajuba to request patent registration to the National Institute of Industrial Property – INPI. Also, they inducted the development of technological research which objectify to obtain a system composed of transondas, signs switch modules and specific softwares. This system will be used for measure of draining speed of liquid or gaseous fluids in pressured pipes or in artificial or natural channels.

## 3 THE BASES OF THE RESEARCH

For illustration, the figure 1 shows the Pitot and Darcy tubes. These instruments facilitate to obtain speeds in pipes not pressured and on pressure. These captors are linked to differential manometer and the speed is obtained with the application of energy conservation law. The equation resultant is shows in 1. where: The speed is  $v$  (m/s); the gravity acceleration is  $g$  ( $m/s^2$ ); the stagnation pressure  $P_{stag}$ , the static pressure is  $P_{stat}$  is ( $N/m^2$ ); the density is  $\rho$  ( $kg/m^3$ ); the height difference is  $Dh$  (m) and  $k_s$  is the coefficient of the probe. This coefficient is obtained in the calibration of the probe. It can be considered equal to 1. The accuracy is smaller to 1,5 % for normalized probes.

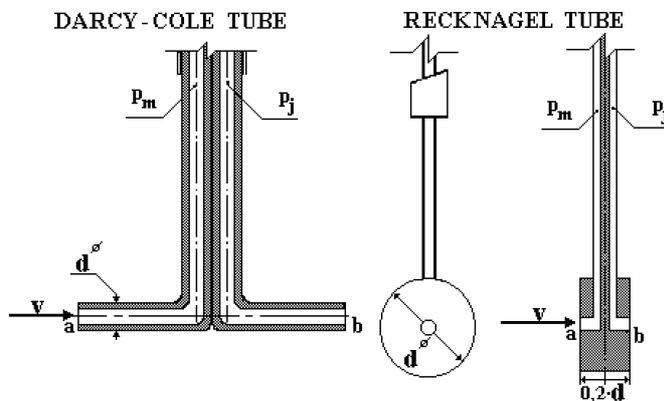
$$v = k_s \cdot \sqrt{2 \cdot g \cdot \frac{P_{\text{stag}} - P_{\text{stat}}}{\rho}} = k_s \cdot \sqrt{2 \cdot g \cdot \Delta h} \quad (1)$$



**Figure 1** - Pitot and Darcy tubes

The advantage of Darcy tube in relation to the of Pitot tube is in the largest easiness for reading of the height difference, since, the pressure of the air after the valve can be reduced allowing to transport of the height difference for other place where the reading can be made with larger easiness.

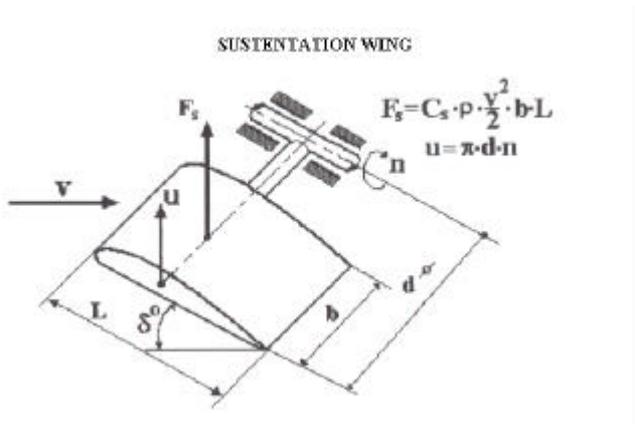
If there is the need of increasing the height difference is used the Darcy-Cole and Recknagel tubes. The coefficient these probes depend of its geometry, of the pressure takes in the points **a** and **b** and of Reynolds number  $-N_{Re}$ . For Reynolds Number between  $10^3 \leq N_{Re} \leq 4 \cdot 10^4$  the coefficient of captor Darcy-Cole is between  $0.84 \leq k_s \leq 0.89$ .



**Figure 2** - Darcy-Cole and Recknagel tubes

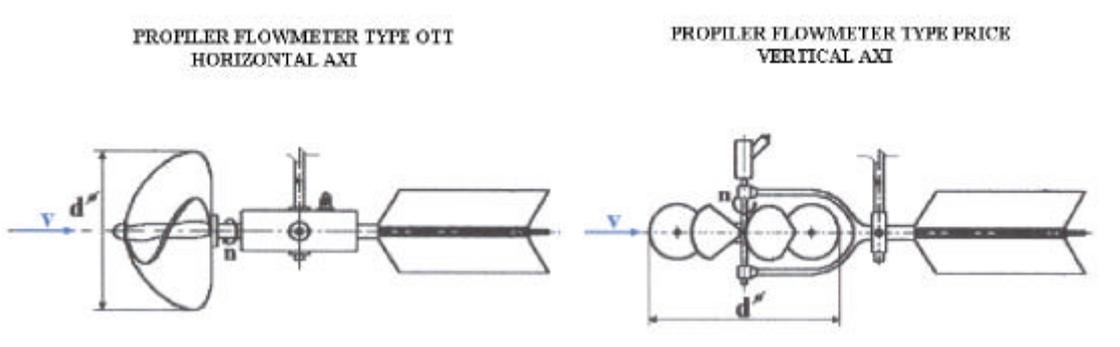
The propiler flowmeters operate for the principle of the sustentation wing. The rotation is established when the wing is dived in a fluid with an attack angle  $d$  in relation to direction of the draining speed  $v$ . A sustentation force  $F_s$  appears on the wing, in the perpendicular direction of the speed. This force is proportional to the product of the area wing by the speed to a square, This proportionality is the sustentation coefficient  $C_s$ .

If this wing is fixed to an axis, according it is shows in the figure 3, the sustentation force will give origin to a tangential speed  $u$ , which will provoke the rotation of the wing. This rotation is related with the draining speed by the expression  $v = a + b \cdot n$ .



**Figure 3** - Characteristics of a sustentation wing of fixed to an axis

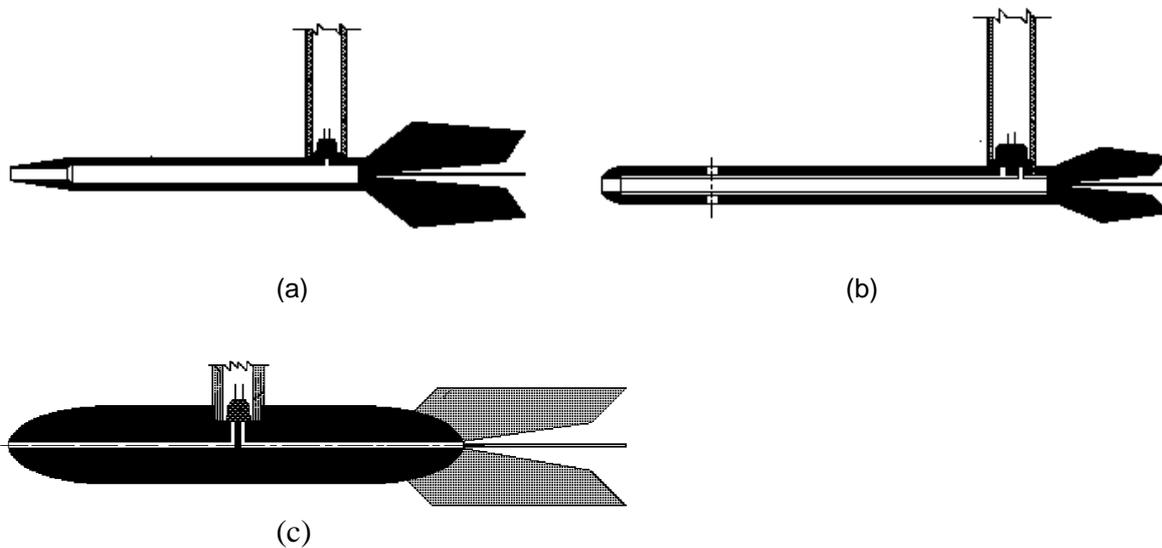
The propiler flowmeter can have horizontal or vertical axis and the shovels of the rotor of them can have many forms as illustrated in figure 4.



**Figure 4** - Typical propiler flowmeters

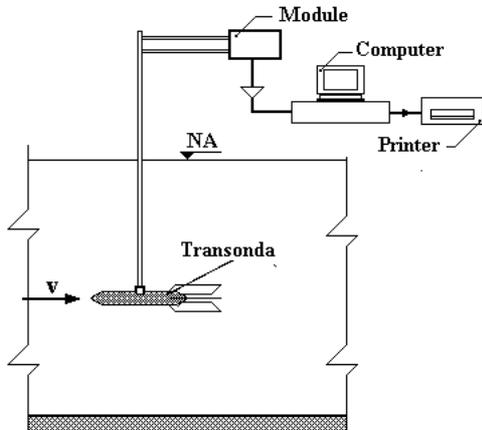
On the alignment of these flowmeters in relation to the draining speed direction, the common types are insensitive for angles of even  $\pm 5^\circ$ . There are special types which allow, with the same precision, angles of even  $\pm 45^\circ$ .

the basic models of the transondas compatibles with the Pitot, Plandtl and Darcy-Cole tubes are presented in figure 5.



**Figure 5** – The basic models of transondas

The figure 6 shows a complete system of speed measure. It is composed of a transonda, of a switch signs module, of a printer and of a computer inside of which there is a card of data acquisition and the software of data treatment.



**Figure 6** - System of mensuration of the proposed speed.

The great advantage between the transondas and the propiler flowmeters is the elimination of the rotation systems. This characteristic eliminates the problems with bearings and the turns accountant.

The system module-software-personal computer-printer allows the direct obtaining of the local speed. The distributed displacement of the transonda in the vertical plan allows the determination, once established the measure plans, the medium speed of the traverse section and, consequently, the respective flow.

The calibration of the complete system can be done of static way establishing a correlation between the pressure or difference pressure with electric sign and it making the calculation of the speed. Other way is install the transonda in series with a pattern and to obtain the direct relation between electric sign and the draining speed.

#### 4 PRELIMINARY TESTS

The first tests objectified to verify the behavior of the transonda in relation to a Prandtl tube. Firstly, It was considered only the stagnation pressure in many current lines of draining of air in permanent and stationary regime. The aspects of interest were the oscillation and the measured medium values. Secondly, considering the measures of the static pressures supplied by the Plandtl tube, it the objective was determine and confront the respective speeds.

The used methodology consisted of building a transonda coupling a body built in teflon to a pressure transmitter. This body has the same dimensions of the Prandtl tube and the pressure transmitter from MARKARE has a range of -300 and +300 (mmca). This preliminary version of transonda is shows in the figure 7.



**Figure 7** - First version of transonda

I eat it was already said, That transonda and the Plandtl tube were installed in series in the pressure pipe of a centrifugal fan, as shown in the figure 8.



**Figure 8** - Assembly of the probes in the pressure tube of a fan

Initially the calibration of the system transsonda was made with a pattern manometer of water column. In this case system was composed by the transsonda, for a sign switch module of 16 channels from Linx, a card of data acquisition of and a software of data treatment called Daisylab, from Advantech. The height of the water column was varied e it was obtained the corresponding electric tension. The equation 2 presents the calibration curve, where  $h_{stag}$  in (mmca) and  $V$  in (volts).

$$h_{stag} = -449,08362 + 175,44708 \cdot V \quad (2)$$

The transsonda and the Plandtl tube were positioned in series in the pressured tube of the fan in the following radial distances starting from the wall of the tube: 16; 28.8; 60; 82.3 mm.

After having established the respective permanent regimes, they were done 6 (six) readings of electric tension supplied by the transsonda and 6 readings of the stagnation and static pressures supplied by Plandtl tube for each position. The values these parameters are show in the table 1. The speeds were calculated by the equation 1, where  $k_s$  is 1 and  $g = 9,785 \text{ (m/s}^2\text{)}$ .

Table 1 - Result of the preliminary tests

Read values			Calculated values		
Transsonda	Plandtl tube		Transsonda		Plandtl tube
Voltage (V)	$P_{stag}$ (mmca)	$P_{stat}$ (mmca)	$P_{stag}$ (mmca) <sup>1</sup>	V (m/s)	V (m/s)
The radial distances starting from the wall of the tube is 16 mm					
3.316	151	44	132.67	1.32	1.45
The radial distances starting from the wall of the tube is 28.6 mm					
3.392	165	49	146.09	1.38	1.51
The radial distances starting from the wall of the tube is 60 mm					
3.369	159	47	141.97	1.37	1.48
The radial distances starting from the wall of the tube is 82.3 mm					
3.362	157	43	140.86	1.3	1.50

The figure 9 shows the behavior of the speeds and of the pressures in function of the distance from the wall of the tube.

<sup>1</sup> equation 2

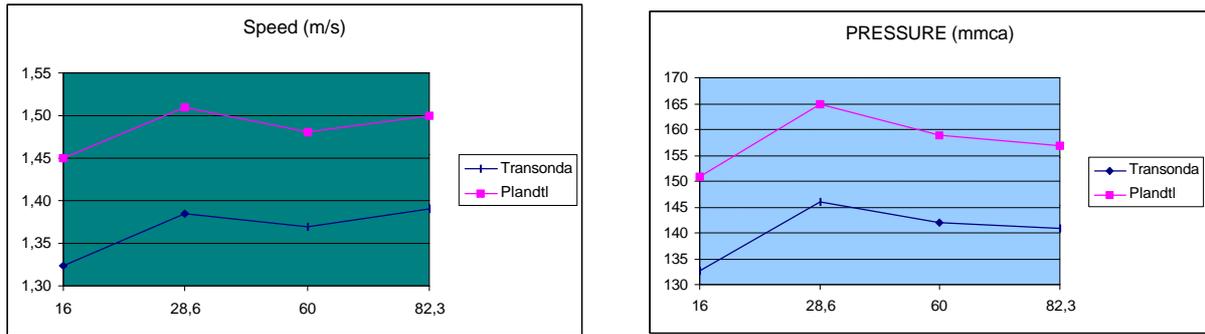


Figure 9 – The behavior of the speeds and pressures in function of the distance from wall of the tube

## 5 DEVELOPMENT AND TESTS OF THE PROTOTYPE

Starting from the preliminary tests was built a transonda (figure 10) composed of the following parts: A central body which enclosed a pressure sensor of range of 0 to 500 (mmca); a wrapping to protect the sensor and to support the transonda by its stem; a stagnation pressure take and static pressure take in which the were fix the directional fins.



Figure 10 - Prototype of the transonda.

Similarly to the preliminary tests, the prototype of the transonda was set up in series with the Plandtl tube in the pipe of pressure of the fan. The electric current from transonda was measured with a multimeter and the difference pressure supplied by the Plandtl tube was measured with a manometer in U, as presented in the figure 11.



Figure 11 - Assembly of the prototype and of the Plandtl tube in the work-bench

In this test the calibration of the transonda against the Plandtl tube was made in the pressure tube of the fan to eliminate the systematic error verified in the preliminary tests. Both instruments were installed in the center of the pressure tube of the fan. Initially, for each flow were made 6 (six) readings of the electric current from transonda and 6 reading of the difference of pressure ( $P_{\text{estag}} - P_{\text{stat}}$ ) supplied by the Plandtl tube. The medium values are presented in the table 2.

Table 2 – The results of the prototype tests

Read values <sup>2</sup>		Calculated values		
Plandtl tube	Transonda	Plandtl tube	Transonda	
$\Delta h$ (mca)	i (mA)	$v^3$ (m/s)	$\Delta h^4$ (mca)	$v^4$ (m/s)
0,052	4	1,01	0,053	1,02
0,068	4,5	1,15	0,066	1,14
0,080	5	1,25	0,078	1,24
0,090	5,5	1,33	0,091	1,34
0,104	6	1,43	0,103	1,42
0,113	6,4	1,49	0,113	1,49
0,116	6,5	1,51	0,116	1,51

Therefore, It was obtained the correspondence among the difference pressure and the electric current, as presented by the equation 3, where  $\Delta h$  is in mca and  $i$  is in mA.

$$\Delta h = -0,04674092 + 0,025036452 \cdot i \quad (3)$$

To follow the draining speed was calculated with the equation 1 and it was established the correspondence of the speed with the electric current, according to equation 4, where  $v$  is in m/s.

$$v = \sqrt{-0,95321552 + 0,4989361 \cdot i} \quad (4)$$

## 6 ANALYSIS AND CONCLUSIONS

The analysis and the conclusions of the preliminaries tests are:

- The values of the stagnation pressures read during the tests, according with the Table 1, presented equivalent oscillations between transonda and the Plandtl tube. In this aspect, this demonstrates that the transonda can operate well in gaseous draining.
- The systematic error verified among the speeds supplied by the transonda and by the Plandtl tube is due to the fact of the calibration to have been accomplished with water and the tests to have been accomplished with air.
- The relationships among the medium stagnation pressures stayed practically constant, i.e., 0.88; 0.88; 0.89; 0.90. This indicates that there is a good possibility of being obtained a constant of calibration or, in the maximum, a linear function of calibration. The same considerations are valid for the speeds.

The analysis and the conclusions to the tests that the prototype are:

- The oscillations presented in the preliminary tests recommended to build and to test in air a differential transonda.
- The smaller error of the curves of calibration of the prototype demonstrates that the differential transonda is a good instrument for that application. This argument is countersigned considering that the standard deviation among the measured speeds for the two instruments is inferior to 1 percent.

<sup>2</sup> Average value of 6 reads.

<sup>3</sup> As equação 1. The calibration Error is smaller than 0,2 %.

<sup>4</sup> As equação 4. The calibration is 1% approximately.

## 7 THE NEW STAGE OF THE DEVELOPMENT

The next steps of the research are the substitution of the current pressure sensor for other with compatible range to a speeds found in channels and rivers (0 to 80 mmca) and it to make the tests in water and it compares the results with the propiler flowmeter.

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