

## PRELIMINARY DESIGN STUDY TO IMPLEMENT MULTIPURPOSE VIRTUAL SENSORS

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**Abstract:** This paper describes a method to perform the task of measuring some different magnitudes with a unique differential pressure transducer. To do so, it is necessary to perform the task of calibrate the primary elements of transducers by computing the acquired data with significant non linearities and time varying parameters mainly in the primary element of transducers. The estimated value of any measured variable is the output of a virtual sensor implemented by means of a virtual engineering programming tool.  
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### 1. INTRODUCTION

Some measuring installations mainly for control applications in chemical industries where corrosive gases or fluids, as well as fluids, which crystallise or solidify easily are encountered, needs sophisticated instrumentation. In order to reduce the amount of such devices it is intended to implement a measuring system based in the use of multipurpose instrumentation. The concept of multipurpose instrumentation means that a unique device can perform the task of measuring sequentially and cyclically several different magnitudes.

When such exceptionally chemicals like corrosive gases or fluids, or fluids that crystallise or solidify are processed into a reactor where processing data is required, special care must be taken to select proper measuring devices. In many cases pressure repeaters are necessary. That is, magnitudes such temperature pressure, level or flow can be measured by means of a multipurpose transducer connected to pressure repeaters as shown in figure 1.

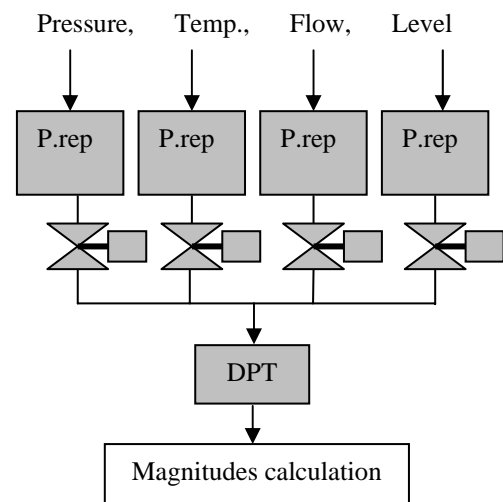


Fig. 1. Structure of a multipurpose measuring device

The basic idea consists in use primary elements such that its measuring magnitudes can be converted into differential or gauge pressure by means of pressure repeaters (P.rep). A pressure repeater detects process

pressure and repeats the same ratio 1:1 pneumatic output signal. This can be done easily for measure magnitudes such as pressure, temperature flow and level, and in general magnitudes whose primary elements generates a differential pressure and consequently can be measured by means of differential pressure transmitters (DPT). With this structure, multiplexing the output signal of the pressure repeaters permits to measure every magnitude in a cyclic and sequential measuring task.

In the case of conventional fluids a classic structure can be adopted in which pressure repeaters are not necessary. It consists in using a DPT for every measuring magnitude as shown in figure 2.

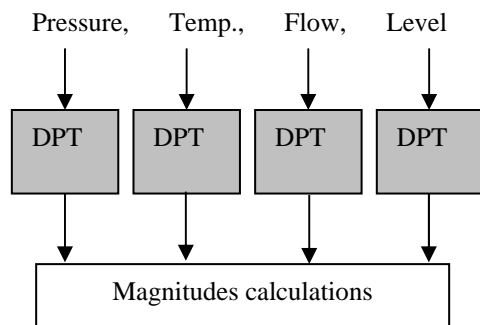


Fig. 2. Structure of a measuring system based on DPT as primary element.

In section 2 a strategy to develop the measuring system by means of a proper algorithm included functional approximation is described. In section 3 an implementation of the program to calibrate and exploit results are described. In section 4 some conclusions are achieved.

## 2. VIRTUAL SENSORS DESCRIPTION

A standard differential pressure transmitter is the key hardware (Tari Ozkul, 1996) to develop a measuring system based in virtual measuring methods to display virtual measured magnitudes.

There are many cases in which differential pressure is applied as input variable to measure other magnitudes such as flow, level, gauge pressure and in special applications, temperature. Some standard series intelligent two-wire DP, measure the difference between two pressures and transmit a proportional or square root (flow) electrical signal, in either analog (4-20 mA) or digital mode. In this work it is assumed that such device is being used under digital output and consequently differential pressure is expressed by a real number. If no differential pressure but only gauge pressure is necessary to acquire a particular magnitude like for instance a temperature captured by means of a

filled bulb, the low pressure connection of the DPT is open to the atmosphere pressure.

Virtual sensor implementation requires the task of adjusting every magnitude to be measured. This procedure requires a master measuring device for each magnitude to be adjusted.

Adjusting procedure consists in read experimental data gathered from every magnitude by means of a proper master sensor and stores the input/output data under a mapped data structure. Figure 3 shows the block diagram of a sequence to acquire the necessary data for an adjusting procedure.

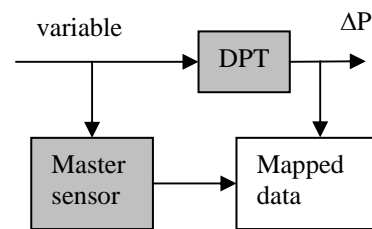


Fig. 3. Mapping data into an associative memory

Mapped data consist in a deterministic associative memory which once stores, can be used not only to measure any magnitude in a virtual mode but also to detect changes at the primary element of the DPT. In this case we are performing a diagnostic task of the sensor. Mapped data can be arranged into an array structure.

In Table 1 it is shown an example of mapped data from a master flow sensor and the output value of a DPT. Obviously there is a non linear relation between input and output

Table 1. Mapped data from a flow sensor calibration task

Flow (dm <sup>3</sup> /s)	0	1	2	3	4
ΔP (bar)	0	.1	.14	.17	.2

Here are proposed three main procedures to extract virtual information from an associative memory.

The simplest method to extract information from stored mapped data is to look for the array element whose index is the actual value given by the output variable of the DPT. If more precision is required, then a linear interpolation improves the results.

Another method consists in using a Lagrange interpolation algorithm, which is particularly useful when the number of elements of acquired array are not numerous.

Under the same circumstances of above described case, a functional approximation algorithm based in a polynomial regression of high order is an alternative.

In all cases, data to be entered into the virtual sensor is the output of the DPT, while after applying one of the described methods of magnitude evaluation, its result is the output of the proposed virtual sensor as shown in figure 4.

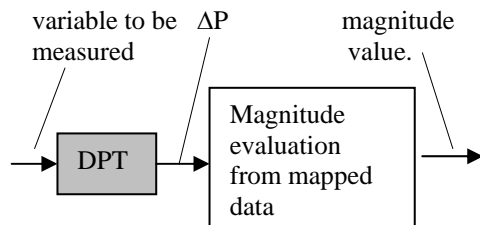


Fig. 4. Scheme of a virtual sensor exploitation.

### 3. PROGRAM IMPLEMENTATION

Implementation of proposed virtual data acquisition system, which is based mainly in the application of differential pressure transmitters, require to apply a real time management program, developed with the help of an object oriented programming tool like HP- Vee from Hewlett-Packard or Delta V (PlantWeb) from Fisher-Rosemount, among some others.

In figure 5 it is shown the results of a task in which there are two operations: The virtual flow sensor calibration and the application of such a virtual sensor. The sub-task dedicated to the sensor calibration read co-ordinated data from a master flow sensor and data from a differential pressure transmitter connected to both sides of a flow nozzle (square edge orifice plate meter) of the pipe. This pares of data are stored by an associative memory to be used in the sub-task dedicated to virtual sensing.

In the sub-task of virtual sensing, data from the smart differential pressure transmitter is processed according selected algorithm

- Linear interpolation
- Lagrange interpolation
- Linear approximation
- Polynomial approximation

Optionally, polynomial approximation of 3d-order degree is applied.

Right hand display of figure 5 shows that the variation of the magnitude to be measured illustrates two graphs. Each graph is associated to the value of the output of pressure transmitter and the algorithm processed to determine the fluid flow. The value of

interest is really the output of the algorithm, which represent the actual virtual flow.

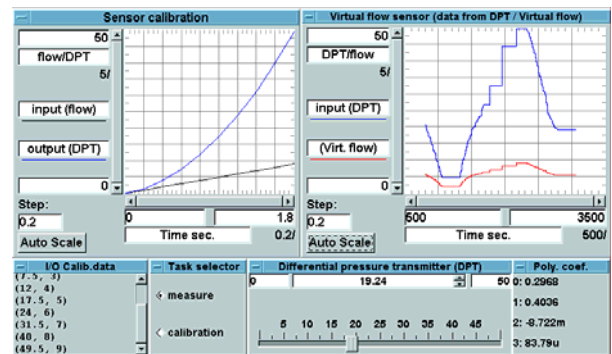


Fig. 5. Virtual flow sensor calibration and application results.

### 4. CONCLUSIONS

In this work, a general guide to compute the value of several measuring magnitudes with low hardware installation is described.

The application or use of a unique type of transmitter (a standard and intelligent differential pressure transmitter) for measuring different magnitudes represents an advantage.

The ability of the method to perform a diagnostic task based in the knowledge about DPT behaviour is another advantage.

The advances in virtual engineering programming tools bring the possibility to implement any virtual instrument at low cost or effort mainly due to the facilities for implement object oriented multitask computations.

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