FLOW SENSOR

SIARE “MicroFlow”

SIARE "MicroFlow" FLOW SENSOR

The aim of research and development activity promoted by SIARE ENGINEERING INTERNATIONAL GROUP srl, is to realise a flow sensor at magnetic disturbance to be inserted in the pulmonary ventilators of SIARETRON, SIRIO PLUS, MORPHEUS and FALCO lines.

WHEREAS: STATE OF THE ART IN FLOW SENSORS FOR RESPIRATORY USE

In order to opportunely focus in the issue, it is useful to resume briefly the various techniques that, nowadays, are used for measuring the flow mixtures inspired and/or expired by the patient.

Before reviewing the different types of sensors it is necessary to make some considerations on measurements and sensors requirements. The sensor should resist to any airways pressure during respiration (i.e. , the PEEP).

Furthermore, the sensor should not oppose to much resistance to the inspired and/or expired flow (the American Thoracic Society suggests for volumetric flowmeters used for the forced expiration tests a resistance to the flow lower than 1.5 cmH2O/(l/s)).

The sensor must respond to a series of specific statistics and dynamics (accuracy, precision, resolution, reproducibility, statistical control, static sensitivity, controlled zero drift and sensitivity, linearity, wide range of inputs, adequate inlet impedance, order of the system which models the known sensor, know exit delay).

With respect to the expiratory flow one of the major contaminant factor is the water or the water vapor; the sensor could be a dew point of water vapor.

To avoid this phenomenon the sensor sensitive part could be heated at a temperature higher than the body one.

The temperature and gas composition changes can alterate the calibration values of the various spirometers.

The sensor should alterate as less as possible the system which is going to measure. The main features of the sensor are: range amplitude, measurement accuracy, frequency response.

The most common volumetric flow sensors for application in respiratory field are the following:

1. The flow sensors by **ROTATING VANE (TURBINE)**: they are based on the movement of a turbine, whose rotation can be connected to gas flow.

The mass of mobile parts and their friction are the main limits to the use of this type of sensor.

The turbine hardly follows the high frequency movement of the flow due to its inertia.

This sensor type, because of the wide margin of error that is subject, is suitable for an initial clinical investigation, not too deep.

2. **HEAT CONVENTION (HOT WIRE)** flow sensors**:** they use as sensitive elements wires and metallic films and thermistors which vary the electric resistance upon temperature.

They can be used in different modalities. In the self-heating modality the wire is traversed by a current that heats to a temperature higher than that of the fluid, and passing through, it removes the heat; the rate of haeat loss depends on the local mass flow, on the temperature, on the specific heat, by kinematic viscosity and on thermal conductivity of the fluid.

By means of a feedback circuit, it is possible to keep constant the temperature of the sensitive element

A second not heated wire can be used to compensate the local effects caused by temperature. Anyhow, the wire is affected by the water vapor.

It works well with those gases whose properties are sufficiently constant.

The outlet voltage of these circuits is a non-linear function of the mass flow.

The flow sensors which uses this principle are called hot-wire anemometers and they are used both for one-way and two-way flows.

The wire has a diameter of 5 micron and a lenght of half a millimeter.

For a gas at constant density the volumetric flow passing through a cross section is proportional to the mass flow average on the section.

Considering this is a local measurement, the sensor must be positioned on a representative point of the line.

To have information on the flow direction it is possible to position more than one sensor in the flow direction.

The variable composition of the expired gases can alterate the transfer of heat from the heated wire.

The sensor must be calibrated for the particular gas mixture to which is exposed.

The disadvantages of the hot wire anemometers for the respiratory applications are the following: they must be heated to burn the external substances and during these phases the reading of respiratory parameters like tidal volume and expired volume, breathing rate is performed.

3. **DIFFERENTIAL PRESSURE** flow sensors**:** they are based on a known relationship and, possibly, linear relationship between pressure difference and flow.

It is possible to measure the flow through the measurement of a pressure.

Among these measuring instruments the Venturi tube and the Orifizi[1] which have a linear relationship between pressure and flow and also use calibration cards.

There is also the Pneumotacometer: it is the reference point of the respiration laboratory; it uses the resistances which creates a nearly linear relatioship between pressure and flow.

The resistance is formed by a grid or a bundle of capillary tubes. Also in case of not stationary flows these resistances allow to have a nearly linear relationship between flow and pressure.

This instrument can distinguish the flow way.

The pressure outlets or tubes positioning are critical choices which determine the relationship between pressure and flow.

It is necessary to find the best compromise between the exigence of linearity, which would require a large axial distance between the pressure outlets, and the introduced error which increases, due to inertial phenomena, as increases the distance between the pressure outlets.

To prevent the formation of vortices, the area of cross section in correspondence of resistive elements must be quite large to reduce the gas speed.

The volume within the adapters ed the line must be considered in the calculation of dead space for cyclic gas administration to the patient.

[1] De O. Fortuna A., Gurd J.R., 1999.

The mathematical model describing the pressure failure foresees to include a resistive term, which takes into consideration the viscosity of the gas, and an inertial term, which takes into consideration the inertial effects.

The problem of these sensors is that the grid and the tubes can be blocked by external substances.

In the respiratory applications these sensors are located nearby the patient on the Y connector, therefore they are highly subject to receive an expiratory flow rich of humidity and small secretions.

Such components can easily come into the 2 lines which detects the airways pressure signal upstream and downstream of known resistance within the sensor creating a variation of such signal, and even its reading failure.

To prevent the above, these systems foresee periodically the generation of a flow to release the 2 lines from moisture and undesired particles.

Obviously, during such a phase no respiratory parameters, like tidal volume and expired minute volume, breathing rate are detected.

OPERATION PRINCIPLE OF MICROFLOW SENSOR

In consideration of these disadvantages, Siare Engineering International Group in 1993 decided to design a dedicated sensor for spirometry applications in lung ventilation and realized a flow sensor which is made of a steel foil at high magnetic permeability, connected, on one side only, to a metallic support, so to form an interlocking shelf; the tab, as the result of the stress produced by the flow, moves from its equilibrium position.

Its movement produces an inductance variation (using the auto-induction phenomenon) of two coils.

The signal is detected and sent to an electronic board where a dedicated electronic component, the AD598 (LVDT Signal Conditioner)[2] in the Half-Bridge Transducer configuration, provides to transform the variation of position into a voltage related to the shift from a non-linear relationship.

The AD598 electronic component was designed to elaborate a signal arising from a phenomenon of auto and mutual induction.

The mutual inductance (M) and the autoinductance (L) have the same physical dimensions but, if in case of a device of LVDT type the signal is proportional to the difference between the inductances of the two winding, in the case of the examined sensor the electric signal to elaborate is related to the variation of L inductance from a non-linear relationship.

Finally, the signal, once transformed into electric signal, will be elaborated by a microprocessor and sent to a display.

The great advantage of this sensor respect to the other is that it is not affected by humidity and it does not need periodic calibrations during its use; furthermore, it is reusable as long as it should occur an accidental or mechanical break, being chimically or steam-disinfectable, unlike the other which are mainly disposable or single-patient use.

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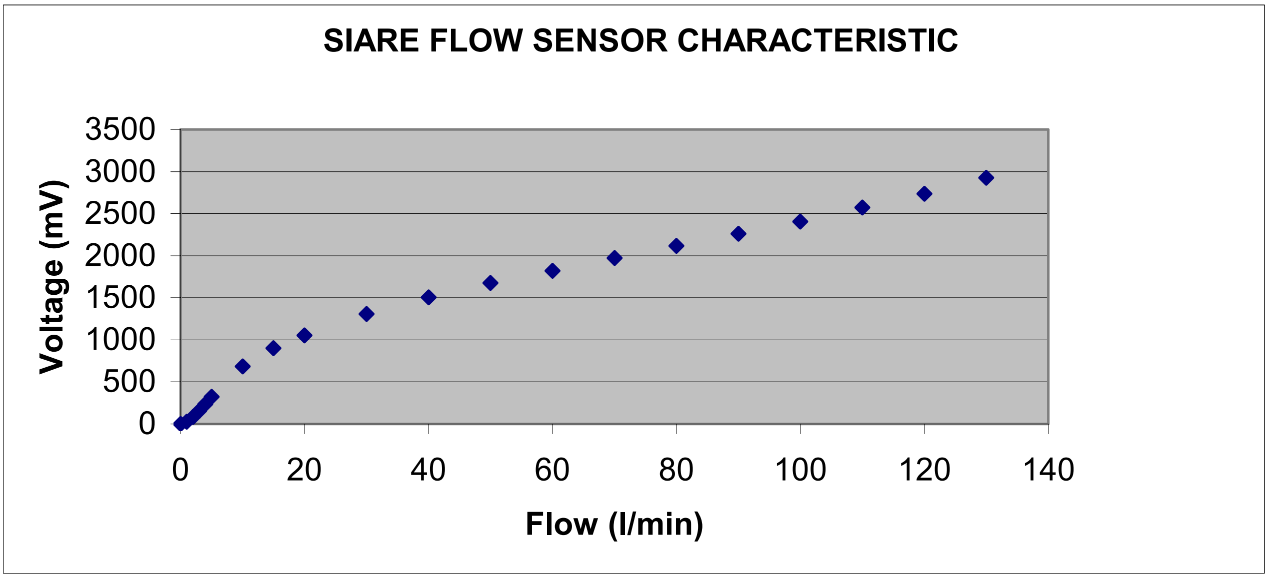
[2] V. Data Sheet dell'Analog Devices.



Thanks to the sensitivity, due to its operation principle, the flow sensor is able to detect very low flows from 0,1 l/min, which allow to have the reading of tidal volumes from 5ml; therefore, it is suitable for monitoring respiratory parameters in neonatology, also in case of prematures.

Since 1995 around 8000 ventilators were installed in anaesthesia, resuscitation and emergency departments which detect the patient breathing parameters through this flow sensor ensuring a reliability and constant accuracy over time of its measurements.