**Association européenne pour la Biomasse**

**European Biomass Association**

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## Report to project Key Issues for Renewable Heat in Europe - K4RES-H

# Measuring bioheat

Task 4.2., deliverable 7, July 2006

# 1. Introduction

The purpose of this report is to identify the technologies used to measure the energy output of a bioheat installation and to give a rough estimation of the cost. We focus here on sensors implemented to measure the calorific power and energy for a water circuit, for example in a central heating unit.

It should be noted that heat dispersion by convection or radiation are not covered by direct measurement. It means that stoves are not covered by the present report.

# 2. Principle

Different types of parameters have to be measured to calculate the quantity of heat produced :

- the flow F [$m^3$ / s]
- the temperature:
    - the in temperature $t_{in}$ [K]
    - the out temperature $t_{out}$ [K]
- the time t [s]

Those parameters allow calculating the heat power P [kW]:

$$P = \rho * C_p * V * (t_{in} - t_{out})$$

With :

- ρ: the volumetric mass [kg/ $m^3$ ]
- $C_p$ : the mass heat capacity [J/ (kg*K)]

The mass heat capacity depends on the pressure, the temperature and the nature of the fluid used. For example, if the water contains glycol in a certain percentage, it is necessary to adapt $C_p$. If the pressure varies, it is also necessary to measure it.

> *Definition*
> Mass heat capacity: quantity of energy, bring by heat exchange, for increasing the temperature of one unit of mass by one degree[1].

With the power, it is possible to calculate the quantity of heat energy Q [kJ] [2]:

$$Q = P * t$$

[1] GIECK K. + R. (1997) Formulaire technique. Gieck Verlag, D-82110 Germering
[2] BERA F. (April 2006), personal communication. Professor in the “technologie des industries agroalimentaire”, Faculté des sciences agronomiques de Gembloux, Belgium

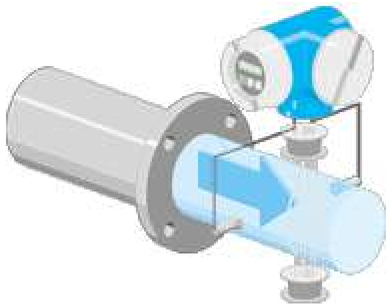
# 3. Sensors

## 3.1. Flow meter

There are a lot of types of flow meter which can be used:
- electromagnetic flow meter (used for conductive liquid: water, water with glycol)
- coreolis mass flow meter
- ultrasonic flow meter
- vortex flow meter
- flow meter with irradiation impeller

**Principle of electromagnetic flowmeter[3]**

Faraday's law of induction states that a conductor moving in a magnetic field induces an electrical voltage. With a magnet, the flowing fluid is the moving conductor. The constant-strength magnetic field is generated by two field coils, one on each sides of the measuring tube. Two measuring electrodes on the inside wall of the tube are at right angles to the coils and detect the voltage induced by the fluid flowing through the magnetic field. The induced voltage is proportional to flow velocity and thus to the volume of the flow.



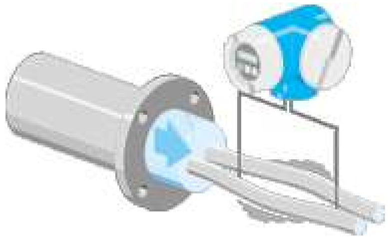
The magnetic field is generated by a pulsed direct current with alternating polarity. This ensures a stable zero point, and makes the measurement insensitive to influences from multiphase or inhomogeneous liquids or low conductivity.

*Advantages of electromagnetic flowmeter*

- The principle is virtually independent of pressure, density, temperature and viscosity
- Even fluids with entrained solids can be metered (e.g. ore slurry, cellulose pulp)
- Large nominal-diameter range available (DN 2...2000)
- Free pipe cross-section (CIP/ SIP cleaning, piggable)
- No moving parts
- Minimum outlay for maintenance and upkeep
- No pressure losses
- Very high turndown up to 1000:1
- High degree of measuring dependability and reproducibility, good long-term stability

[3] www.endress.com, April 2006

**Principle of coreolis mass flowmeter[3]**



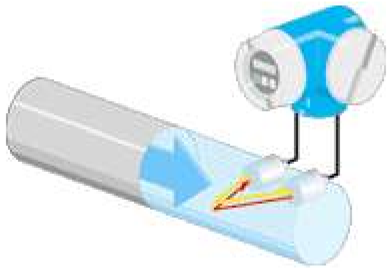
If a moving mass is subjected to an oscillation perpendicular to its direction of movement, Coriolis forces occur depending on the mass flow. A Coriolis mass flow meter has oscillating measuring tubes to precisely achieve this effect. Coriolis forces are generated when a fluid (= mass) flows through these oscillating tubes. Sensors at the inlet and outlet ends register the resultant phase shift in the tube's oscillation geometry. The processor analyzes this information and uses it to compute the rate of mass flow. The oscillation frequency of the measuring tubes themselves, moreover, is a direct measure of the fluids' density.

The temperature of the measuring tube is also registered for compensating thermal influences. This signal corresponds to the process temperature and is also available as an output signal.

*Advantages of a Coriolis mass flow meter*

- Universal measuring principle for liquids and gases
- Simultaneous and direct measurement of mass flow, density, temperature and viscosity (multivariable sensors)
- Measuring principle is independent of the physical fluid properties
- Very high measuring accuracy (typically ±0,1% o.r.)
- Not affected by flow profile
- No inlet/ outlet runs necessary

**Principle of ultrasonic flowmeter [3]**



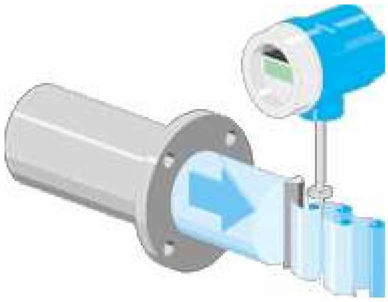
Swimming against the flow requires more power and more time than swimming with the flow. Ultrasonic flow measurement is based on this elementary transit time difference effect. Two sensors mounted on the pipe simultaneously send and receive ultrasonic pulses. At zero flow, both sensors receive the transmitted ultrasonic wave at the same time, i.e. without transit time delay. When the fluid is in motion, however, the waves of ultrasonic sound do not reach the two sensors at the same time. This measured "transit time difference" is directly proportional to the flow velocity and therefore to flow volume.

*Advantages of ultrasonic flowmeter*

- Non-contact measurement from outside. Ideal for measuring highly aggressive liquids or fluids under high pressure

- With homogeneous fluids, the principle is independent of pressure, temperature, conductivity and viscosity
- Usable for a wide range of nominal diameters (DN 15...4000)
- Direct meter installation on existing pipes. Retrofitting is also possible
- Commissioning without process interruption
- Non-invasive measurement
- No pipe constrictions, no pressure losses
- No moving parts. Minimum outlay for maintenance and upkeep
- High life expectancy (no abrasion or corrosion by the fluid)

**Principle of vortex flow meter [3]**



This measuring principle is based on the fact that vortices are formed downstream of an obstacle in a fluid flow, e.g. behind a bridge pillar. This phenomenon is commonly known as the Kármán vortex street. When the fluid flows past a bluff body in the measuring tube, vortices are alternately formed on each side of this body. The frequency of vortex shedding down each side of the bluff body is directly proportional to mean flow velocity and therefore to volume flow. As they shed in the downstream flow, each of the alternating vortices creates a local low pressure area in the measuring tube. This is detected by a capacitive sensor and fed to the electronic processor as a primary, digitized, linear signal.
The measuring signal is not subject to drift. Consequently, vortex meters can operate an entire life long without recalibration.
Capacitive sensors with integrated temperature measurement can directly register the mass flow of saturated steam as well, for example.

*Advantages of vortex flow meter*

- Universally suitable for measuring liquids, gases and steam
- Largely unaffected by changes in pressure, temperature and viscosity
- High long-term stability (lifetime K factor), no zero-point drift
- No moving parts
- Marginal pressure loss
- Easy to install and commission
- Large turndown of typically 10:1 to 30:1 for gas/ steam or 40:1 for liquids
- Large temperature range from -200...+400 °C

**Flowmeter with irradiation impeller[4]**

It is a measuring instrument which determines the flow with the rotation velocity of the impeller. After flow of a specific volume, the flowmeter sends an impulse to the calorimeter.

[4] www.resol.de, April 2006

The figure 1 shows flowmeter with irradiation impeller

*Figure 1 : Flowmeter with irradiation impeller*

## 3.2. Temperature sensor

Two types of temperature sensors can be used in this application :
- the resistance temperature detector
- the thermocouple thermometer

**Resistance temperature detector [3]**

A Resistance Temperature Detector (RTD) is a temperature responsive device based on a predictable resistance change in the sensing element. The EN 60751 standard specifies requirements for industrial Platinum resistance sensors and covers the Pt 100 thermometers.

The Pt 100 sensing element has a resistance of 100 Ω at 0°C.

According to EN standard and most common industrial applications, the Pt 100 type sensors are used for temperature measurement and control in the range from -50°C to 400°C or -200°C to 600°C.

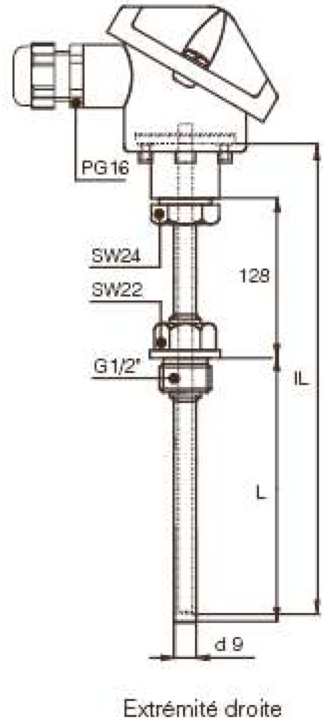
RTDs offer three main advantages:
- high accuracy
- excellent long-term stability
- high signal output level which allows transmission over long distances without ancillary equipment.

Basic construction of Platinum resistance elements cannot be used directly in contact with process environments, hence the complete thermometers are built as assemblies which can withstand light, medium and heavy duty industrial conditions.

In general, the sensor assembly includes three components:
- the resistance thermometer inset
- the protecting tube (thermowell)
- the terminal housing.

The figure 2 shows a RTD PT 100

*Figure 2: RTD PT 100*




**Thermocouple thermometer** [3]

A thermocouple (TC) consists of two wires of different conductive material, connected each other by means of two junctions forming an electrical circuit. If one junction is at temperature T1 and the other at T2, then an electromotive force is generated in the circuit, that depends on the materials and temperatures T1 and T2 (Seebeck effect). In an industrial TC thermometer one junction is the measuring joint, and the other is a reference one which is usually located in correspondence of the conversion electronics (transmitter).

According to EN/ ANSI standards and most common industrial applications, the thermocouple sensors are used for temperature measurement and control in the range from -40°C to 1800°C.

Thermocouples offer three main advantages:
- good accuracy
- excellent response time
- wide measuring range (especially for highest temperatures)

Basic construction of thermocouple sensing elements cannot be used directly in contact with process environment; hence the complete thermometers are built as assemblies which can withstand light, medium and heavy duty industrial conditions.

In general, the sensor assembly includes three components:
- the thermocouple inset
- the protecting tube (thermowell)
- the terminal housing

The price of that sensor is about 30 €

### 3.3. Calculator

With the above described sensors, the parameters are measured. But it is necessary to calculate the calorific power and the calorific energy using an electronic calculator. Such device can give instantaneous measurement values as well as cumulative values.

## 4. Cost/benefits

As it is explained beforehand it is easily possible to measure the calorific power and the calorific energy. But the price of these systems can vary a lot. The following costs have been collected for three systems in order to give a rough estimation. VAT was excluded.

a. Flow meter for small scale systems

A typical system is sold by Resol Gmbh, made of :
- 1 flow meter with impeller (DN 20: 147 €- DN 32 : 315 €)
- 2 resistance temperature detector PT1000 (14 €* 2 = 38 €)
- 1 calculator (136 €)

The complete system is available for 321 – 489 €

b. Flow meter for industrial application

- For the system of Endress and Hauser made of :
  - 1 electromagnetic flow meter (DN 50: 1 711 €- DN 200: 3 062 €)
  - 2 resistance temperature detector PT100 (2*237 €)
  - 1 calculator (726 €)

The complete system is available for 2911 – 4262 €

- For a coreolis flow meter the price increase in the range of 8 000 €

A measuring system has to be installed in any case when there is a need for industrial processes or when the heat is sold.

For small scale bioenergy systems the same principle as for fossil based system applies. Measuring devices are almost never installed expect on special request by the customer. The amount of bioheat is barely known by the small scale users that have only an interest in the biomass for heat.

We cannot argue that promoting the installation of measurement systems at small scale will improve statistics because only a small fraction of the systems will be equipped and the efforts to collect the data would be disproportionate.

However measuring the heat output would sensibilize the owner of the boiler to the efficiency of the system and possible heat losses.

As conclusion we can state that adding some hundreds of euros to the investment costs of small scale biomass boilers would not make sense according to this brief cost/ benefit analysis. This would increase the investment costs barriers for biomass boiler (see report on financial incentives).

**Useful addresses**

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