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A DIGITAL CALORIMETER AND ITS APPLICATIONS IN CHEMICAL INDUSTRY

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In addition to parameters such as temperature, pressure, quantity of streaming material, as well as various other physico-chemical parameters, the quantity of heat is a very important characteristic figure in the chemical, pharmaceutical, and energetical industries, etc., and any other industrial branch where thermal energy is used or produced. Until a few years ago, the simple, accurate and reliable determination was solved by the development of the Digital Calorimeter type DIGITCALOR NORX QM-121. (Hungarian Patent No. 158.601 of the United Chemical Works.)

The above-mentioned continuous-operation, digital calorimeter enables the quantity of heat brought into or carried away from a system by a streaming medium to be determined, both as an instantaneous value and as one integrated for a given period of measurement.

PRINCIPLE OF OPERATION

The quantity of heat absorbed or emitted by a system can be determined on the basis of the following equation:

$$Q = V \gamma c \Delta\Theta \qquad \text{kilocalories/hour} \qquad (1)$$

where

V is the amount of heat transfer medium (cu.metre/hour)

γ is the density of the heat transfer medium (kg force/cu.metre)

c is the specific heat of the heat transfer medium (kilocalory/kg force.^{o}C)

$\Theta = \Theta_{out} - \Theta_{in}$ is the temperature difference in the heat transfer medium.

The quantity of heat absorbed or emitted by the system during a period T can be determined by the equation

$$Q = c\ \gamma \int_{o}^{T} V\ \Delta\Theta\ dt$$

or, using summarization instead,

$$Q = c\ \gamma \sum_{i=0}^{n} V_i\ \Delta\Theta_i\ \Delta t_i \qquad (2)$$

The algorithm of the operation of the digital calorimeter is given by Equation (2).

The amount and temperature difference of the streaming heat transfer medium is measured, the product of the two values is produced, corrected by the constant $c\ \gamma$, and the results obtained are summarized for a given measurement period T by the instrument.

It follows from the algorithm of the operation that the following conditions are to be fulfilled in the measurement:

1. No process involving a latent heat (change in physical state, and chemical reaction, etc.) may occur in the heat transfer medium.

2. The specific heat and specific gravity of the heat transfer medium can be regarded as constant and their temperature dependence can be neglected.

The above conditions are met with in the overwhelming majority of measuring tasks and in such cases the calorimeter operates at the prescribed level of accuracy.

The block diagram of the instrument is shown in Fig.1.

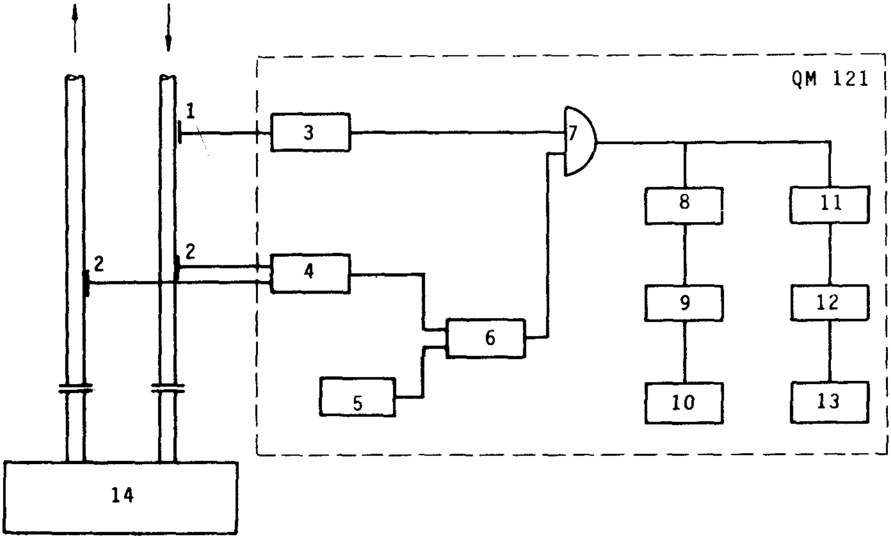


Fig. 1

The volumetric flow rate of the heat transfer medium flowing into system 14 is measured by turbine-type flowmeter 1. Quantity meter 3 transforms the output signal of the turbine-type flowmeter - which is an approximately sine-wave signal of a voltage higher than 10 mV and of a frequency of 0 to 2000 Hz - into a train of pulses corresponding to the level of the TTL logic. This signal is conducted to the first input of AND-gate 7.

The temperature of the medium on entering and leaving is measured by resistance thermometers 2. Temperature difference measuring unit 4 converts the signal of the resistance thermometers into a DC signal: a DC voltage proportional to the temperature difference appears at its output. This voltage is compared to a lineary varied reference voltage by comparator 6. The reference voltage is produced by generator 5. A time-code, proportional to the temperature difference, appears at the output of comparator 6 in the form of a logic signal of varied switching ratio.The latter signal controls the second input of AND-gate 7 and consequently the AND-gate is open and allows the pulses of the quantity measuring unit to pass for a period proportional to the temperature difference.

The number of pulses appearing at the output of the AND-gate is proportional to the product of the signals conducted to the input of the gate, that is to say, with the heat quantity.

The pulses appearing at the output of AND-gate 7 are counted by counter 8. The content of the counter passes intermediate storage 9 and is shown in a digital form by display 10. Summarization is carried out - via frequency devider 11 and switching amplifier 12 - by electromechanical pulse counter 13.

Fig. 2 illustrates the time diagram of the operation showing: the analog signal of temperature difference meter 4; the linearly varied reference voltage; the controlling signal of comparator 6,the output signal of quantity meter 3, and the train of pulses appearing at the output of the AND-gate.

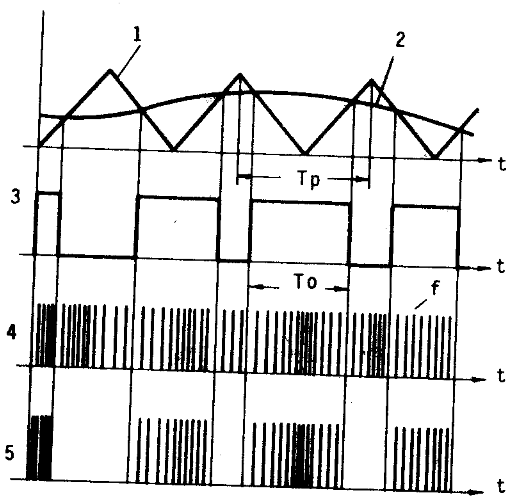


Fig.2. Diagram of operation plotted against time 1: linear reference voltage; 2: voltage proportional to temperature difference; 3: output of comparator (6); 4: output of quantity meter (3): 5: output of AND-gate.

Accordingly, if the pulse train, whose frequency is proportional to the quantity of the streaming medium, is multiplied by the time code proportional to the temperature difference by means of an AND-gate (sampling multiplication), the number of pulses appearing at the output during one period is

$$N = f\ T_o = k\ V\ \Delta\Theta$$

where

f is a frequency proportional to the quantity (sec^{-1})

T_o is the time code of the temperature difference, i.e. the "open" time of the AND-gate (sec)

k is an instrument constant (cf. Fig. 2).

MEASURING UNITS

The simplest calorimetris system comprises the following units:

- TURBOQUANT, turbine-type flow meter
- resistance thermometers in the entering and leaving medium
- electronic section of calorimeter type QM-121 (Fig. 3).

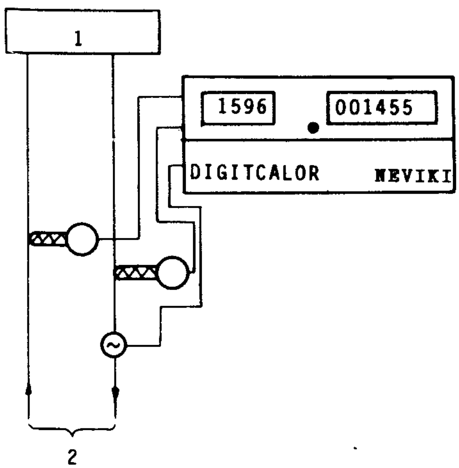
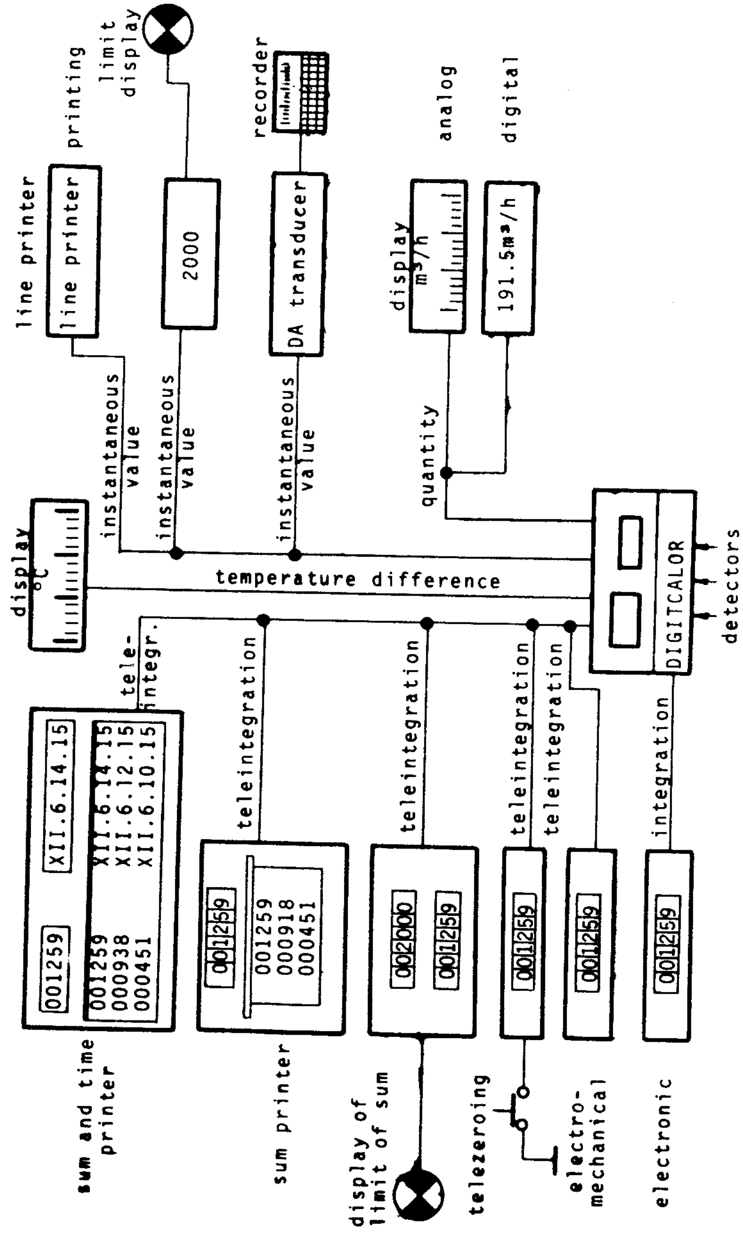


Fig.3. 1 - heat source or heat sink
2 - heat transmitting medium

The system composed according to the above enables the instantaneous value of the heat quantity or its integral for a given period of time to be determined.

The instantaneous value is seen on the digital display of the in-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sum printer
display of limit of sum
telezeroing
electro-mechanical
electronic

Fig. 4.

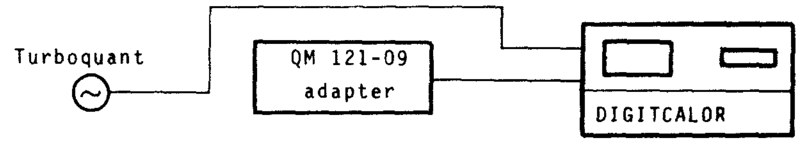

Fig. 5. Measurement of quantity

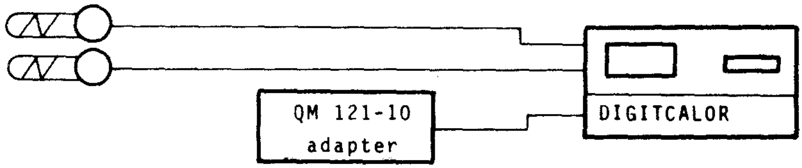

Fig. 6. Measurement of temperature difference

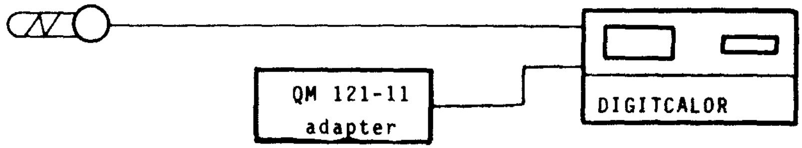

Fig. 7. Measurement of temperature

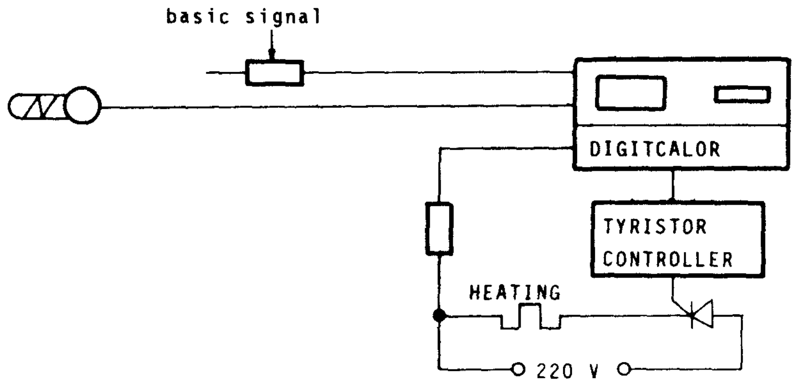

Fig. 8. Temperature regulation

strument, whereas the integral value of the heat quantity can be read from the electromechanical pulse counter built into the front plate of the instrument.

Further data acquisition systems can be connected to the electronic system of the calorimeter; these are illustrated in Fig. 4.

The construction of the calorimeter type QM-121 also enables further parameters to be measured, such as quantity (Fig.5), temperature difference (Fig.6) and temperature (Fig.7).

Fig. 8 shows an interesting measuring setup: by means of thyristors and thyristor controllers, the electronic section of the calorimeter is used as a temperature controller.

INDUSTRIAL APPLICATION

In the description of the fields of application, only those concerned with calorimetric determinations were mentioned. As a consequence of the wide variety of the production and consumption of thermal energy, it is not the aim of the present paper to attempt complete coverage of the field. A few typical possibilities of application are shown and,within these, some technological applications of particular interest from the point of view of chemical industry are described.

Measurement of energy production. In this field, the determination of the heat energy (e.g. hot water) or cold energy (e.g. refrigerated brine) produced by energy producers (e.g. thermal power stations, and refrigerating stations) is the most important task.

The measurement of the heat quantity produced enables continuous production control to be carried out, which is a basic condition of maximum efficiency.

Measurement of energy consumption. The calorimeter enables the energy consumption of a factory, and within this, that of a manufacturing plant or a sub-unit to be measured. The quantity thus determined can also be used for accounting purposes. The energy consumption may represent a considerable fraction of the costs of the production of goods, and consequently, an exact calculation or determination of costs is quite impossible without the measurement of energy.

Technological measurements. The heat effects of chemical reactions are in a quantitative connection with the progress of the reaction and consequently the measurement of heat quantity enables conclusions to be drawn on the progress of a reaction. This may be especially important in cases where no other simple technique of checking is available.

As an example of the application of the Digital Calorimeter for technological purposes, the thermal measurements carried out at the Chinoin Factory for Pharmaceuticals and Chemicals will be described.

In the course of fermentation, biological heat is produced as a consequence of the oxygen uptake of the micro-organisms. The heat produced is dissipated by cooling water.The amount of cooling heat and its input and output temperatures are measured by the Digital Calorimeter. Accordingly, the measured calories give the amount of heat carried away by the cooling water. This is, of course, not identical to the amount of biological heat produced, but the effect of other pârameters on the energy balance can be neglected or can be taken into consideration in the evaluation, in view of the fact it is constant.

The results of the measurements are shown in Figs. 9 and 10. Fig.9 shows the thermal pattern of a normal fermentation reaction. It is apparent that there was a period of initial intensive respiration (1), followed by a decrease in the biological heat production due to the decrease in the quantity of carbohydrate present in the fermentor (2), i.e. the necessity of carbihydrate addition, and the effect of the addition (3). The repeated decrease in carbohydrate concentration was counteracted by renewed addition, and the effect of this is seen in section (5).

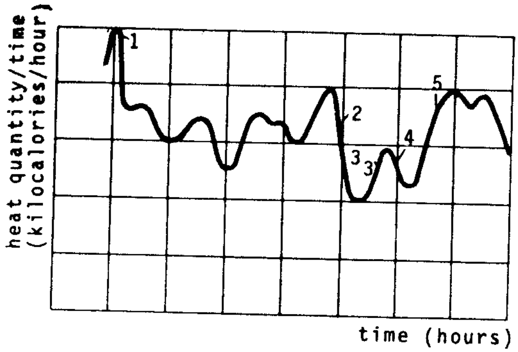

Fig. 9.

Fig. 10 shows the progress of fermentation where infection occurred. After the initial active respiration period (1) a pronounced decrease in biological heat production can be observed (2) which indicates a decrease in respiration and active material production as well.

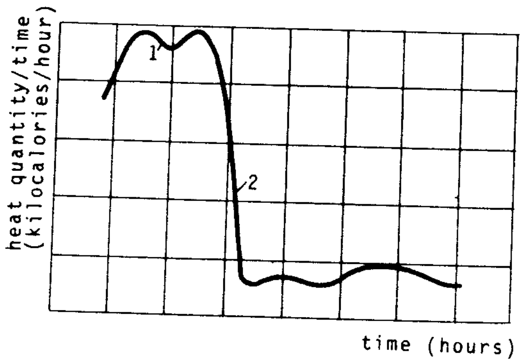

Fig. 10.

Results gained in the caloric measurements agree well with those of other instrumental measurements; however, the connections and discrepancies could not be elucidated in all respects.

The following of chemical reactions with the Digital Calorimeter is of considerable value because it supplies information on the progress of the reaction while the process is occurring and with practically no delay, thereby enabling, if necessary, prompt measures to be taken. The production of the active material in fermentation processes depends on a number of parameters. Consequently, the state of the process can only be defined by the collective examination of these and by knowing the tendency of the changes. However, these can be decided only afterwards, after carrying out a time-consuming evaluation. On the contrary, the measurement of biological heat is fast and it supplies information characteristic of the essence of the process.

In our opinion, the possibility for the determination of the heat of reaction may become a valuable quantitative parameter in the control of chemical industrial processes.

In conclusions, the technical data of the calorimeter type DIGITCALOR NORX QM-121, described in the foregoing, are set out here:

Range of quantity determination	min. 0.03 to 0.3 cu.metre/hour max. 50 to 500 cu.metre/hour
Range of temperature difference determination	min. 0 to 10°C max. 0 to 100°C
Accuracy	1 %
Sampling frequency	max. 2 seconds
Functions	determination of instantaneous value integration
Display	instantaneous value: 4 decades integral value: 6 decades
Frequency divider of integrator	1:1,000; 1:10,000
Output	for teleintegration by electrochemical pulse counter
voltage	24 Volts
current	300 milliamperes
Mains voltage	220 Volts, 50 Hertz
Ambient temperature	+5 to +50°C
Power consumption	8 voltamperes approx.
Dimensions	230 × 110 × 380 millimetres

Weight	5.5 kg force
Form	laboratory or instrument board pattern

РЕЗЮМЕ

Кроме температуры, давления, интенсивности тока и различных физико-химических параметров в химической, лекарственной, энергетической промышленности, и в других областях промышленности, в которых тепловая энергия потребляется или производится, знание количества тепла имеет большое значение. Простое, точное и достоверное измерение этой величины встречало большие трудности до последнего времени. Для устранения этого недостатка сотрудники института выработали цифровой тепломер типа "Digitcalor NORX QM-121".

Этот цифровой тепломер непрерывного действия пригоден для измерения мгновенного значения и суммы тепла, ввеленного в систему и отведенного из системы текущей средой.