A MICRO–PORTABLE HEAT RADIATION DETECTOR AND ITS APPLICATION

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ABSTRACT

A micro–portable heat radiation detector carried on fire–fighters is described in this paper. Summing up some techniques such as thermopile, precise cold–junction compensation and measuring circuit, it could measure and display heat radiation intensity and temperature in the fire field where man is situating. It will send out a warning signal according to dangerous threshold that man can take emergency measures to protect himself and escape being hurt. It provides a security protect instrument for fire–fighters.

(Keywords: Fire, Heat Radiation, Measurement)

INTRODUCTION

In the course of research work in fire science, data collection in the spot of fire and body protection of fire-fighters, heat radiation and its intensity are critical data. But in the civil fire-fighting market, it hasn't had any kinds of portable self-protecting and measuring apparatus that can tell us the temperature and radiation intensity where man or object is situated. Today, man has pay attention to research in fire science and human protection day by day, and the apparatus we made just fill in the gaps in this field.

Our country has a vast territory, but its forests, oil fields and buildings have a rather weaker fire–fighting ability. It may has important and realistic significance of reducing the wealth lose of the people and the country that fire–fighters can grasp the fire information while fire occurs. So, it may be the essential instrument to fire–fighters in large area forest and oil filed fires.

MEASURING PRINCIPLE

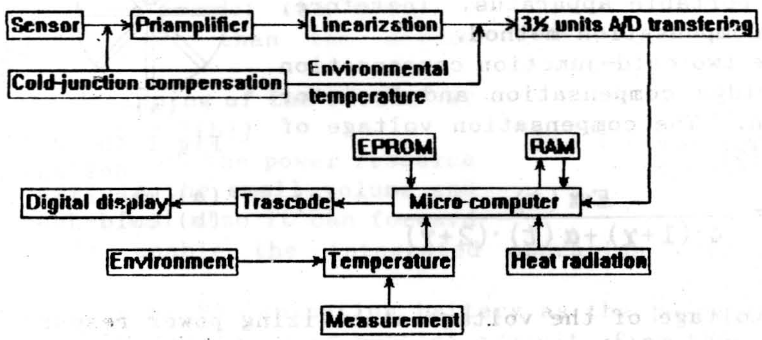
Putting this measuring instrument to the spot that men or combustibles are situated, the effect of total radiation energy that comes from the flame and reaches to the sensors may cause the sensors' temperature to rise. At the thermal balance point, the relationship between temperature and radiation energy may be described by the Stefan-Boltzmann law:

$$E = \sigma_0 \cdot T_p^4 \tag{1}$$

E —— radiation energy(W/m^2)
σ_0—— Stefan-Boltzmann constant. $\sigma_0=5.67\times10^{-8}$
T_p—— the temperature of the sensor(K)

We at best measure the absolute temperature, this means that the sensor must be placed into a black body. The making of the black body is critical. Considering that most bodies are not the same, therefore, measuring the difference between the sensor and radiation ratio of the body can be regarded as another method. So it is reasonable to use the above equation as the measuring principle.

The function frame of this apparatus is shown as follows:



CIRCUIT DESIGNING

1.The designing and choice of sensor

The sensor to be used normally has thermocouple, thermistor and photo resistance. Adopting thermocouple for sensor in this instrument has obvious advantages: it has better linear relations with temperature, higher sensitivity, faster response time and limitless receiving bands. In order to rise sensitivity, we choose the thermopile which is made up of eight couples of thermocouples(Fig 1(a)). Comparing with single, the later can gain larger heat potential even if only has smaller temperature changes or slight radiation energy. The thermocouple uses Nichrome—Constantan material because of its fine stability.

(1).The cold—junction designing of the thermopile

In the course of the designing of this instrument, we put the cold—junction to the junction box of the measuring apparatus, so that the cold—junction and the measuring end are situated in two different planes(Fig 1). Because there has a body that separate the measuring end from the junction box, the temperature inside the junction box is not influenced by the fire radiation and almost unchangeable, and insure the temperature of the cold—junction to be much steady. Therefore, the difference of temperature between the measuring end and the reference end of the thermopile and also the thermo-potential are formed.

(2).The choice of the compensation method

According to the principle of the temperature measuring of thermocouple, only under the condition when the temperature of the cold—junction is fixed to the temperature value that is stipulated by the relationship of the dividing electric potential (usually 0°C) can we decide the temperature of the measuring end according to the output thermo–potential. To delete the error caused by the factor that the reference end of the thermocouple is not 0°C, we introduce two solving methods, the constant temperature method and compensation method. Although the former can be done as very accurate, it is not suitable to portable apparatus. Therefore, we use the compensation method.

There are two cold–junction compensation methods: Bridge compensation and Resistor compensation. The compensation voltage of the former is:

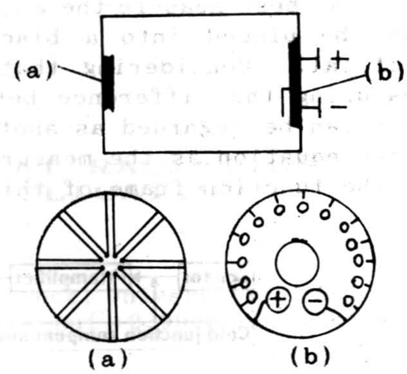


Fig.1 The cold-junction designing
(a) mesuring end
(b) cold-junction

$$V_1 = \frac{E\cdot\alpha(t)}{4\cdot(1+\chi)+\alpha(t)\cdot(2+\chi)} \qquad (2)$$

E——the voltage of the voltage-stabilizing power resource

χ——the ratio of the current limiting resister to the bridge–arm resister

$\alpha(t)$——the temperature coefficient of the thermo resistor, to the copper thermo resistor: $\alpha(t)=4.28899\times10^{-3}\cdot t-2.133\times10^{-7}\cdot t^2+1.233\times10^{-9}\cdot t^3$

Adopting differencing–circuit and amplifying system(Fig 3(a)), the compensation voltage of the thermo resistor compensation is:

$$V_2 = I\cdot R_0\cdot\alpha(t)\cdot K \qquad (3)$$

I——the constant current

R_0——the value of the thermo resistor in 0°C

K——the amplification coefficient

If we achieve total compensation under the temperature t_n, we should have:

$$V_1 = V_2 = n\cdot E(t_n,0) \qquad (4)$$

$E(t_n,0)$——the output potential when the hot-junction and the cold–junction have the temperature of t_n and 0°C respectively

n——the number of the thermocouple of the thermopile.

From above, we have:

Bridge compensation:

$$\frac{E}{4\cdot(1+\chi)+\alpha(t_n)\cdot(2+\chi)} = \frac{n\cdot E(t_n,0)}{\alpha(t_n)} \qquad (5)$$

Resistor compensation:

$$K\cdot I\cdot R_0 = \frac{n\cdot E(t_n,0)}{\alpha(t_n)} \qquad (6)$$

The value of $E(t_n,0)/a(t)$ about Nichrome Constantan thermocouple is from 13.82 to 14.86 in the temperature range between 1°*C* and 100°*C*. In the coordinate system, its a slightly tilting up curve. To the terms left to the equal-sign of formula (5), it is a curve that slightly tilts down. Obviously, the terms left to the equal-sign of formula (6) is a straight line(Fig 2).

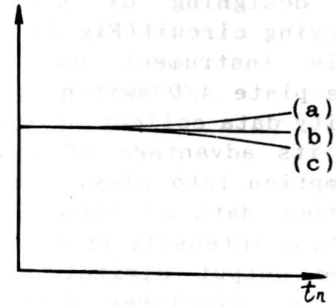


Fig.2 Comparing of the two compensation effect

Therefore, the effect of the Resistor compensation is better than the Bridge compensation.

2.The choice and designing of the circuit of the power resource(Fig 3(b))

The characteristic of the power resource of this instrument is the small volume and the large capacity, and also it can forward enough voltage to enable the integrated operation circuit to work normally.

This instrument uses 9*V* lamination battery as the power resource. We also design an voltage—stabilizing partial circuit, from this circuit, we produce a positive/negative bi—resource that is needed by later circuits, and the image earth potential about these circuits. The calculation and display of the temperature and radiation are all based on this earth potential.

3.The calculation of the radiation intensity and the designing of the circuit

Because the signals measured by the sensors are temperature signals of the thermocouple and we must calculate and then acquire the radiation intensity signals, we adopt equation (1) as the basement of calculation, the reasonability has been related carefully in former texts.

It is consisted of three parts of circuits.

(1).Potential—temperature circuit(Fig 3(c))

The compensation potential from the differential—circuit and the output potential of the thermopile add up to form the thermo—potential data of the thermocouple dividing meter. According to Ohm's law, the output potential from the thermopile is the sum of each thermocouple's potential. When it is doubled, it just equals to the value of the temperature.

(2).The transferring circuit from °*C* to *K*(Fig 3(d))

The temperature acquired from former circuit is indicated by "°*C*". After being transferred, it becomes the temperature indicated by "*K*". The mathematical relationship between "°*C*" and "*K*" is:

$$T(K) = T(^\circ C) + 273.15 \qquad (7)$$

(3).The power circuit(Fig 3(e))

After being calculated by the equation (1), the temperature $T(K)$ becomes the radiation intensity. This course is conducted by the power circuit. The power circuit is made up of the Logarithm circuit and the anti–Logarithm circuit.

4.The designing of the digital displaying circuit(Fig 4)

This instrument uses *ICL7106* single–plate *A/D* switcher, the low velocity data collecting system can bring its advantage of low energy consumption into play. It changes the input data of temperature and radiation intensity from the sensor to the output digital data, and drive the displayer directly and display the $3\frac{1}{2}$ units of digital signals from the liquid crystal plate.

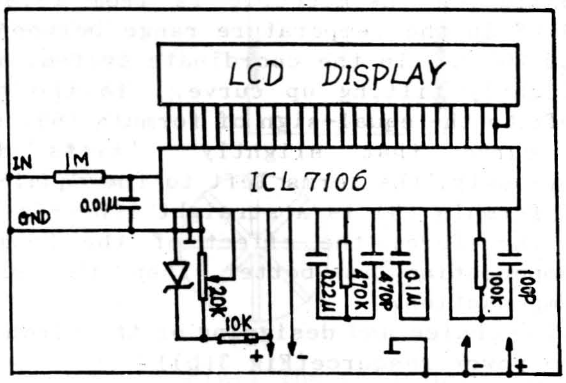


Fig.4 Digital display circuit

5.The designing of the warning system

The warning sound of this instrument is high enough even under the high circumstance noise. The warning frequency rises with the temperature(Fig 3(f)).

CONCLUSIONS

The technological parameters of this portable heat radiation measuring warning instrument are listed as follows:

(1).The range of the temperature measurement: 0—200°*C*
(2).The accuracy of the temperature measuring: ±0.1°*C*
(3).Allowed basic error: <±1.3°*C*
(4).Measuring range of radiation: 300—2000 W/m^2
(5).The accuracy of the radiation measuring: ±1 W/m^2
(6).Working bands: 0—∞ μm
(7).Display: $3\frac{1}{2}$ units of digital display
(8).Measuring distance: free
(9).Sampling frequency: 4/s
(10).Cold–junction compensation: 0—100°*C*
(11).weight: 0.5*Kg*

REFERENCES

[1] Chen Zeshao et al., *Calorimetry and Thermophysics Property Measurement*, Publishing House of USTC, Hefei,1980.(in Chinese)
[2] Cheng Xiaofang, *Flame radiation and Temperature and Its Measurement*, Publishing House of USTC, Hefei,1990.(in Chinese)
[3] He Shisheng, *Pyrological Measurement*, Publishing House of Electric Power Industry, 1980. (in Chinese)
[4] Lu Guangping et al., *500 Examples of Integrated Circuit Application*, Publishing House of People Post, 1983. (in Chinese)
[5] T.G.Fisher(U.S.A), *Alarm and Interlock System*, Publishing House of Mechanic, 1985. (in Chinese)
[6] Zhou Zuoyuan et al., *Fundamental of Temperature and Fluid Parameter*

Measurement, Publishing House of Tsinghua University, 1986. (in Chinese)

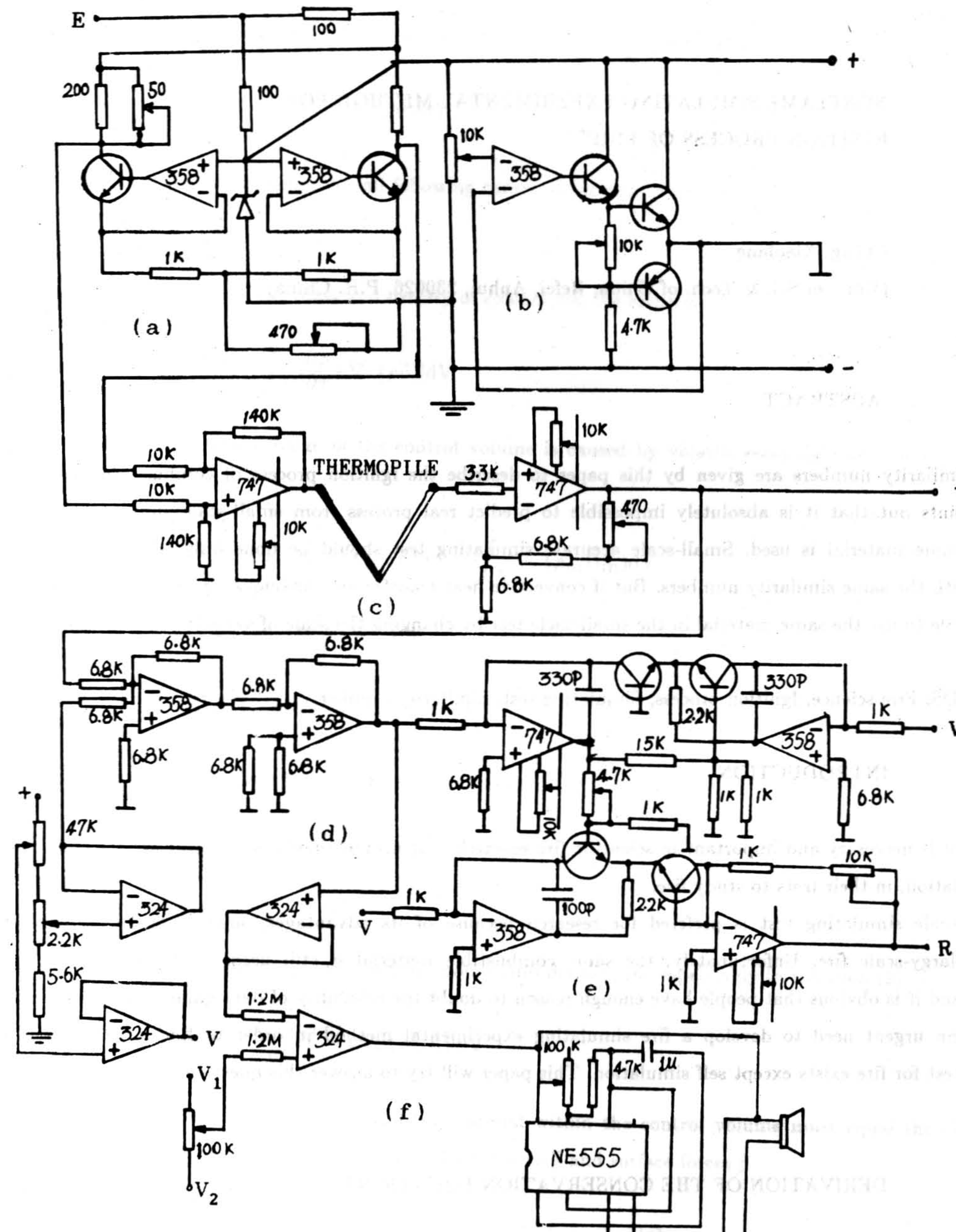


Fig.3 The circuit of this instrument

(a) Constant current resource and differential circuit. (b) Voltage stabilizing partial circuit. (c) The potential-temperature circuit. (d) The transferring circuit from 0°*C* to *K*. (e) The power circuit. (f) The warning circuit.