# LOW CURIE TEMPERATURE FERRITES AND THEIR APPLICATION

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## 1. Introduction

For the purpose of temperature measurements and temperature control that physical phenomena is used by which the value of a physical quantity varies by temperature. The degree of variation is characterized by the $TK$ temperature coefficient which is defined as:

$$TK_x = \frac{1}{x} \frac{\partial x}{\partial \vartheta} \tag{1}$$

where $TK_x$ is the temperature coefficient of the
$x$ quantity,
$\vartheta$ is temperature.

Table I contains the temperature coefficients of some physical quantities. The temperature coefficient is generally also a function of temperature. The data given in the table are valid for room temperature.

**Table I**

Temperature coefficients of different physical quantities at room temperatures

| | |
|---|---|
| Coefficient of linear thermal expansion for copper .. | $+1.65 \cdot 10^{-5}$ |
| Coefficient of cubic thermal expansion for mercury | $+1.82 \cdot 10^{-4}$ |
| Coefficient of cubic thermal expansion for ideal gas .................................... | $+3.66 \cdot 10^{-3}$ |
| Temperature coefficient of resistivity for copper ... | $+4 \cdot 10^{-3}$ |
| Temperature coefficient of resistivity for type TG10 thermistor .................................. | $-4 \cdot 10^{-2}$ |
| Temperature coefficient of the dielectric constant of calit .................................... | $+1.4 \cdot 10^{-4}$ |
| Temperature coefficient of starting permeability of Maferrite .................................. | $-2 \cdot 10^{-3}$ |

For the purpose of temperature measurement and temperature control those physical quantities are best suited which have the greatest possible temperature coefficients.

Fig. 1 shows the well known changes of the relative initial magnetic permeability of ferrites as a function of the temperature. At temperatures much lower than the Curie temperature —$\vartheta_c$ — the relative initial magnetic permeability increases by increasing temperature, consequently $TK\mu$ is positive, and is relatively small. Near the Curie temperature $TK\mu$ is negative and has a high value. In the literature, that temperature is named Curie temperature, above which the ferromagnetic material becomes paramagnetic. It is difficult to accurately define this temperature by measuring. Therefore, practically

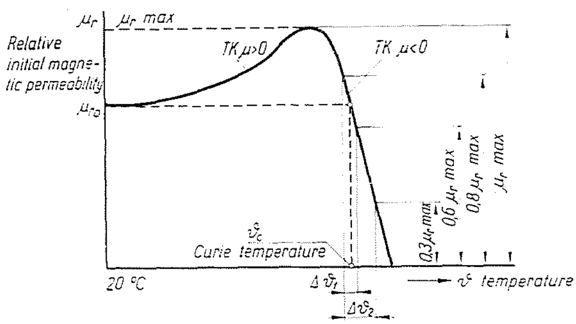


*Fig. 1.* The variation of magnetic permeability plotted against temperature change

that temperature is regarded as Curie temperature where the decreasing magnetic permeability reaches the value measured at 20° C by again increasing the temperature.

The Curie temperature values of ferrites depend on their chemical compositions. In case of manganese—zinc ferrites by increasing the iron oxide content, it also increases, while by decreasing the zinc oxide content the Curie temperature decreases. Consequently ferrite materials having the same Curie temperature can be realized by a complete series of ferrites having different ratios of the three oxide components.

The Curie curves of these ferrites, that is the initial permeabilities plotted against the temperature are, however, different. A governing factor for deciding the initial permeability, besides the chemical composition, is the crystal structure of the material. The crystal structure on the other hand depends a great deal on the quality of the raw materials used for the production technology, and especially on the temperature and atmosphere of sintering, and on the circumstances of cooling.

Table II sums up the characteristic data of ferrites having different chemical compositions. The production technologies were so composed that their

Table II

| No. | $\mu_{r0}$ | $\vartheta_c$ °C | $\frac{\mu_{r\max}}{\mu_{r0}}$ | $\Delta\vartheta_1$ (80 − 60%) °C | $\Delta\vartheta_2$ (80 − 30%) °C | $TK\mu_1$ 80 − 60% [°C]$^{-1}$ | $TK\mu_2$ (80 − 30%) [°C]$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1. | 1550 | 197 | 4.05 | 0.5 | 1.5 | 0.59 | 0.61 |
| 2. | 1970 | 167 | 3.13 | 0.5 | 1.0 | 0.57 | 0.91 |
| 3. | 1580 | 148 | 1.59 | 1.0 | 3.0 | 0.29 | 0.28 |
| 4. | 2050 | 128 | 1.81 | 0.4 | 1.0 | 0.72 | 0.90 |
| 5. | 2240 | 110 | 1.51 | 0.25 | 0.85 | 0.98 | 1.17 |
| 6. | 1900 | 79 | 1.18 | 1.0 | 2 | 0.29 | 0.54 |
| 7. | 2140 | 58 | 1.10 | 1.0 | 2 | 0.22 | 0.25 |

Table III

| No. | $\mu_{r0}$ | $\vartheta_c$ °C | $\frac{\mu_{r\max}}{\mu_{r0}}$ | $\Delta\vartheta_1$ (80 − 60%) °C | $\Delta\vartheta_2$ (80 − 30%) °C | $TK\mu_1$ (80 − 60%) [°C]$^{-1}$ | $TK\mu_2$ (80 − 30%) [°C]$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1. | 1400 | 73 | 1.18 | 1 | 2 | 0.29 | 0.54 |
| 2. | 1420 | 70 | 1.29 | 1 | 3 | 0.28 | 0.45 |
| 3. | 1370 | 68 | 1.23 | 2 | 3 | 0,14 | 0.25 |
| 4 | 1400 | 71 | 1.28 | 2 | 4 | 0.14 | 0.22 |
| 5 | 1440 | 66 | 1.21 | 2 | 5 | 0.14 | 0.19 |
| 6. | 1380 | 66 | 1.23 | 2 | 6 | 0.14 | 0.14 |
| 7 | 1350 | 66 | 1.17 | 4 | 6 | 0.07 | 0.14 |
| 8. | 1360 | 70 | 1.19 | 4 | 9 | 0.07 | 0.10 |
| 9. | 1400 | 71 | 1.12 | 5 | 10 | 0.05 | 0.09 |
| 10. | 1380 | 69 | 1.10 | 6 | 12 | 0.05 | 0.07 |

relative permeability $\mu_{r0}$ measured at 20° C should unanimously be at about 2000. The initial permeability as a function of the temperature was measured on each ferrite type from room temperatures up to their Curie points.

The table makes it evident, that in the decreasing range after the $\mu_{r0}$ maximum, the $TK\ \mu$ is generally ten times greater than the temperature coefficient of thermistors best suited for temperature control applications.

The wide application of ferrites for such purposes is greatly facilitated by the fact that by the proper choice of chemical composition a material having the demanded Curie temperature can be realized, i.e. in other words, the high range can be transponed into any temperature interval. (An upper limit for ferrites is the Curie point 575° C of the ferroferrite). Table III and Fig. 2 represent the results of those series of experiments, during which by varying the production technology of ferrites having the same chemical compositions, i.e. the same Curie temperature, temperature curves with different steepness could be achieved. It can be seen that the temperature coefficient of the measured ferrites is between 0.54° C and 0.07° C.

The decreasing part of the curve representing the relative permeability as function of the temperature in the first case in a 2° C, and in the second case in a 12° C temperature range, is nearly linear.

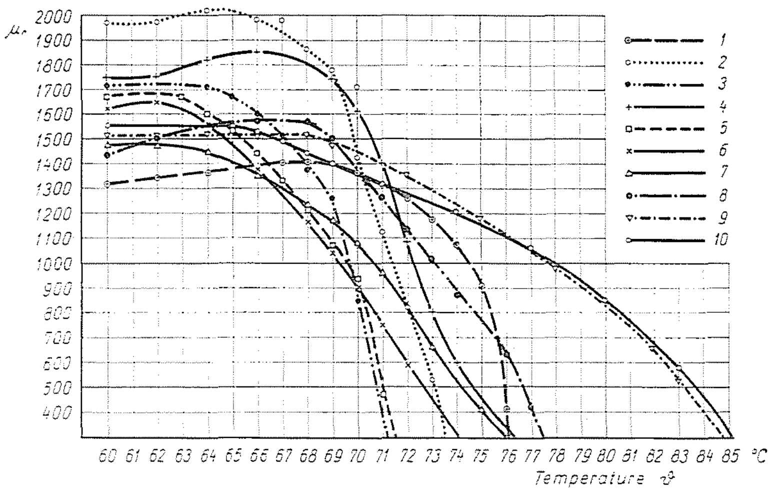


*Fig. 2.* Magnetic permeability variations of differently composed ferrites plotted against temperature change

Of the many possible fields of applications for low Curie temperature ferrites only those are dealt with here in detail which have thermostat construction using the dependence of the magnetic permeabilities of the ferrites on the temperature changes, and the measurements of the activity of radioactive isotopes.

## 2. Thermostat

Ferrites having low Curie temperature are especially suitable for controlling thermostats designed to sustain constant working temperatures.

Several designs were successfully tested. As regards operation a controlling device comprised of a bridge circuit is perhaps the simplest one. Its sketch is shown on Fig. 3.

The inductances $L_1$, $L_2$ and $L_\vartheta$ comprise the bridge which is fed by an L. F. generator. The operating temperature where the bridge is balanced can be set by varying $L_2$ in a few tenth degree centigrade intervals. Consequently the inductance $L_2$ (together of course with $L_1$) generates the basis signal. If the temperature of the thermostat deviates from the prefixed operating temperature, then a control signal, $U_r$, proportional to the temperature deviation appears across the bridge terminals.

$$U_r = U_0 \frac{\Delta \mu r}{2(2\mu_r + \Delta\mu_r)} \tag{2}$$

where $U_r$ is the unbalanced bridge voltage in volts resulting from a $\Delta\vartheta$ temperature variation.
$\mu_r$ is the relative permeability at the working point,
$U_0$ is the voltage feeding the bridge, in volts,
$\Delta\mu_r$ is the relative permeability deviation in response to a $\Delta\vartheta$ temperature deviation.

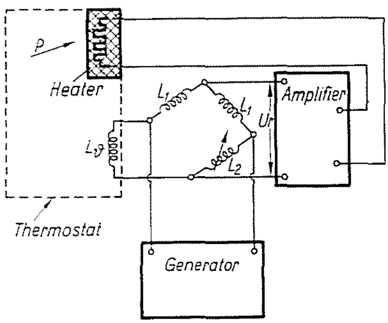


*Fig. 3.* Thermostat for temperature control using low Curie temperature ferrites in bridge circuit

From Eq. 1 we obtain

$$\frac{\Delta\mu_r}{\mu_r} = TK\mu \cdot \Delta\vartheta \tag{3}$$

$$Ur \cong \frac{TK\mu}{4} \cdot \Delta\vartheta = K_1\Delta\vartheta \tag{4}$$

In case the amplifier receives a $U_r$ input voltage then it provides the thermostat with a

$$P = K_2 U_r \tag{5}$$

heating power, which compensates for the thermal power loss escaping through the thermostat walls.

$$\vartheta - \vartheta_k = K_4 P \tag{6}$$

where $\vartheta$ is the operating temperature of the thermostat in centigrades,
$\vartheta_k$ is the ambient temperature in centigrades,
$K_4$ is the inverse of the heat conductance of the thermostat in centigrade/watt.

In case of an ambient temperature change the temperature of the thermostat and consequently that of the ferrite will also change and the change of the controlling signal will set the heating power to the appropriate level.

The shorter the lag between the ferrite temperature change and that of the thermostat, and the greater the loop amplification of the controlling system, the more perfect will the whole control be.

The control system can be analyzed on the basis of the substituting picture shown on Fig. 4.

The basic signal, $\vartheta_a$ represents the desired temperature. The difference in the sensitive element consisting of the bridge circuit, produces a signal pro-

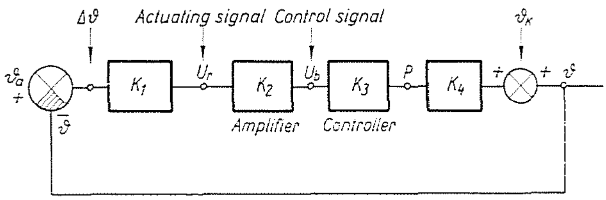


*Fig. 4.* Substituting circuit of the temperature controlling loop

portional to the difference of $\vartheta$ (operating temperature of the thermostat) and $\vartheta_a$ (the desired temperature difference). $K_1$ is the coefficient of the bridge. The difference in the sensitive element may be regarded as a proportional stage without time delay, from a control technical viewpoint. Its transfer function is: $Y_2 = K_1$

The A. C. voltage modulated in phase by the bridge is amplified by the following amplifier and at the same it is rectified. The amplifier is a proportional stage having first order delay. Its transfer function is

$$Y_2 = \frac{\mathscr{L}[U_b(t)]}{\mathscr{L}[U_r(t)]} = \frac{K_2}{1 + pT_1} \tag{7}$$

where $\mathscr{L}[U_b(t)]$ is the Laplace transform of the output signal of the amplifier, $\mathscr{L}[U_r(t)]$ is the Laplace transform of the input signal, both at zero conditions,

$K_2$ is the (D. C.) amplification factor,

$T_1 = \frac{1}{\omega_B}$ is the time constant (D. C.), that is the inverse of the bandwidth between the 3 dB points of the amplifier.

The output signal of the amplifier is transformed to heating power by the controller. The controller is also a proportional stage without time delay, its transfer function is

$$Y_3 = K_3 .$$

The ambient temperature, $\vartheta_K$ (this being the disturbing feature of the control) is taken into consideration by the way of an added stage corresponding to the following equations:

$$\vartheta - \vartheta_K = Y_4 P; \qquad \vartheta = Y_4 P + \vartheta_4 \tag{8}$$

where $Y_4$ is the transfer function of the thermostat which is determined by its thermal isolation. By substituting the thermal inertia of the thermostat (controlled section) with a proportional stage having first order delay, we obtain

$$Y_4 = \frac{K_4}{1 + pT_2} \tag{9}$$

Here $T_2$ is the time constant of the thermostat.

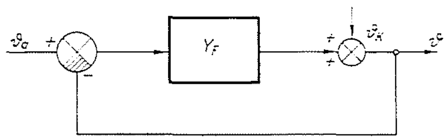


*Fig. 5.* Simplified substituting circuit for temperature controlling loop

The essential scheme of the controlling loop is given on Fig. 5.

The resulting transfer function of the main channel is

$$Y_F(p) = Y_1 Y_2 Y_3 Y_4 = \frac{K}{(1 + pT_1)(1 + pT_2)} \tag{10}$$

where

$$K = K_1 K_2 K_3 K_4 \tag{11}$$

Introducing the following designations

$$\mathscr{L}[\vartheta_a(t)] = \Theta_a(p) \tag{12}$$

$$\mathscr{L}[\vartheta(t)] = \Theta(p) \qquad \text{and} \qquad \mathscr{L}[\vartheta_K(t)] = \Theta_K(p) \tag{13}$$

With these we get:

$$\Theta_p = \frac{Y_F}{1 + Y_F}\,\Theta_a(p) + \frac{1}{1 + Y_F}\,\Theta_K(p) \tag{14}$$

As far as control is concerned the following problems must be dealt with:

*a)* Stability of the controlling loop.
*b)* The characteristics of the transients of the controlling.
*c)* Noise sensitivity.

*a) Stability analysis*

The control loop is stable if all roots of the $1 + Y_F(p)$ equation lie in the left half of the complex $p$ plane. In our case

$$1 + \frac{K}{(1 + pT_1)(1 + pT_2)} = 0 \tag{15}$$

From this

$$p^2 T_1 T_2 + p\,(T_1 + T_2) + K + 1 = 0 \tag{16}$$

Since the characteristic equation is of second order, the condition for stability is fulfilled if every coefficient is greater than zero.

*b) Transient analysis*

Let us assume that the temperature to be reached changes according to unit-step function, and let us determine the response of the control for such a basic signal (Fig. 5).

By disregarding the disturbing part we obtain

$$\Theta_{(p)} = \frac{Y_F}{1 + Y_F}\,\Theta_a(p)\,, \tag{17}$$

where $\Theta_a(p) = \dfrac{1}{p}$

after substitution:

$$\Theta(p) = \frac{K}{T_1 T_2 p^2 + (T_1 + T_2)\,p + 1 + K} \cdot \frac{1}{p} \tag{18}$$

By rewriting the denominator into the normal Bode form: $p^2T^2 + 2\,\zeta\,T_p + 1$ we get:

$$\Theta(p) = \frac{K}{1 + K}\,\frac{1}{p^2 T^2 + 2\zeta Tp + 1} \cdot \frac{1}{p} \tag{19}$$

where

$$T = \sqrt{\frac{T_1 T_2}{1 + K}} \quad \text{and} \quad \zeta = \frac{T_1 + T_2}{2\sqrt{T_1 T_2}} \cdot \frac{1}{\sqrt{1 + K}} \tag{20}$$

The change of the operating temperature of the thermostat is

$$\vartheta(t) = \mathscr{L}^{-1}[\Theta(p)] = \tag{21}$$

$$= \frac{K}{1+K}\left\{1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_0 t} \cdot \sin\left[\omega_0\sqrt{1-\zeta^2}\cdot t + \operatorname{arc\,cos}\zeta\right]\right\} \tag{22}$$

where $\omega_0 = \frac{1}{T}$.

Let us determine the duration and magnitude of the overshoot ($t_M$, $\varepsilon$). $\vartheta(t)$ has its first maximum, where

$$\frac{d}{dt}\Theta(t) = 0 \tag{23}$$

This results in

$$t_M = \frac{\pi}{\omega_0\sqrt{1-\zeta^2}} \tag{24}$$

The value of the overshoot is:

$$\varepsilon = \vartheta(t_M) - \frac{K}{1+K} = \frac{K}{1+K} e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} = \frac{K}{1+K} e^{-\zeta\omega_0 tM} \tag{25}$$

The overshoot in percentage is:

$$e^{-\Delta} \text{ where } \Delta = \frac{\pi\zeta}{\sqrt{1-\zeta^2}} \tag{26}$$

Finally let us determine the duration of the transient. The control might be regarded as being finished if the temperature of the thermostat differs only $\pm 2\%$ from the stationary value. The time necessary for the control to reach the $\pm$ 2% limit can be calculated as

$$t_0 = \frac{4}{\zeta\omega_0} \tag{27}$$

The operating temperature of the thermostat does not reach the value prescribed by the basic signal in the stationary condition, but remains below it. Therefore, the remaining control error (stationary error) is

$$e_{st} = 1 - \lim_{t\to\infty} \vartheta(t) = 1 - \frac{K}{1+K} = \frac{K}{1+K} \tag{28}$$

In order to decrease the remaining control error the loop amplification must be kept as high as possible. By doing so, however, the value of $\zeta$ decreases, which on the other hand increases the overshoot and so results in an unsatisfactory transient response (in practice $\zeta > 0.4$ !).

*c) Noise sensitivity*

Let us again assume that a change, $\Delta\vartheta_K$ takes place in the ambient temperature, $\vartheta_{K0}$ the method of the change being similar to that of a unit step function (Fig. 6). Let us determine the change of the operating temperature of the thermostat in case of constant basic signal.

$$\Theta_{(p)} = \frac{Y_F}{1+Y_F}\Theta_a(p) + \frac{1}{1+Y_F}\left[\Theta_{K0}(p) + \Delta\Theta_K(p)\right] \tag{29}$$

where

$$\Delta\Theta_K(p) = \mathscr{L}\left[\Delta\vartheta_K(t)\right] \tag{30}$$

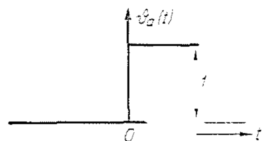


*Fig. 6.* Temperature change response for unit step function

The change of the temperature of the thermostat is

$$\Delta\Theta(p) = \frac{1}{1+Y_F}\Delta\Theta_K(p) \tag{31}$$

After substitution

$$\Delta\Theta = \frac{p^2 T_1 T_2 + p(T_1 - T_2) + 1}{p^2 T_1 T_2 + p(T_1 + T_2) + K + 1} \tag{32}$$

Let us now determine the value of the change in the inside temperature corresponding to a change of $\Delta\vartheta_K$ in the outside temperature. Here we can use the following theorem, valid for Laplace transforms: if $F(p)$ is the Laplace transform of $f(t)$, and if $F(p)$ has singularities neither on the right half plane, nor along the imaginary axis, then

$$\lim_{t\to\infty} f(t) = \lim_{p\to 0} pF(p) \tag{33}$$

Consequently

$$\lim_{t\to\infty}\Delta\vartheta(t) = \lim p\frac{\Delta\vartheta_K}{p}\,\frac{p^2 T_1 T_2 + p(T_1 + T_2) + 1}{p^2 T_1 T_2 + p(T_1 + T_2) + K + 1} = \frac{1}{1+K}\Delta\vartheta_K \tag{34}$$

Therefore, the higher the loop amplification, the lower the change of the inner temperature of the thermostat is.

## 3. Activity measurements of radioactive isotopes

Several methods are used for the measurements of the radiating activity $\alpha$, $\beta$ and $\gamma$ radiation of radioactive isotopes. The activity measurement can be carried out either by way of comparison, or in a calorimetric way, using direct energy measurements.

Only the calorimetric methods can be regarded as absolute measuring methods. In view of the resulting small temperature changes in consequence of the dissipated radiation, the realization of such methods brings about great difficulties. The above mentioned fact also means, that only high values of activity can be measured with acceptable accuracy by using this method. The increase of the sensitivity and accuracy of the calorimetric measuring method can first of all be achieved if it is also possible to increase the sensitivity and accuracy of the temperature change measurements.

The isotope to be measured is placed within a suitably formed ferrite body. The ferrite body, as a core, is wound with wire, thus forming a coil. This ferrite body is then placed into a constant temperature space. The radiation of the radioactive isotope placed inside the ferrite body, will be dissipated by the ferrite material and as a result of the dissipated radiation it becomes warmer. The activity of the isotope can be determined by the value of the warming up. The ambient temperature of the outer space around the ferrite body should be chosen somewhere in the neighbourhood of the Curie temperature of the ferrite, so that the warming up, caused by radiation should make the relative permeability of the ferrite to greatly decrease.

The ferrites contain heavy metals, therefore, their radiation dissipation is high. The $\alpha$ and $\beta$ radiations are dissipated even by ferrites having a small mass like the ones generally used in the communication field. For the $\gamma$ radiation measurement ferrites containing lead-ferrite should be used.

An advantage of this method is that the radiation is directly transformed to heat in the heat-sensitive element. Consequently there are no losses in heat transfer and the relatively simple means make it possible to detect very small temperature differences, and so the sensitivity of such a measurement is appr. ten times as high as those of other methods.

A further advantage of this method is the simple way in which the telemetry and the registration of the series of measurements can be realized. The measuring set up is represented on Fig. 7. The radioactive isotope, $A$ is placed within the cave formed by the ferrite body $B$. The cave in the $B$ ferrite body is covered with another ferrite body $C$. The ferrite bodies $B$ and $C$ are so shaped, that along the touching edges practically no radiation can escape. The ferrite bodies $B$ and $C$ at the same time form the core of coil $D$. If the ferrite bodies $B$ and $C$ warm up, the inductivity of $D$ changes. The activity of the radioactive isotope can be determined by the change in inductivity.

The calibration of the apparatus can, for example, be carried out by placing a small heater wire within the ferrite body. The activity measuring instrument using low Curie temperature ferrites can be the most simply analyzed if it forms a sphere. The isotope is placed inside the ferrite cave having an $r_2$ inner and an $r_1$ outer radius. It follows from the symmetry of the sphere, that the power density of the radioactive radiation (Poynting vector) is constant along the concentrical sphere-surfaces, each containing the ferrite, and so the higher the sphere radius, the lower the power density will be.

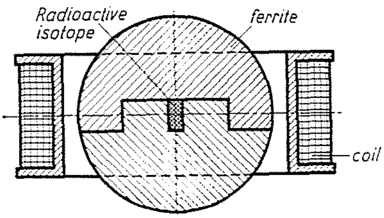


*Fig. 7.* Activity measurement of radioactive isotopes using low Curie temperature ferrites

$$P(r) = P_0 e^{-\varrho r} \tag{35}$$

where $P(r)$ is the power in watts on the surface of the sphere having $r$ radius,
$\varrho$ is the absorption coefficient of the ferrite material measured in $m^{-1}$,
$P_0$ is the power (in watts) reduced into the centre of the sphere.

It follows from Eq. (35) that the power dissipated in a sphere shell surface having a thickness of $dr$ and a radius of $r$ is:

$$d\,P(r) = -\varrho P_0 e^{-\varrho r} \tag{36}$$

From Eq. (36) it is possible to determine the power loss, $W$, dissipated in a unity cubature

$$W = \frac{\varrho P_0 e^{-\varrho r}}{4 \pi r^2} \tag{37}$$

The Bio-Fourier differencial equation of thermo-conductance in spherical co-ordinate system is given by Eq. (38), if the result depends only on the $r$ co-ordinate:

$$\frac{d\vartheta}{dt} = \frac{\lambda}{\gamma c} \frac{1}{r^2} \frac{d}{dr} \left( r^2 \frac{d\vartheta}{dr} \right) + \frac{1}{\gamma c} \varrho \frac{P_0 e^{-\varrho r}}{4 \pi r^2} \tag{38}$$

By concentrating on the stationary state only, we get:

$$\frac{d\vartheta}{dt} = 0 \tag{39}$$

If the power $P(r_1)$ dissipated on an $r_1$ surface is substituted with power $P_0$ or the power reduced in the centre of the sphere, we obtain

$$P(r_1) = P_0 \, e^{-\varrho r_1} \tag{40}$$

The solution of the differential equation (39) for the stationary conditions is the following

$$\vartheta(r_1) - \vartheta(r_2) = \frac{P(r_1)\, e^{\varrho r_1}}{4\pi\lambda} \left\{ \frac{1}{r_2} (e^{-\varrho r_2} - e^{-\varrho r_1}) + \varrho [E_i(-\varrho r_2) - E_i(-\varrho r_1)] \right\} \tag{41}$$

In case of $\beta$ radiation $\varrho$ is very high and our calculations can considerably be simplified. Let us determine the limits of Eq. (41) if $\varrho \to \infty$. By rearranging Eq. (31) we obtain

$$\vartheta(r_1) - \vartheta(r_2) = \frac{P(r_1)}{4\pi\lambda} \left\{ \frac{1}{r_2} [e^{-\varrho(r_2 - r_1)} - 1] + \varrho\, e^{\varrho r_1} [E_i(-\varrho r_2) - E_i(-\varrho r_1)] \right\} \tag{42}$$

Eq. (42) represents the indefinite $0 . \infty$ type form if $\varrho \to \infty$, which can be calculated by using the l'Hospital rule.

The limits of Eq. (42) are

$$\vartheta(r_1) - \vartheta(r_2) = \frac{P(r_1)}{4\pi\lambda} \left[ \frac{1}{r_1} - \frac{1}{r_2} \right] \tag{43}$$

The expression in Eq. (43):

$$R_h = \frac{1}{4\pi\lambda} \left[ \frac{1}{r_1} - \frac{1}{r_2} \right]$$

is the thermo resistance of the sphere shell surface, while $\vartheta(r_1) - \vartheta(r_2)$ represents the temperature difference between the two walls of the sphere shell, if the inner surface is heated by the power $P(r_1)$.

A few possible uses of low Curie temperature ferrites have been discussed. A far wider application can greatly be facilitated if such technological methods are available, by which it is possible to produce ferrites having arbitrary Curie temperatures below 500° C.

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## Summary

Typical applications of ferrites having low Curie temperature are dealt with: temperature control of thermostats and measurement of the activity of radioactive materials.

The paper gives experimental data on temperature coefficients of low Curie temperature ferrites developed by the authors.

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