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# APPLICATIONS OF AMORPHOUS MAGNETIC CORES TO INSTRUMENT AND CONTROL DEVICES

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ABSTRACT

In this paper the author describes systematic investigations on the flux control characteristics of amorphous magnetic cores and on their applications to instrument and control devices.

The results of these investigations will be make clear the utility on the actual uses of amorphous magnetic material and will be of great service to the design of the amorphous devices at the magnetic applications.

## 1. INTRODUCTION

The advantages of amorphous magnetic materials are that their coercive force is small, and permeability, saturated flux value and specific resistance are large and that they have also manufacture characteristics which are exhibited by the fact that their tape thickness can be thinned.

The present paper describes systematic investigations made into necessary items and applicable fields and so on when amorphous magnetic materials are applied to instrument and control devices.

## 2. CLASSIFICATION OF FLUX CONTROL

When amorphous magnetic materials are applied to instrument and control, they may be divided broadly into two categories: applications of closed magnetic circuits and of opened magnetic circuits. In case of closed magnetic circuits it will be proper to use the materials as toroidal cores.

Under such notion the flux control of amorphous magnetic core into four sorts as shown by Fig. 1.

(i) 1st type flux control
This system makes the magnetic flux alternate between positive and negative saturation values as shown in Fig. 1(a). This is a most general form of the use of magnetic cores.

(ii) 2nd type flux control
This system controls the magnetic hysteresis loop in the form of a minor loop.

(iii) 3rd type flux control
This system is a form that uses the flux values between positive and negative saturation flux values by dividing then into N.

(iv) 4th type flux control
This system is a form that uses the flux saturation values by changing them as functions of magnetizing force rated by 90°, thermal energy and pressure.

## 3. CHARACTERISTICS OF AMORPHOUS MAGNETIC MATERIALS TO APPLICATIONS

Above mentioned four sorts of experiments of flux controls were carried out with various materials and shapes of amorphous magnetic cores. The distinguishing traits are as follows:

As advantages:

(i) The control magnetizing force is small and moreover hysteresis loop of good rectangularity can be got.

(ii) The magnetic field rotated by 90° is applied, the magnetic hysteresis loop rapidly decreases its saturation flux values, holding the rectangularity. This characteristics is about seven times as excellent as that of Supermalloy which has been used hitherto.

(iii) Even if the volume of amorphous tape is small in making toroidal, there is no remarkable deterioration of magnetic characteristics.

(iv) It is easy to make magnetic cores.

(v) It is easy to make magnetic materials with large change of magnetic characteristic for the stress application.

(vi) So-called temperature sensitive magnetic materials with low Curie temperature can be made easily.

Some points at issue which should be improved on hereafter are as follows.

(i) The decrease of ascending value of flux after resetting is over.
(ii) The decrease of core noise.
(iii) The establishment of a basic measurement of the magnetic core.
(iv) Making of a large tape breadth.
(v) Insulation between layers of toroidal cores.
(vi) Prevention of aging effect of magnetic characteristics.
(vii) Mass production of uniform characteristic materials.
(viii) Elucidation of mechanism of dynamic magnetization.

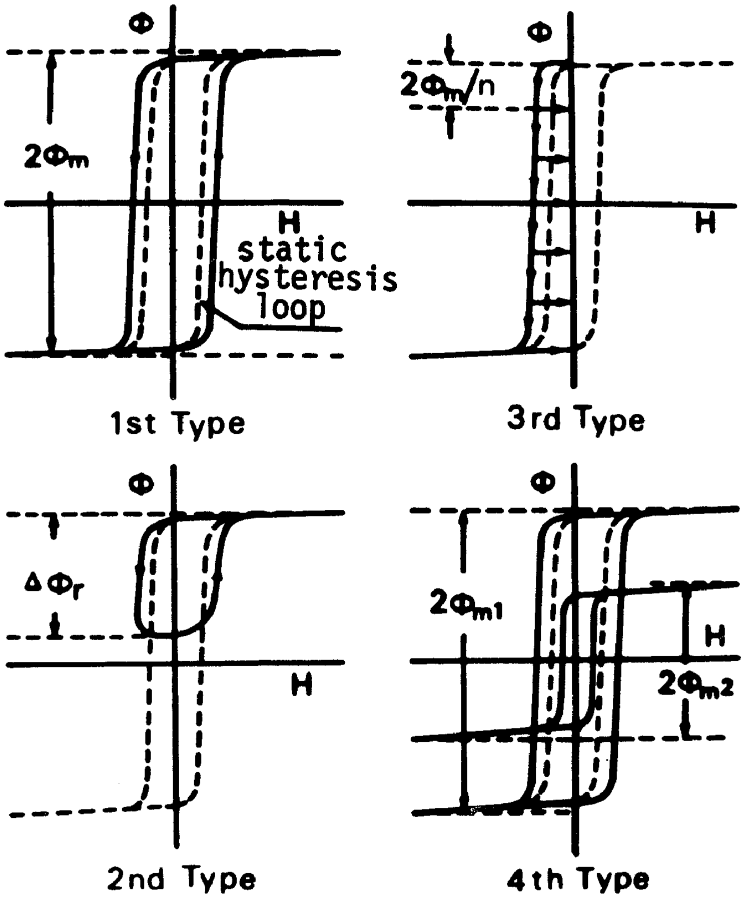



Fig. 1. Classification of flux control.

| Magnetic materials | $G_0$ ( $O_e^{-1}$ ) |
|---|---|
| S P S | 1.8 |
| 50% Fe-Ni | 6.5 |
| Mo-Permalloy | 21.0 |
| Supermalloy | 22.2 |
| Amorphous 1 | 42.1 |
| Amorphous 2 | 21.2 |

Table. 1. Values of Specific core gain of magnetic materials.

Let us explain some important items of the above mentioned, by using the results of experiments.

First let us measure CMC concerning various toroidal amorphous cores and show them indicated with magnetizing force H and flux density value $\Delta B$ in Fig. 2.

Table 1 shows Specific core gain obtained using the measurement results above mentioned. This table leads us to understand visibly that amorphous core are excellent as magnetic materials.

Next as for amorphous cores, as is shown by Figs. 3(a) and (b), under the constrained magnetization and when the control is constant, the reset value $\Delta\phi_r$ fluctuates irregularly around the reset value $S_0$ between $S_1$ and $S_2$. Accordingly the induced voltage repeats increase and decrease, as shown by Fig. 3(c).

This phenomenon is one of the faults of amorphous cores at present. But experiments reveal that there is little fluctuation of the characteristic if the control impedance is made zero and the flux control is done by the voltage reset. It can be regarded as one of the uses of amorphous cores.

Fig. 4 shows the ascending values of flux $\Delta\phi_u$ measured after the flux reset of the amorphous core. By this figure it is found that the ascending value of flux is about twice as large as that of 50 % Fe-Ni core. How to decrease this value is a problem which remains to be solved.

Fig. 5 shows example of measured B-H loops when an amorphous core was supplied with magnetizing force rotated 90° and the 4th type flux control was carried out. From this figure the author finds that the magnetizing force required for full control is one-seventh to one-eighth of that of 50 % Fe-Ni core. It means an excellent advantage of amorphous cores.

Fig. 6 indicates the measured results when the 4th type flux control was carried out by heating. In this case the irreversible change is brought about from amorphous materials to crystalline and this is a trait which no temperature sensitive magnetic materials hitherto used possess.

In addition to this, when an amorphous core is applied as instrument and control element it is core noise that regions its performance limit. From many experiments we find that the value of core noise of the amorphous magnetic core is superior to that of 50 % Fe-Ni core, but a unit inferior to that of Supermalloy core. [1]

Besides there are still irregular change of the permeability values of cores owing to the difference of the amplitude of exciting current and the exciting frequency, magnetic domain patterns and mechanism of magnetizing, and aging effect of magnetic characteristics and other important items of which the mechanism must be clarified for their practical use.

$$G_0 = \alpha_0 \cdot \beta_0$$

$$\alpha_0 = (1 - \Delta B_b / \Delta B_m)$$

$$\beta_0 = 1/H_r$$

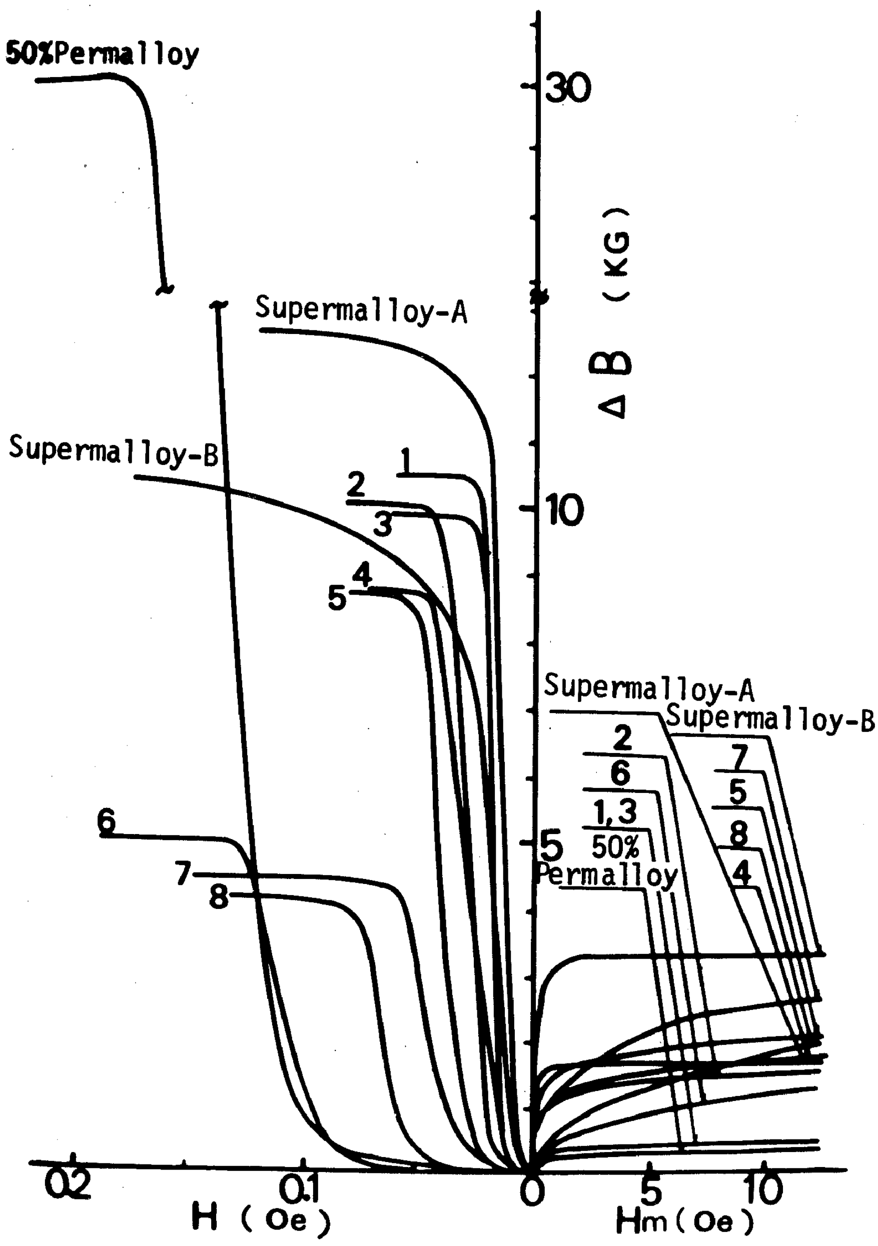
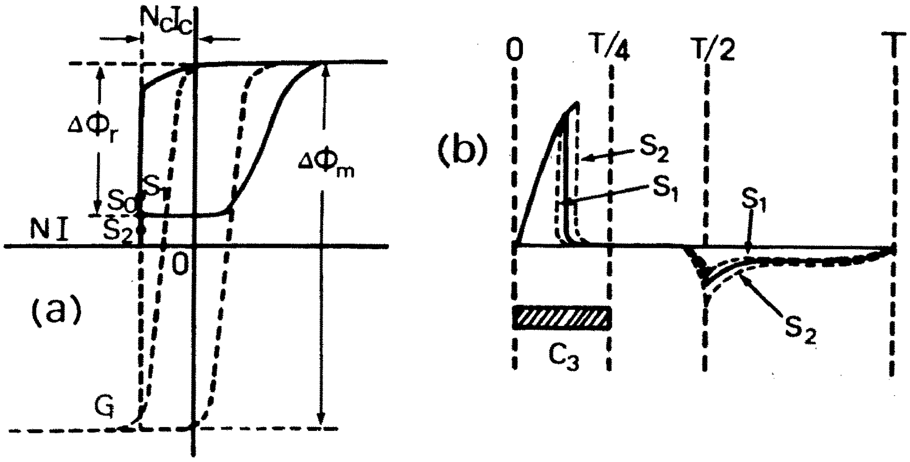
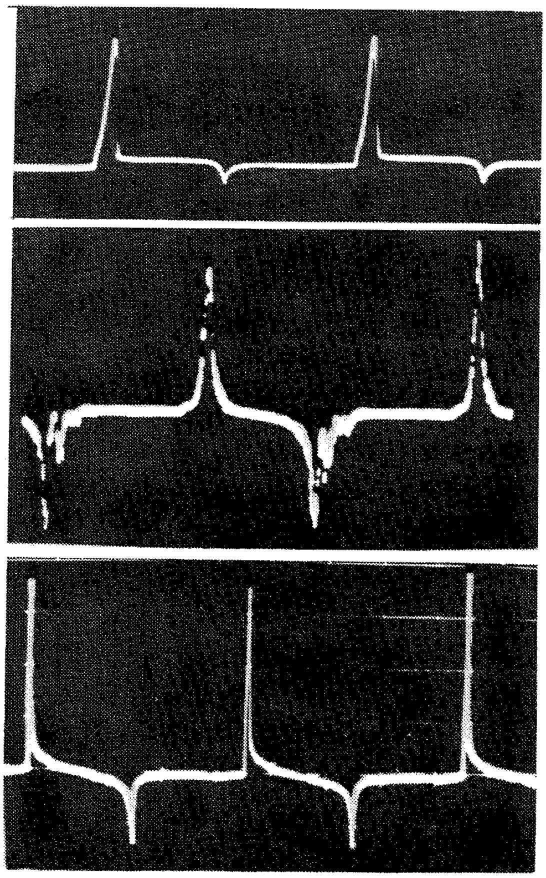



Fig. 2. Control magnetization curves indicated with magnetizing force H and flux density value ΔB.



(C)

50% Fe-Ni

Amorphous core 6

Amorphous core 7

Fig. 3. Explanation of fluctuation of reset value. (a) Minor hysteresis loop in the operation. (b) Induced voltage wave shape. (c) Observed wave shapes in experiments.

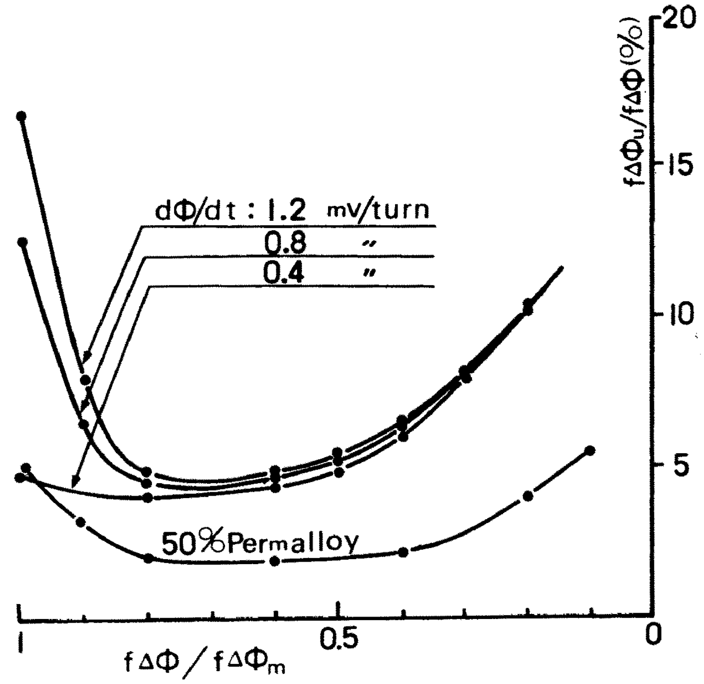



Fig. 4. Ascending flux values measured after the flux reset.

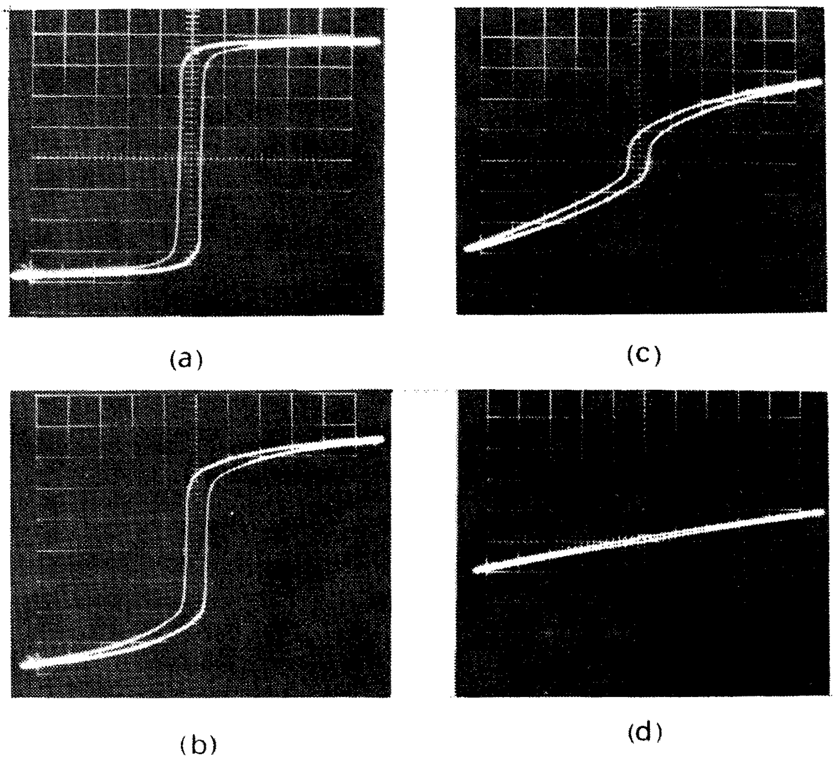



Fig. 5. Measured B-H loops of an amorphous core supplied with magnetizing force rotated 90°.

## 4. APPLICATION CIRCUITS

Examples of application of amorphous materials by making the good use of their characteristics are reported as follows:

### 4.1 Magnetic shielding [2]

By making the most of the high permeability of amorphous magnetic materials, a magnetic shielding which has better shielding effect than Supermalloy has been made.

### 4.2 Tensile stress transducer [3]

An example of tensile stress transducer is made by making the best use of the characteristic of an amorphous magnetic core that greatly changes its magnetic characteristic by dint of the tensile stress. By experiments a linear DC output voltage in this transducer was obtained between 0 and 10 $kg/cm^2$ or so of tensile stress.

### 4.3 Current transformer [4]

It is reported that by using the facts that an amorphous core has little core loss and that its linearity under high permeability is good, C. T. of a circuit including semiconductors has been made with good results.

### 4.4 Leakage current alarm device

This apparatus is a leakage current alarm device which can be sensitive enough to detect leakage of 1 mA or so by making the good use of high permeability of amorphous magnetic material and easy construction of a magnetic core. Figs. 7 and 8 show the basic circuit and the practical apparatus, respectively.

### 4.5 Applications to wattmeter, phasemeter and DC-CT

If a toroidal amorphous magnetic core with high permeability and rectangular hysteresis loop is combined with a common iron core of low permeability as shown in Fig. 9(a), 4th type flux control can be easily done. Fig. 9(b) shows the connection of its circuit.

Now let us $N_c$ winding be supplied with DC or AC signal current $i_c$, and we find the toroidal magnetic core decreases the maximum flux value in proportion to $i_c$, keeping still the rectangularity of the hysteresis loop.

If this characteristic is used, DC-CT, phasemeters or analog to digital converters which are simple in construction, can be made easily. Especially wattmeter are most suitable for the measurement of electric power is small quantity. Fig. 10 is an example of the measurement of a small power wattmeter.

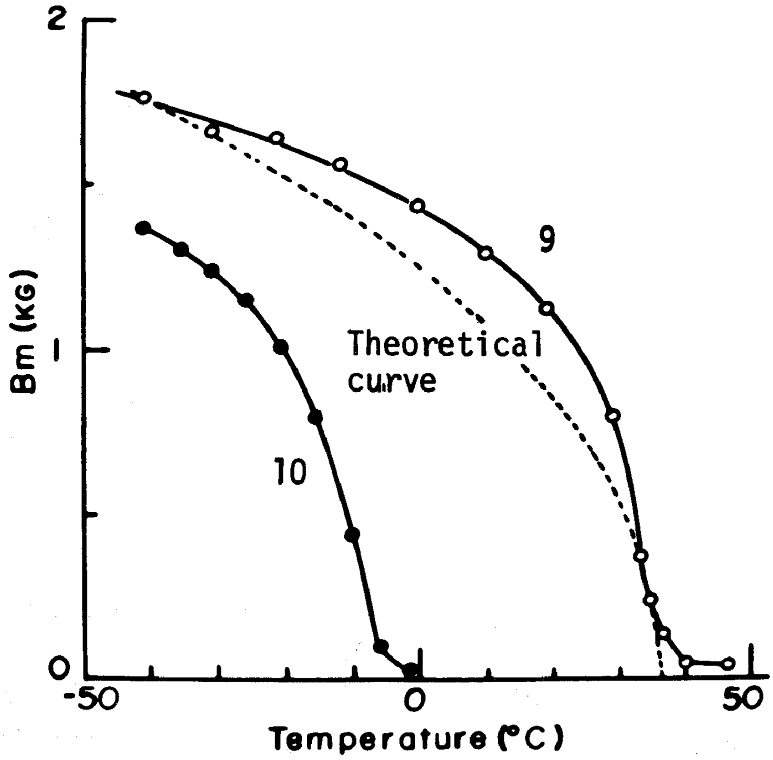



Fig. 6. Temperatue sensitive magnetic characteristics of amorphous cores.

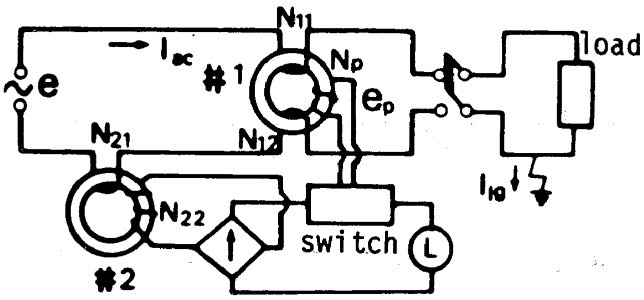



Fig. 7. Basic circuit of leakage current alarm device.

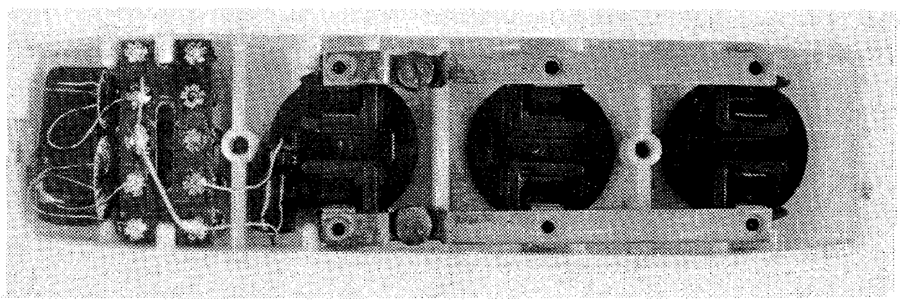


Fig. 8. An example of practical apparatus.

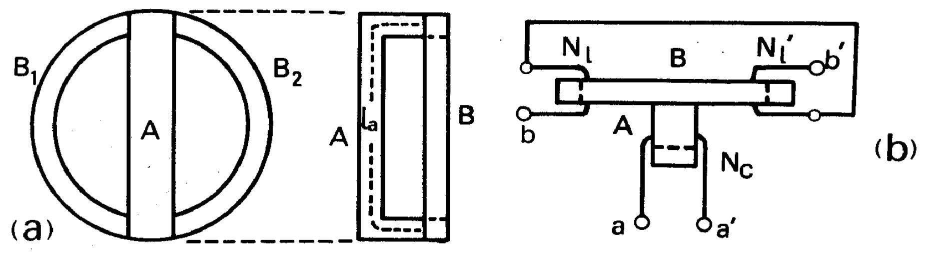



Fig. 9. Bridge-connected magnetic circuit using amorphous core. (a) Magnetic circuit. (b) Connection of windings.

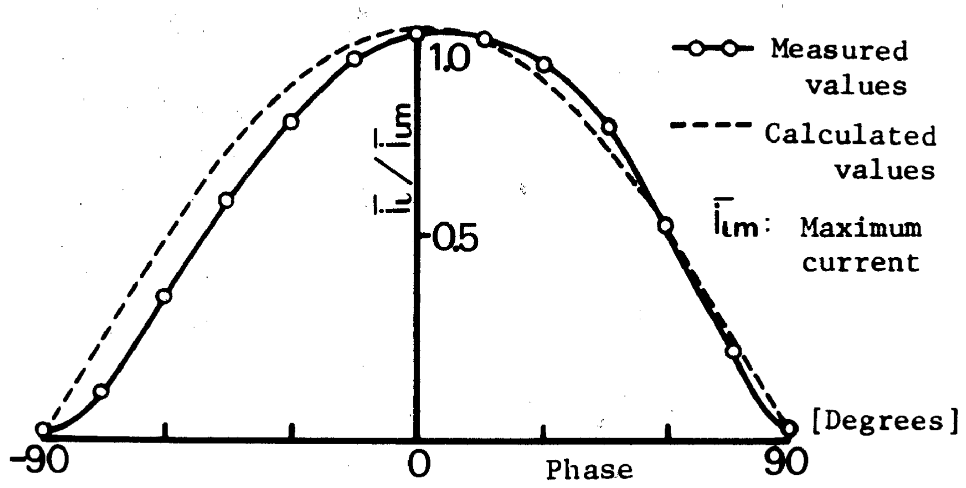



Fig. 10. An example of the measurement of a small power wattmeter.

### 4.6 Overcurrent alarm device with temperature memory

This apparatus is an overcurrent alarm device which makes use of the fact that amorphous magnetic material of low Curie temperature transfers from amorphous material to crystallic by the product of the heat added to it and the spent time and changes the saturation value $B_m$ of amorphous magnetic material and coercive force $H_c$.

It is characteristic of this apparatus that one can assume what kind of heating was carried out in the past by watching the induced voltage waveform through this apparatus.

## 5. CONCLUSION

The advantages of amorphous magnetic materials used practically and some points on which more data for the improvement are needed in future have been described and some circuits to which they were applied have been reported.

Although at present amorphous magnetic materials possess some defects which should be corrected in future in the practical use, they have characteristics that the magnetic cores used hitherto did not possess.

It may safely to said that the amorphous magnetic material is a very interesting magnetic material in the magnetic applications.

## 6. REFERENCES

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