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NEW *TELEPERM* ABGRIFF (PICK-UP)

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I. INTRODUCTION

The electrical transmitter is largely classified into an electronic transmitter, a force balance type transmitter and an ABGRIFF (pick-up of displacement type) transmitter. The features of the ABGRIFF transmitter are that it is easy of field indication, immune from the effect of electric failure, and that for high pressure measurement, in particular, it has a simple construction and is economically advantageous, etc.

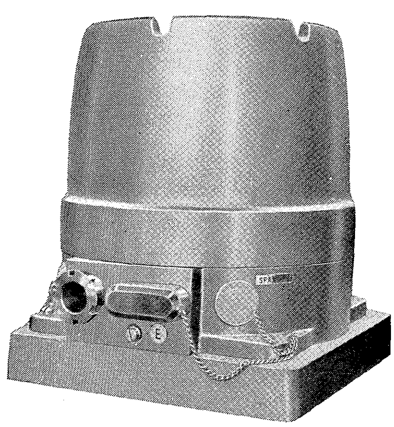
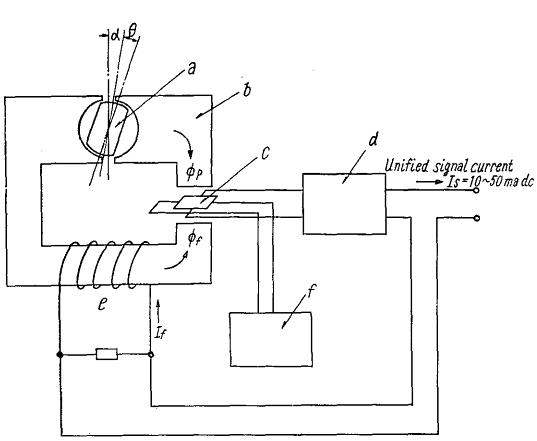


Fig. 1 New TELEPERM ABGRIFF



a : Permanent magnet
b : Magnetic circuit
c : Hall generator
d : Transistor amplifier
e : Non-liner feedback circuit
f : High frequency oscillator

Fig. 2 Principle diagram of New TELEPERM ABGRIFF

Our displacement type transmitter is extensively known as TELEPERM ABGRIFF and has been used widely in many fields. This paper is a report on a new TELEPERM ABGRIFF developed on the basis of the technique and rich experience that were used to built the former TELEPERM ABGRIFF.

One of the most outstanding features of the New TELEPERM System lies in the common power supply by "dc two wire system"; in other words, only two lines are employed for the transmission power and signal. The advantages of this system are that it does not require wiring work for power source, that it is economically superior, that it does not require power source on the field and that, for this reason, the danger of explosion is lessened.

II. PRINCIPLE OF OPERATION

As shown in *Fig. 2,* the principle of the new TELEPERM ABGRIFF is to obtain TELEPERM unified signal current I_s (I_s = 10~50 ma dc) in proportion to angular deflection: $\theta+\alpha(\theta=0\sim22.5°)$ of a permanent magnet. The angle α in the figure is an angular deflection necessary to send base current of 10 ma in the TELEPERM unified signal current of 10~50 ma.

All kinds of process variables which are transformed into angular deflection by various detectors are conveyed to the shaft of permanent magnet of TELEPERM ABGRIFF. The permanet magnet *a* is placed in the magnetic circuit *b* and generates magnetic flux ϕ_p approximately proportional to angular deflection $\theta+\alpha$. This magnetic flux is detected by Hall generator *c* which transforms it into Hall electromotive force V_H. The Hall electromotive force is amplified by transistor amplifier *d* and is fedback to non-linear feedback circuit *e*. Magnetic flux ϕ_f in proportion to feedback circut current I_f is directed reversely against magnetic flux ϕ_p by the permanent magnet, the feedback current is always so regulated that magnetic flux in magnetic circuit to be zero and the feedback current I_f is in perfect proportion to the magnetic flux ϕ_p by the permanent magnet. Consequently the signal current I_s is in proportion to the angular deflection $\theta + \alpha$ of the permanent magnet.

III. OPERATION

Fig. 3 shows the principle of operation in a block-diagram. The moment at switching on, current flows to the regulated voltage supply through the resistor connected between the collector and the emitter of a power transistor. The regulated voltage generated by this current actuates an oscillator, providing the Hall generator and the synchronous detection circuit with ac power source, and the transistor amplifier with dc power source through a rectifier circuit to render the equipment operative. It takes about two seconds from the switching on to this operative condition. When the current is given, the Hall electromotive force that is in proportion to the magnetic flux generated by a permanent magnet comes from. The control current of the Hall generator being given from the oscillator, the Hall electromotive force comes out as ac voltage. The reason for making control current alternative is that ac amplification is more advantageous in the drift of the amplifier and, at the same time, that insulation from the power source circuit (signal current circuit) may be arranged more easily. After the Hall electromotive force is sufficiently amplified by the transistor amplifier, it is transformed into dc signal through synchronous detector in order to control the power amplifier.

It is also possible to take dc power source for the transistor amplifier from the regulated power supply directly and, although this may be less expensive as it can dispense with a rectifier circuit, the method of rectifying output of the oscillator has the possibility of selecting voltage freely, securing insulation of the amplifier from other circuits, and choosing the point of earthing freely. The transistor amplifier has its minus side connected to the case but it is insulated from other circuits.

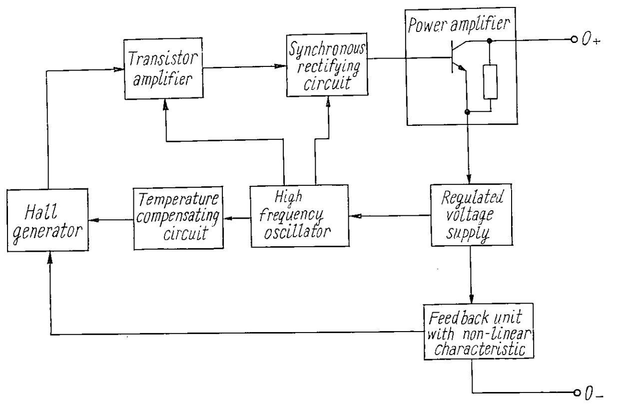


Fig. 3 Block diagram of New TELEPERM ABGRIFF

IV. CONSTRUCTION

Fig. 1 displays the appearance of the TELEPERM ABGRIFF (pick-up), while *Fig. 4* shows the interior.

In *Fig. 4,* ① shows the amplifiing unit in which the transistor amplifier, oscillator and synchronous detecting circuit are incorporated. ② shows the detecting unit which includes the permanent magnet, magnetic circuit, Hall generator, non-linear feedback circuit and temperature compensation circuit. ③ is a span adjustor and ④ is a zero point adjustor. ⑤ is a check terminal of signal current and ⑥ shows the printed circuit of the detecting unit. Three variable resistors seen on the printed circuit of the detecting unit are for span adjustment, temperature conpensation and linearity adjustment, respectively.

The detecting unit and amplifying unit are independent, in addition, they are interchangeable. The amplifying unit can be removed easily by pulling-out the connecting pin. Electrical connection between two section is made by the plug-in connector.

As is clearly seen in *Fig. 4,* the span and zero point adjustments may be made from outside. Both shafts use "0" rings, and the drip-proof quality is maintained even at the time of adjustment.

As *Fig. 5* illustrates, the shaft of a permanent magnet is fitted with a pointer and the mechanical

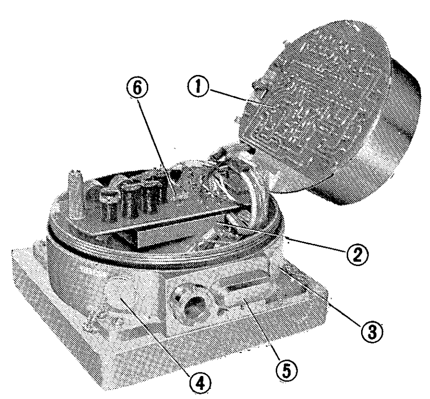


Fig. 4 Inner view of TELEPERM ABGRIFF

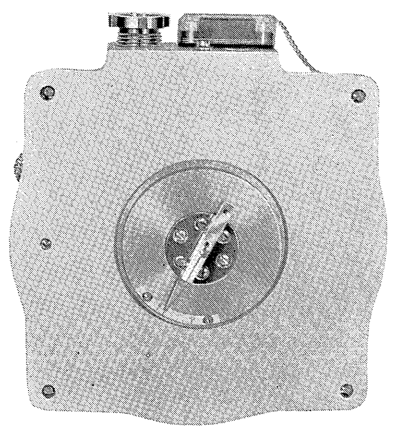


Fig. 5 Pointer for angular deflection

linkage between the permanent magnet shaft and the detector is easy.

Fastening screws are provided at four corners and the fitting size is the same as with the TELEPNEU ABGRIFF (pick-up) and the explosion-proof the new TELEPERM pick-up.

Exterior wiring may be conducted by removing the case cover and opening the amplifier.

V. EXPLANATION OF ELEMENTS

1. Permanent Magnet and Magnetic Circuit for Detection of Angular Deflection.

In order to insert a Hall generator in the magnetic circuit and to deflect the permanent magnet without friction, an air gap of about 2 mm is required. For the length of the permanent magnet, the air gap of 2 mm is large, so a permanent magnet of high coercive force is needed. In this equipment, a magnet with the characteristics as illustrated in *Fig. 6* is employed (designated as NFW-8).

For the magnetic circuit, we use vacuum-melting 98% permalloy with very little coercive force in order to lessen hysterisis.

2. Hall Generator

The Hall generator, used for magnetic flux detection of the new TELEPERM ABGRIFF (pick-up), is a new type of germanium Hall generator.

The most conspicuous problem that arises in the use of a Hall generator is the characteristic variation due to temperature fluctuation caused by the application of germanium semi-conductor. There are two characteristic variations, one is sensitivity (Hall coefficient) and the other is unbalance voltage (also called residual resistance). The former does not cause a problem because a magnetic flux balancing circuit (i. e., the flux is always zero) is used.

The temperature characteristic of unbalance voltage of the Hall generator is caused by the geometrical position of the output lead terminal and the lack of uniformity of impurity density of the pellet, and so it is not certain whether it appears on the plus side or the minus side. For this reason, it is necessary to select polarity of the temperature compensation circuit. A special construction is adopted to prevent variation of the Hall electromotive force by mechanical stress.

The Hall generator, as shown in *Fig. 7*, consist of four terminal elements. Flow control current I_c through two terminals in the X axis, and apply magnetic flux density B to the direction of Z axis and between two terminals in the Y axis will be generated the Hall electromotive force as shown in following

$$V_H = R \cdot \frac{I_c B}{d} \quad \cdots\cdots (1)$$

where, V_H: Hall electro motive force
R: Hall constant
B: Magnetic flux density
I_c: Control current
d: Thickness of pellet

3. Temperature Compensation Circuit

A bridge circuit is composed as seen in *Fig. 8*, and one arm of it is made copper winding resistor and manganin winding resistors are used for the other three. The polarity of compensation is decided by selecting the polarity of the power supply (oscillator side) and the absolute value is adjusted by changing

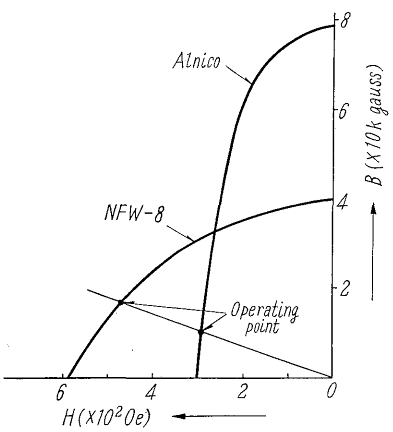


Fig. 6 Characteristics of permanent magnet

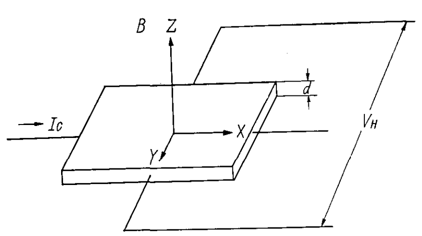


Fig. 7 Principle diagram of Hall generator

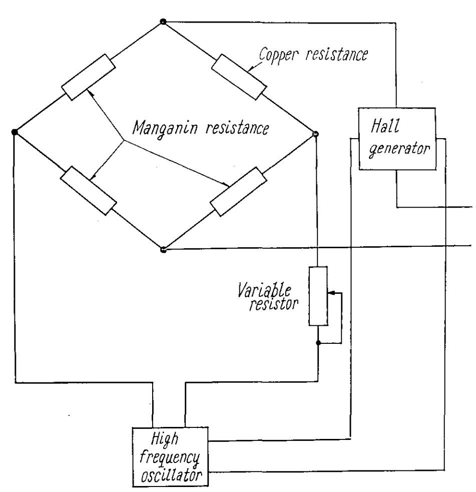


Fig. 8 Circuit diagram of temperature compensating circuit

the variable resistor inserted in series between the bridge circuit and power supply. The manganin resistors and the variable resistor are assembled in the printed circuit of the detecting unit and the copper resistor is housed in a shield case in order to match the temperature of Hall generator, thus precluding an abrupt temperature fluctuation that may be caused when the case cover is removed. All the elements that might affect temperature characteristic are all placed in the detecting unit to ensure interchangeability.

4. Oscillator

This oscillator is basically the same one with the oscillator used in the new TELEPERM EMF transmitter, and is a kind of magnetic multi-vibrator. It is hence not necessary to give a detailed account to it here except to mention that as the power source 16 v dc is utilized.

5. Transistor Amplifier

This is a three-stage transistor ac amplifier of which first and second stages are directly coupled while the second and the third by CR coupling. The transistor is all of silicon to check the drifting by temperature fluctuation and, by means of dc current feedback, the stability of the operating point is secured.

The overall amplification degree of the amplifier is approx. 500, and then loop gain is approx. 250.

6. Synchronous Rectifier Circuit

One transistor is used for synchronous detection and amplification simultaneously.

7. Non-linear Feedback Circuit

Fig. 9 shows the principle of non-linear feedback circuit.

As already stated under the principle of operation, the magnetic flux that acts on the Hall generator is a difference between the permanent magnet flux ϕ_p and the feedback current flux ϕ_f, and so the Hall electromotive force V_H is from equation (1), as follows:

$$V_H = R_1 \cdot I_c(\phi_p - \phi_f) \quad \cdots\cdots (2)$$

Where R_1: Coefficient determined by Hall constant and magnetic circuit

$$\phi_f = K_1 I_s \quad \cdots\cdots (3)$$

Where K_1: Coefficient determined by feedback coil and magnetic circuit

When the amplification degree of the amplifier is defined as K_2, it follows from equation (2) and (3) that:

$$I_s = K_2 V_H = K_2 R_1 I_c(\phi_p - K_1 I_s) \quad \cdots\cdots (4)$$

From equation (4)

$$I_s = \frac{K_2 R_1 I_c \phi_p}{1 + K_1 K_2 R_1 I_c} \quad \cdots\cdots (5)$$

Provided the amplification degree of the amplifier is sufficiently large and $K_1 K_2 R_1 I_c \gg 1$, then,

$$I_s = \frac{\phi_p}{K_1} \beta \quad \cdots\cdots (6)$$

The relationship between angular deflection $\beta(=\theta+\alpha)$ of the permanent magnet and ϕ_p of the permanent magnet flux is, when actually measured, in the range of $0\sim50°$,

$$\phi_p = K_3 \sin\beta \quad \cdots\cdots (7)$$

Therefore,

$$I_s = \frac{K_3}{K_1} \sin\beta \quad \cdots\cdots (8)$$

As is evident from equation (8), the signal current I_s is in proportion to the sine function of the deflection angle β. In the new TELEPERM pick-up, the defletion angle is set for $\frac{1}{16}\angle R - \frac{5}{16}\angle R$, and there is about 1% non-linearity between β and I_s.

The compensation of this nonlinearity is done as illustrated in the principle diagram *Fig. 9*. The applied voltage of the varistor goes up as the signal current I_s increases, and the shunt current i increases in proportion to the multiplication of n $(n>1)$ of voltage. Equation (3) stands:

$$\begin{aligned}\phi_f &= K \cdot I_f = K(I_s - i)\\ &= K \cdot (1 - i/I_s) I_s = K_4 I_s \quad \cdots\cdots (9)\end{aligned}$$

Provided

$$K_4 = K(1 - i/I_s) \quad \cdots\cdots (10)$$

where K = constant

For nonlinearily compensation, it is sufficient to make the value $(1 - i/I_s)$ of equation (10) approach the value of $\sin\beta/\beta$ as the signal current I_s increases, and when the varistor with varistor cofficient $n=3$

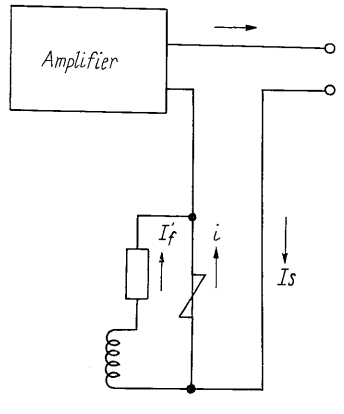


Fig. 9 Diagram of non-linear feedback circuit

is used, there is almost complete linearization as a matter of rule (Pat. pending).

$$I = k E^n$$

where I: Varistor current
E: Varistor voltage
n: Varistor coefficient
k: Constant

8. Check Terminal

This is for the purpose of checking the signal current from outside without cutting the circuit and resistors of approx. 2 ohms connected in series in the circuit. Since the terminal is buried in the silastic gell, there is no danger of corrosion and lowering of insulation resistance due to waterdrops.

VI. VARIOUS CHARACTERISTICS

1. Conversion Characteristic

Fig. 10 shows an example of the conversion characteristic of the new TELEPERM ABGRIFF (pick-up).

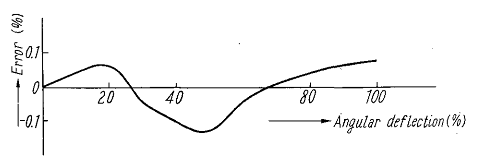


Fig. 10 Conversion characteristic of New TELEPERM ABGRIFF

2. Load Characteristic

Fig. 11 is an example of the load characteristic of the new TELEPERM ABGRIFF (pick-up).

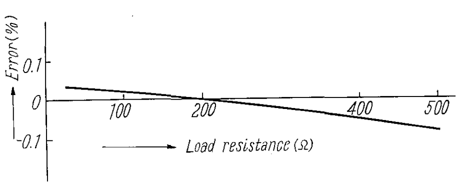


Fig. 11 Load characteristic of TELEPERM ABGRIFF

3. Counter-torque against Deflection

Maximum-torque is 10 g-cm approx. However, since it is in a near linear relationship to the angular deflection it may be disregarded as an error. *Fig. 12* shows an example of the torque in relation to the angular deflection.

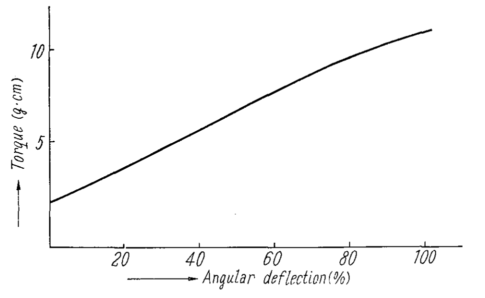


Fig. 12 Torque characteristic of TELEPERM ABGRIFF

VII. COMBINATION TO VARIOUS DETECTORS

Table 1 shows our transmitters in which the new TELEPERM ABGRIFF (pick-up) is used.

Table 1 **TELEPERM transmitters with New TELEPERM ABGRIFF**

Classification	Article	Model	Sensing Element
Pressure Transmitter	Pressure transmitter (for high pressure)	E-PTH	Bourdon tube
	Pressure transmitter (for medium pressure)	E-PTB	Bellows
	Pressure transmitter (for absolute pressure)	E-PTV	Double bellows
Differential Pressure Transmitter	Differential pressure transmitter (Twin bellows type)	E-DTB	Twin-bellows
Liquid Level Transmitter	Liquid level transmitter (Diplacement type)	E-LTE	Float plus torque tube
	Liquid level transmitter (Float type)	E-LTR	Float
Flow Transmitter	Area flow meter	E-FTT	Taper tube
	Flow transmitter (Weir type)	E-FTW	Weir
Tank Level Transmitter	Tank level transmitter	E-HTR	Rope