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NEW *TELEPNEU* DIFFERENTIAL PRESSURE TRANSMITTER

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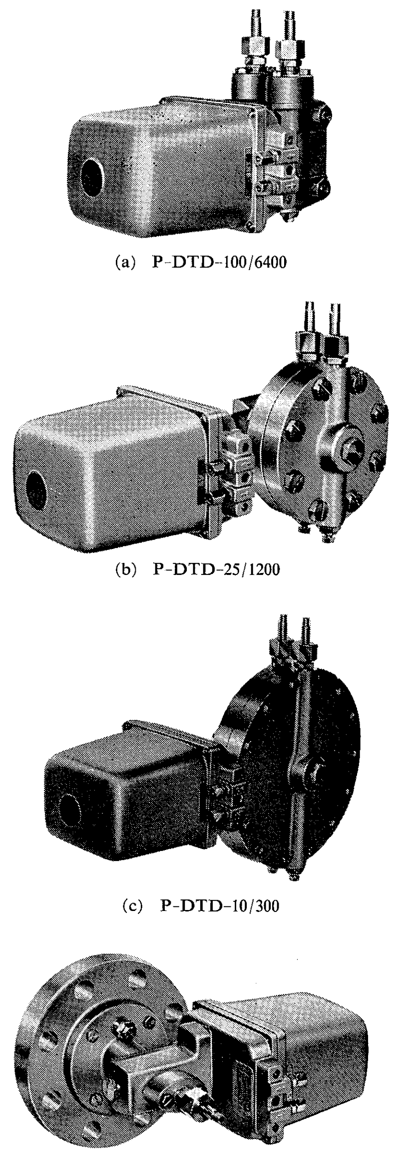
I. INTRODUCTION

The TELEPNEU differential pressure transmitter detects process variables such as pressure, differential pressure, flow, level, etc., converts these into 0.2~1.0 kg/cm^2 pneumatic signals, and transmits them to the TELEPNEU receiver. There are two types of conversion systems, namely the ABGRIFF type and the force-balance type. In the ABGRIFF type of conversion, measured quantities are transformed to standardized varying angles between 0 and 22.5° and are subsequently converted into TELEPNEU signals by means of a displacement balance converter (TELEPNEU ABGRIFF). In the force-balance type of conversion measured variables are converted into forces from which proportional pneumatic signals are obtained under the beam-balance principle.

All of the process variables usually found in industry, differential pressure, pressure, flow, level, density, etc., are detected as differential pressure or pressure. A diaphragm is used to detect differential pressure or pressure, while the transmitter used in obtaining penumatic signals proportional to differential pressure or pressure operates on the force-balance principle. Up to now we have been using Fuji Electric's PUF type TELEPNEU differential pressure transmitter. However a new force-balance transmitter (types P–DTD and P–LTD) has been developed which is more compact and lighter and which has greater precision, wider measuring range, and standardized parts. This new transmitter uses a metal diaphragm and includes a flange mounted level transmitter.

This article describes the types, features, construction, operating principles and capabilities of the pneumatic differential pressure transmitter (P–DTD type) and pneumatic flange-mounted level transmitter (P–LTD type).

These transmitters are depicted in *Fig. 1*.



(a) P-DTD-100/6400

(b) P-DTD-25/1200

(c) P-DTD-10/300

(d) P-LTD-100/6400

Fig. 1 TELEPNEU force-balance transmitters

II. TYPES

With respect to this company's force-balance conversion systems, the electronic TELEPNEU differential pressure transmitter (E–DTD, E–LTD types) corresponds to the pneumatic type TELEPNEU differential pressure transmitters (P–DTD, P–LTD types). However both TELEPNEU and TELEPERM use identical differential pressure detecting elements. The same measuring ranges, working pressure limits,

Table 1 **Types of Force-balance Transmitters**

Description	Type		Material	Detecting Element	Measuring Span (mmH_2O)
	Pneumatic	Electronic			
Differential Pressure Transmitter	P-DTD-100/6400	E-DTD-100/6400	Steel Stainless steel	Metallic diaphragm	500～6400
	P-DTD-25/1200	E-DTD-25/1200	Steel Stainless steel	Non-metallic diaphragm	100～1200
	P-DTD-10/300	E-DTD-10/300	Steel Stainless steel	Non-metallic diaphragm	36～300
Flange-mounted Level Transmitter	P-LTD-100/6400	E-LTD-100/6400	Steel Stainless steel	Metallic diaphragm	500～6400

Table 2 **Specifications**

Accuracy	±0.5%
Output	0.2～1.0 kg/cm²
Air Supply	1.4 kg/cm²
Standard Air Consumption	6N *l*/min
Ambient Temperature	−30～+80°C
Fluid Temperature	−30～+120°C
Ambient humidity	0～95% R.H.

pressure guide tubes, equalizing value manifold, etc., are common to both types. The types of force-balance transmitters are listed in *Table 1*.

Except for the fact that they have different detecting elements, all 4 types of both the pneumatic and the electronic transmitters use the same force-balance mechanism.

Furthermore, the TELEPNEU air set (P–S/G type) used for regulating the air supply and the TELEPNEU local indicator (P–PIU type) used for regulating the transmitter air pressure can be applied to the TELEPNEU differential pressure transmitter as standard attachments.

The P–DTD type differential pressure transmitter is widely used for differential pressure type detection of flow, pressure, level, etc., while the P–LTD type level transmitter is used where flange connections are to be made in processing and is suitable for measuring highly viscuous fluids as well as slurry fluids where it is difficult to apply connections to the pressure guide tubes. Standard specifications for the TELEPNEU differential pressure transmitter are shown in *Table 2*.

III. FEATURES

The features of the TELEPNEU differential pressure transmitter (P–DTD type), and the TELEPNEU flange-mounted level transmitter (P–LTD type) are as fIollows:

1) Since a force-balance system is applied, there are absolutely no effects from friction and inertia. The transmitter has excellent stability, and highly accurate high speed response measurements can be obtained.

2) Differential pressure measurements as well as suppression limits are extended over wide, continuously variable ranges.

3) Corrosive fluids can be measured.

4) The local indicator (output signal indicator) and the air set used as an air supply setting indicator can be easily attached.

5) When used for high differential pressure, ensured stability against pulsations of fluid to be measured is provided by the damping effect of the liquid sealed within the metallic diaphragm.

6) The transmitter case is an all-weather type, protecting the equipment from operational defects and malfunctions due to dust or water.

7) Silver paint is applied to the equipment so as to minimize the effects of heat radiation.

8) Highly viscuous or slurry of liquids can be measured using the flange-mounted level transmitter.

IV. OPERATING PRINCIPLE

The operating principle can be readily explained with the aid of *Fig. 2*. As the differential pressure to be measured is exerted on the measuring chamber diaphragm, a force is produced on the diaphragm, in turn, applying force against one end of the balance beam. As a result of the applied force, the balance beam is tilted and pivots around the cross spring primary fulcrum. The displacement of the balance beam moves the flapper, changing the gap between the flapper and the nozzle and, thus, changes the back pressure of the nozzle. The nozzle back pres-

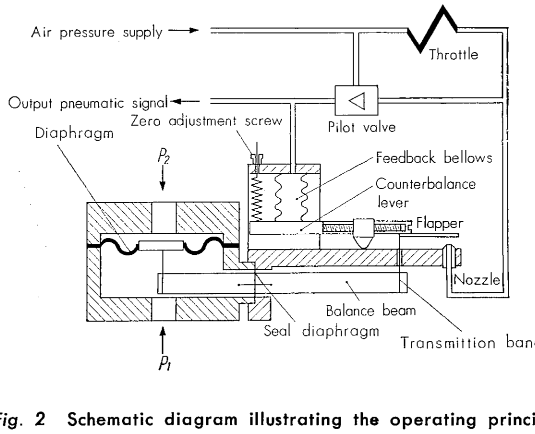


Fig. 2 **Schematic diagram illustrating the operating principle**

sure is subsequently amplified by the pilot valve and the resulting pressure is finally transmitted as a pneumatic signal.

The output pneumatic signal is simultaneously directed to the feedback bellows attached to the counterbalance lever. Finally, with the secondary fulcrum as the pivot the force produced on the bellows withdraws the flapper through the action of the counterbalance lever, returning the nozzle back pressure to its original state.

Output pneumatic signals are transmitted by the transmitter in proportion to the differential pressure being measured in this manner, with the balancing of force from the differential pressure to be measured and the negative feed-back force acting on the balance beam.

Zero adjustments can be made by varying the initial tension of the zero adjustment spring attached to the counterbalance lever, while span adjustments can be made by changing the position of the secondary fulcrum by adjusting the span adjustment screw. Furthermore, in suppression, the required force acting on the diaphragm is preset by the zero adjustment spring for the + side and by the − suppression spring for the − side, making zero point variations practicable.

The balance beam is pressure sealed by the seal diaphragm and the O-ring.

V. CONSTRUCTION

The force-balance transmitter consists of the following 5 principal components:

(1) Pressure chamber
(2) Transmitting mechanism
(3) Detector and amplifier section
(4) Feedback section
(5) Housing

1. Pressure Chamber

The conversion of differential pressures or pressures to forces occurs within the pressure chamber. The detecting element, that is the diaphragm, is contained within the casing and the casing cover aud consists of two measuring chambers.

The casing and casing cover are made of ordinary materials (steel) with zinc plating or non-corrosive materials (stainless steel). Stainless steel or Teflon are also used for the two sealed portions. Connecting terminal union and nut connecting methods are used for the pressure guide tube connecting plug. However use of tapered screws and screw-on methods can also be applied except on the connection fittings. A vent plug or drain plug is provided on the casing opposite the casing cover pressure guide tube connecting plug. Since identical screws are used and are symmetrically positioned, the connecting plug and discharge or drain plug are interchangeable. A plug is provided on the upper

Table 3 Diaphragm

Measuring Span (mmH^{2}O)	Diaphragm Material	Outer Diameter (mm)	Effective Area A (cm^2)
500~6400	Stainless steel	96	24
100~1200	Cloth impregnated Teflon	100	60
36~300		200	240

portion of the casing for use in blocking the hole connecting the diaphragm to the balance beam. In the flange-mounted level transmitter (P–LTD type), the flange-mounting surface serves as the casing cover while parts corresponding to those on the casing such as the discharge and drain plug are provided in the rear of the flange. Furthermore, a pressure guide tube connecting plug is provided for admitting atmospheric pressure when using an open tank or for admitting tank internal pressure, etc., when a closed tank is used.

Specifications for the diaphragms to be used depending on differential pressure measurement range are shown in *Table 3.*

The resultant force F_D (kg) on the diaphragm control portion is related to differential pressure ΔP (kg/cm^2) and effective area A (cm^2) by the following equation.

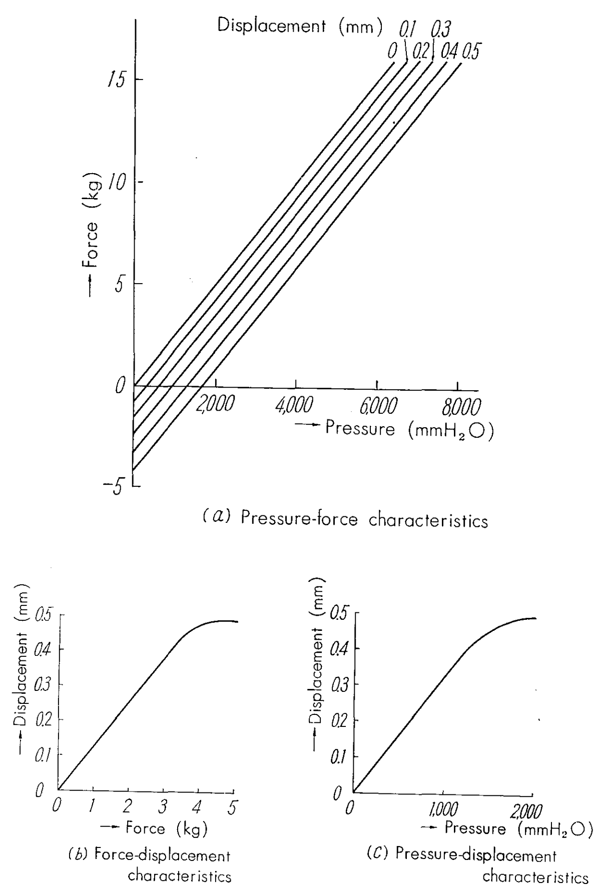


Fig. 3 Diaphragm characteristics

$$F_D = A \cdot \Delta P \quad \text{.......................(1)}$$

Diaphragm pressure-force characteristics are shown in *Fig. 3*.

The non-metallic diaphragm consists of a single layer oscillating diaphram with attachments for transmitting forces to the balance beam attached to its center. The diaphragm chamber is built to fit the diaphragm thereby protecting it from abnormal stress from overload differential pressures. The metallic diaphragm consists of a pair of oscillating diaphrams and two diaphragm ribs and center fittings, and is completely filled with fluid. This non-compressible fluid, sealed within the diaphragm, maintains the required diaphragm displacement, even when acted upon by high pressures, giving a damping effect as well as protecting the diaphragm. Center fittings attached to the center of the diaphragm connect the diaphragm on both sides and transmit differential pressure force to the balance beam.

2. Transmitting Mechanism

The transmitting mechanism transmits the forces produced on the diaphragm and provides balancing action. It consists of the balance beam, fulcrums, transmission band, related moving components, and a frame which supports these components.

The balance beam is of a sufficiently strong construction to withstand rotational movement and is supported by a powerful cross spring. This balance beam projects through the sealed diaphragm, extends from the pressure chamber to the transmitting mechanism, and is firmly set on both seal diaphragm surfaces, thereby keeping the central portion completely sealed. Since screws are used, the seal diaphragm is positioned between the frame which supports the measuring mechanism and the measuring chamber casing. The circumference of the casing is sealed by a close-fitting O-ring.

Plate spring type cross springs are used in the primary fulcrum of the balance beam, while a metallic plate-ball point contact is used for the secondary fulcrum of the counterbalance lever. The balance beam is connected to the counterbalance lever by a plate spring. *Fig. 4* is a schematic diagram of the operating principle of the P–DTD and the P–LTD transmitting mechanisms.

Measuring span adjustments are accomplished by varying the position of the secondary fulcrum. A slider acting as the fulcrum and attached to the counterbalance lever parallel to the frame is used for this purpose. After this slider has been moved by adjustment of the adjustment screw, it is securely fastened on the counterbalance lever by a lock-nut. Not considering the effects of the mechanism spring system, the following condition holds true for the balancing of forces. That is:

$$l_1 \cdot F_D = l_2 \cdot \frac{l_3 - x}{x} \cdot F_B \quad \text{....................(2)}$$

where the force F_D produced on the diaphragm is proportional to the differential pressure, and feedback force F_B corresponds to a $0.2 \sim 1.0\ \mathrm{kg/cm^2}$ output pressure. By varying the distance x corresponding to the secondary fulcrum position, the value of F_D can be changed and the measuring span can be adjusted.

The suppression spring can be set between the balance beam and the frame by screws and on-the-spot adjustments can be made easily.

3. Detector and Amplifier Section

These sectional components transform the slight displacements of the balance mechanism into pneumatic signals and subsequently amplify these signals. The principal components are: the nozzle flapper, pressure guide tube, pilot valve, and tube distribution board. The pressure guide tube transmits nozzle pressure to the pilot valve. The pilot valve amplifies changes in nozzle back pressure into pneumatic signals and also serves to retard the motion of the balance beam mechanism when changes in differential pressure occur thereby limiting the loss of force in the beam balance spring system. A schematic diagram showing the operating principle of the pilot valve is shown in *Fig. 5*.

4. Feedback Section

A bellows is used to convert the output pneumatic signals into feedback force and to transmit this force to the counterbalance lever. The following equation is used to express the proportional relationship of feedback force F_B to transmitting pressure P:

$$F_B = A_B \cdot P \quad \text{......................(3)}$$

Where: A_B represents the effective area of bellows.

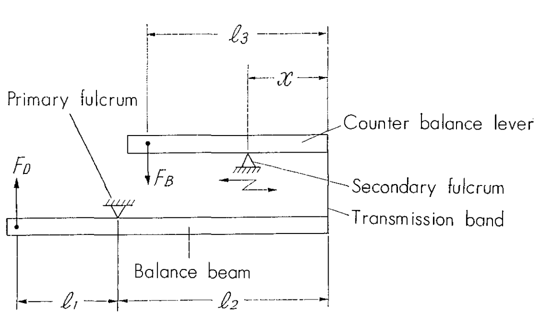


Fig. 4 **Schematic diagram showing operating principle of transmitting mechanism**

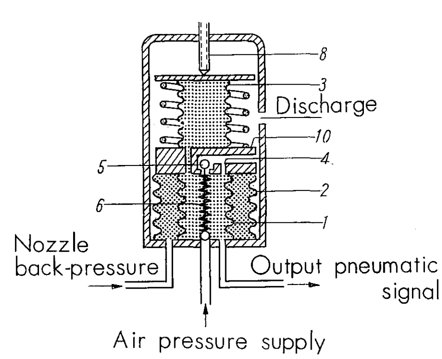


Fig. 5 **Schematic diagram of the pilot valve illustrating the operating principle**

5. Housing

The housing, which protects the equipment from sudden environmental changes, is made of light aluminum alloy. It has been designed and constructed so as to withstand conditions encountered under outdoor installation.

Closely fitted pressure guide tube connecting plugs are used for both input and output pressure to prevent undesirable erroneous measurements from being produced during the transmission of forces between the amplifier section and the connecting plug. Since the connecting plug stand is mounted to permit 180° rotation, the tube distribution can be faced in the opposite direction.

VI. CHARACTERISTICS

1. Transmitting Characteristics and Sensitivity

In terms of %, the values of span, transmitting characteristics, and sensitivity are indicated as follows:

Accuracy: ±0.5%
Hysteresis: less than 0.2%
Sensitivity: less than 0.1%

Fig. 6 shows an example of transmitting characteristics.

2. Static Pressure Characteristics, Overload Pressure Characteristics

With the exception of the diaphragm, effects of changes in static pressure are exhibited as deviations between the line of motion of the balance beam thrust acting on the seal diaphragm and the line of motion of the cross spring force receiving this thrust. When such a deviation between lines of motion exists, a resultant torque is produced on the balance beam due to the action of static pressure causing a static pressure error. Therefore, the deviation between these lines of motion must be adjusted to zero by the adjustment screw. The following equation expresses the relationship between static pressure error ε_p (%) and the distance between the lines of motion l_g (cm).

$$\varepsilon_p = \frac{A' \cdot P}{A_D \cdot \Delta P_{\text{max.}} \cdot l_1} \cdot l_g \times 100 \quad (\%)$$

Here
A': Effective seal diaphragm area (cm^2)
P: Static pressure (kg/cm^2)
A_D: Effective diaphragm area (cm^2)
ΔP_{max}: Measuring span (kg/cm^2)
l_1: Distance between balance beam fulcrum and diaphragm connecting point. (cm)

An example of static pressure characteristics is given in *Fig. 7*.

Fig. 8 shows an example of overload pressure characteristics with a 100 kg/cm^2 pressure applied. The overload pressure error results in deviation of the zero point, with no change in span, and it decreases in inverse proportion to the increase in the measuring span.

3. Temperature Characteristics

Since materials having suitable thermal expansion coefficient are used, compensating for displacement of moving parts and deviations in characteristic values of each segment due to thermal expansion, the undesirable effects of ambient temperature changes are extensively minimized. An example of temperature characteristics is shown in *Fig. 10*.

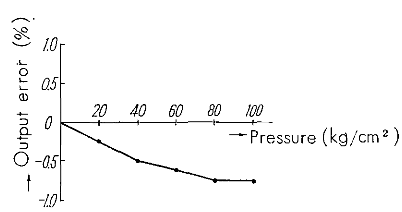


Fig. 7 Static pressure characteristics of P-DTD differential pressure

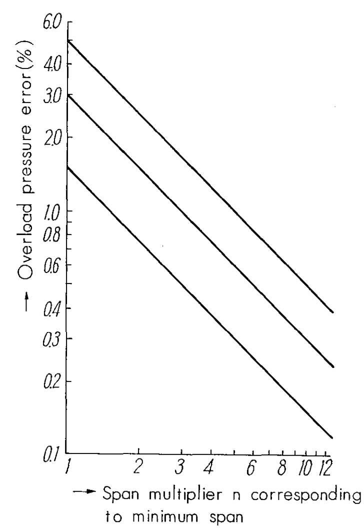


Fig. 8 Overload pressure characteristics of P-DTD differential pressure transmitter

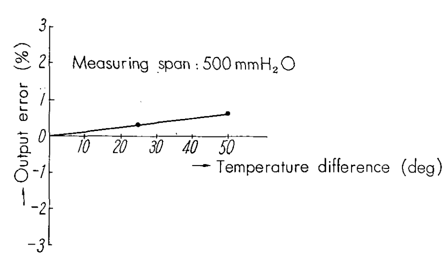
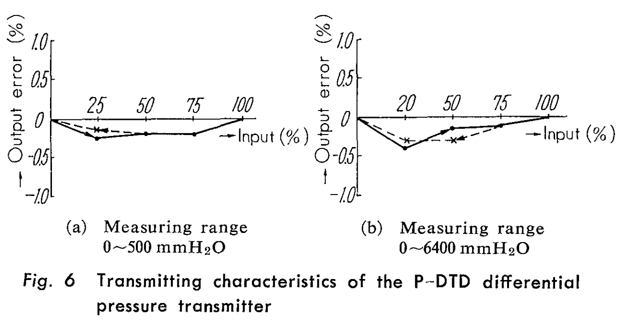


Fig. 9 Temperature characteristics of P-DTD differential pressure transmitter



(a) Measuring range 0~500 mmH_2O (b) Measuring range 0~6400 mmH_2O

Fig. 6 Transmitting characteristics of the P-DTD differential pressure transmitter

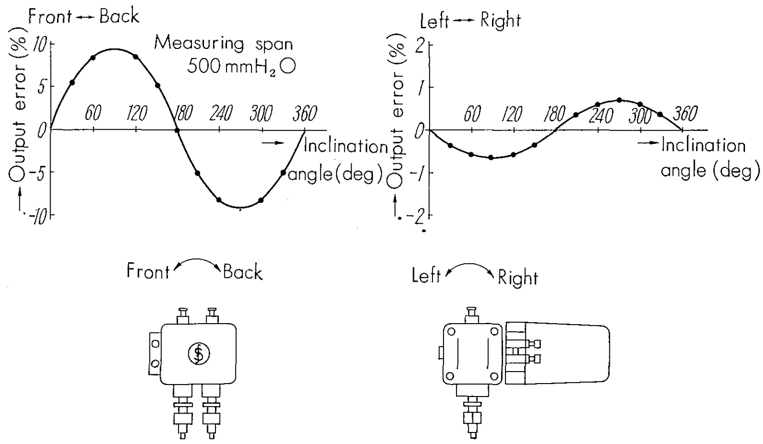


Fig. 10 Inclination characteristics of P–DTD differential pressure transmitter

4. Inclination Characteristics, Effects of Vibration

Variations in output due to inclination consist mainly of zero point deviations with almost no change in span and are greater on the inclination in the direction of the inclination of the diaphragm mounting surface and less along the inclination at an angle to the diaphragm mounting surface. *Fig. 10* shows an example of inclination characteristics.

5. Effects of Fluctuations in Air Pressure Supply

Even with maximum output deviations resulting from fluctuations in pressure of ± 0.05 kg/cm^2, corresponding to an air pressure supply of 1.4 kg/cm^2 (1.0 kg/cm^2 output air pressure), deviations in span amounted to less than 0.25%. When air-set P–S is used, these effects can be disregarded, since pressure can be regulated to 1.4 kg/cm^2 ± 0.035 kg/cm^2 corresponding to fluctuations in air pressure supply of 5 kg/cm^2 ± 2 kg/cm^2.

VII. CONCLUSION

An outline of the TELEPNEU force-balance differential transmitters has been given. These transmitters make full use of the exceptional features of the forcebalance and ABGRIFF types of conversion and were developed so as to combine economy with superb performance in this company's TELEPERM control and TELEPNEU control systems. Sufficient capabilities required for measurements of process variables encountered in every industry have been provided and the measur-ing range has been further expanded with improved quality and performance.