Introduction of Products

THE KOLBEN-FLOWMETER AND ITS SUPPLEMENTARY DEVICES

I. INTRODUCTION

The Kolben-flowmeter is a kind of the so-called a rotary piston type flow integrator, which indicates quantity of liquid passed through the meter by means of the rotation of the Kolben, i.e. a rotary piston, being driven by the stream of the liquid; and which has an extremely excellent measuring accuracy even with its simple structures. For this speciality, this meter provides a wonderful capacity and a wide-spread fields of application, not only for the general heat control, but also for the control system in the various production courses and processes in all kinds of industries. Besides, this Kolben-flowmeter may be equipped with such supplementary devices as the contact device, flow rate transmitter, or quantity pre-setting device, so that it makes possible to conduct tele-metering both quantity of liquid passed and a flow rate of liquid by employment of the above-mentioned devices and to apply for an automatic control of the flow rate of liquid. For this reason, the utilities of this meter as an industrial instrument might be enlarged with a joint employment of these devices together with the meter itself.

The following sections of this Article will give the readers the brief description on the specification, structure, operational principle, capacity, etc. of the Kolben-flowmeter and its supplementary devices.

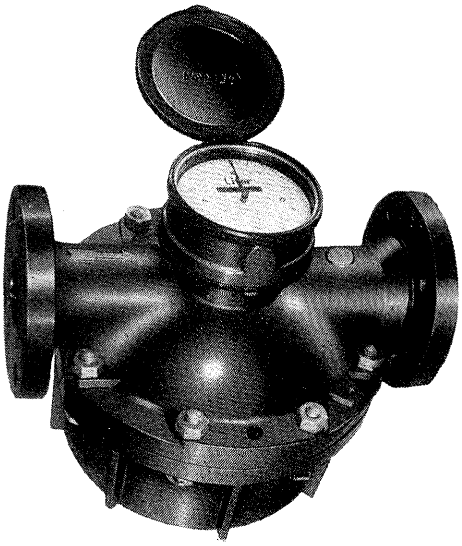

Fig. 1. Kolben-flowmeter

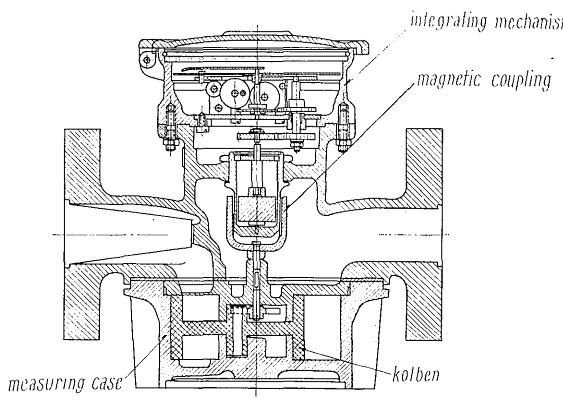

Fig. 2. Construction of Kolben-flowmeter

II. CONSTRUCTION AND OPERATIONAL PRINCIPLE OF KOLBEN-FLOWMETER

The outside appearance and construction of the Kolben-flowmeter are shown in Fig. 1 and 2, respectively. Just as shown in the Fig. 2, the Kolben-flowmeter consists of the three main parts for measuring part, magnetic coupling and integrating mechanism. The Kolben in the measuring chamber is driven by liquid stream, rotation of which is transmitted to the integrating mechanism through the magnetic coupling and the quantity of liquid passed is to be indicated as a result.

The detailed illustration of the measuring part of the Kolben-flowmeter is given by the Fig. 3. Now, several illustrations will be given in the following lines with reference to the Fig. 3.

The measuring room is made by a space being formed by the two concentric cylinders Z_1 and Z_2 in the measuring chamber. The room is parted from each other by a division wall T fixed in the radial direction. There are the flowing inlet E and outlet A at the both sides of the division wall. Any part being connected to the inlet E is securely shut out of the other part connected to the outlet A, always by the division wall T and Kolben K.

The Kolben has a slit S being cut longitudinally at a position of the circumference of the Kolben.

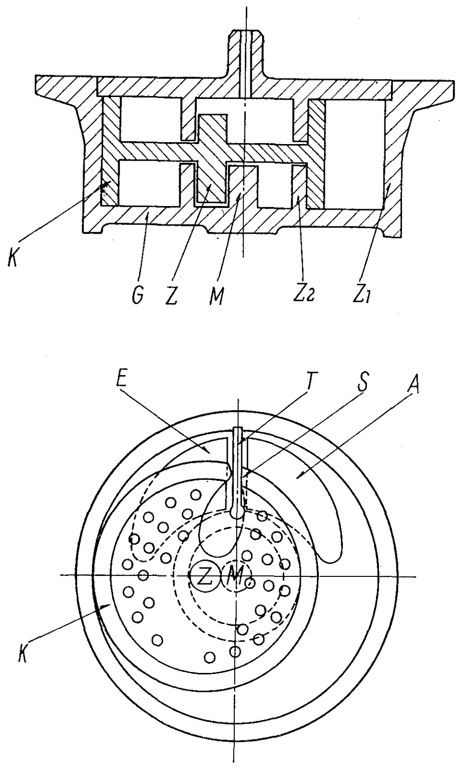

Fig. 3. Measuring part of Kolben-flowmeter

The size of the Kolben is made such that, in chamber where the guide pin Z and slit S of the Kolben move guided by the pin M located at the center of the measuring chamber G, and division wall respectively, the outer side of the Kolben is to touch to the inner surface of the cylinder Z_1 on the outside of the measuring chamber, and the inner side of Kolben also is to touch to the outside surface of the inner cylinder Z_2.

Therefore, it may be clearly shown that the measuring room is divided into the two parts by the Kolben, one of which is connected to the inlet of the meter, the other of which is connected to the outlet.

Whatever position the Kolben may take in, these two parts are securely divided and shut out by it at the inlet and outlet from each other at all times, but each of them is always connected to the inlet and outlet of the meter with each other. In other words, either of these two parts is always closed, at the time when the rest of the two is connected to the inlet, so that the Kolben may rotate with its smoothness without any dead point and that a certain designated quantity of fluid is delivered to the outside of the meter at every rotation of the Kolben round the pin M.

Thus, the volume of the fluid passed through this meter, i.e. the total quantity is to be measured. The Fig. 4 is to show the motion of the Kolben and it is to indicate the positions where the Kolben turns at every 90 degrees.

The detailed description of the motion of the Kolben will be given in the following lines in reference to the above Fig. 4.

(1) The fluid flows into the measuring room (and inside the Kolben) through the inlet E, to fill up the black part of the figure. By the pressure of this part, the Kolben turns in the direction of the arrow mark.

(2) In this position, the crescent-formed part V_2 inside the Kolben is filled and sealed tight with the flown fluid. Even at that time, the fluid is still flowing into the parts outside the Kolben, and by the pressure of this fluid, the Kolben continues its revolving into the direction of the arrow mark, further more.

(3) Then, the fluid inside the Kolben will flow out gradually through the outlet A. And, the fluid is filling into the measuring chamber consecutively to make the Kolben continue its turning in the direction of the arrow mark.

(4) In this position, contrary to that of the (2), the crescent-formed part V_1 outside the Kolben is sealed tight and filled up by the fluid and, at the same time, into inside the Kolben, the fluid is filling through the inlet E, of which the pressure will have got the Kolben turning in the direction of the arrow mark, still further.

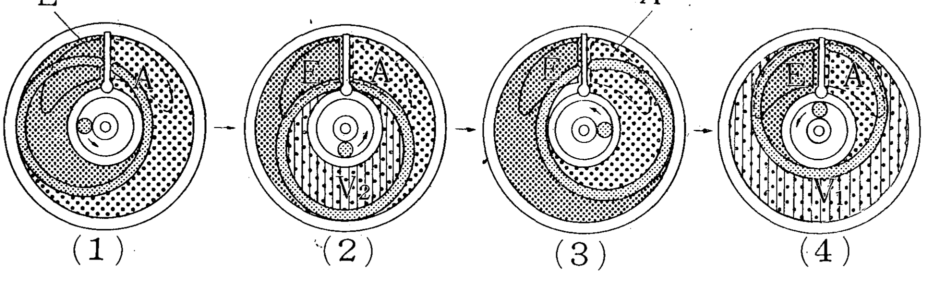

Fig. 4. Motion of Kolben-flowmeter

In this way of the above description, the Kolben is continuously revolving, with no dead point, with its smoothness, and every one rotation of it makes the fluid flow out through the meter by a certain volume $V_1 + V_2$ of it.

III. CLASSIFICATION OF KOLBEN-FLOWMETER

The Kolben-flowmeter can be classified into three standard types with its size of 32 mm, 50 mm, and 80 mm. This differences among its size will decide its measuring range which is made possible in every actual case.

The materials for the housing, the measuring chamber and Kolben itself are required to employ adequate and suitable one, in accordance with the characteristics of the fluid to be actually measured.

The Table 1 is to show several kinds of example applied most commonly.

Table 1. Standard materials for Kolben-flowmeter

Housing, measuring chamber	Kolben	Fluids applicable
Gunmetal	Graphite	Uncorrosive fluid with low viscosity
Cast iron	Cast iron	Uncorrosive fluid with high viscosity
18-8 Ni.-Cr. steel	Graphite	Corrosive fluid with low viscosity

As thoroughly understood by the readers to their satisfaction with the above-mentioned Table, both the housing and the measuring chamber are made of gunmetal and the Kolben, of graphite, for water as an example. For such an oil of high viscosity as a heavy oil, the cast iron shall be applied for the material of the housing, the measuring chamber and the Kolben.

IV. CAPACITY OF KOLBEN-FLOWMETER

Speaking in general, an instrumental error of the Kolben-flowmeter is to be of such as being shown in the Fig. 5 against the flow rate of the fluid. Therefore, the accuracy of the meter will depend on the selection of measuring range. In any way, our Company makes such a range as being within $\pm 0.5\%$ of its instrumental error, the applicable measuring range. In other words, the instrumental error of the Kolben-flowmeter, if it is within the applicable measuring range, will be less than $\pm 0.5\%$.

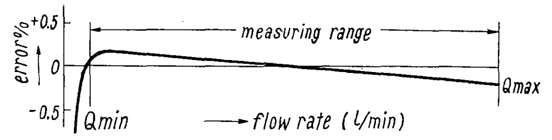

Fig. 5. Instrumental error of Kolben-flowmeter

The instrumental error of the Kolben-flowmeter is to be increased for a comparatively small flow rate with an abrupt pace, because a small quantity of the fluid leakage through a slight space between the Kolben and the measuring chamber is to give a comparatively large affects in case of a small flow rate. Therefore, the higher viscosity the applied fluid has, the smaller quantity of the leakage will result, in which case, the measuring is made effective even against a comparatively small flow rate.

The applicable measuring range for the various sizes of the Kolben-flowmeter is shown in the Table 2.

Table 2. Measuring range of Kolben-flowmeter

Size (mm)	Maximum flow rate (l/min) Conti-nuous	Inter-mittent	Minimum flow rate (l/min) 0.6 cp	1 cp	5 cp	50 cp
32	50	80	6	5	3	1
50	165	330	20	18	10	3
80	500	1,000	35	35	20	6

Note: Example for 0.6 cp: Benzine
Example for 1 cp: Water
Example for 5 cp: Gas oil
Example for 50 cp: Lubricating oil

The pressure losses of the Kolben-flowmeter are to be prevented to a small quantity. Example is shown by the Fig. 6, in which the pressure loss in case of a fluid with the viscosity of 1 cp approx. (i.e. water) is applied to each size of this meter.

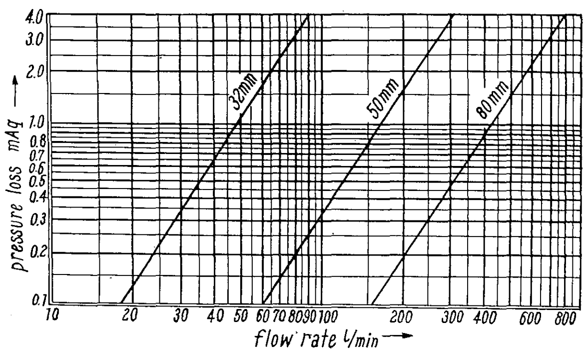

Fig. 6. Pressure losses of Kolben-flowmeter

The main specification of the Kolben-flowmeter is given by the Table 3.

Table 3. Specification of Kolben-flowmeter

Accuracy			±0.5% (within the applicable measuring range of Table 2)
Allowable temperature			Less than 150°C
Applicable pressure	32 mm	For low pressure	10 kg/cm²
		For high pressure	30 kg/cm²
	50 mm	For low pressure	6 kg/cm²
		For high pressure	30 kg/cm²
	80 mm	For low pressure	4 kg/cm²
		For high pressure	30 kg/cm²

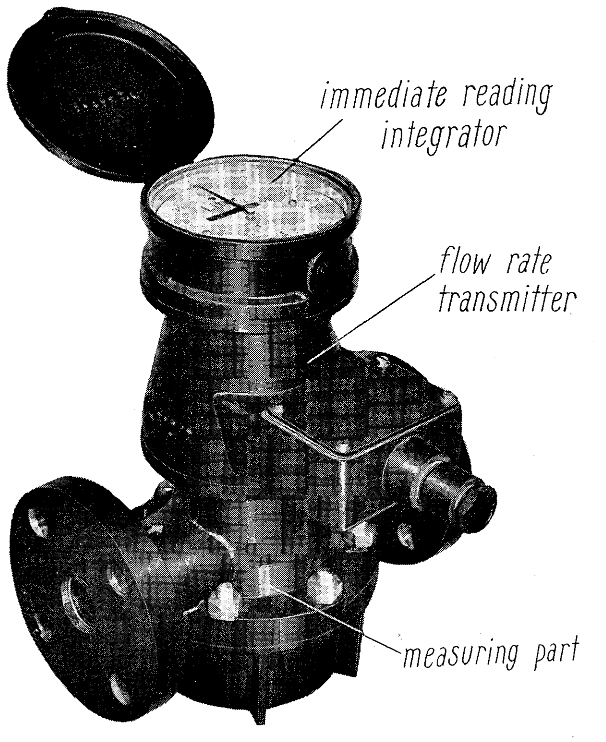

Fig. 7. Kolben-flowmeter with contact device

V. SUPPLEMENTALY DEVICES TO THE KOLBEN-FLOWMETER

As the supplementary devices to the Kolben-flowmeter, the following devices might be mentioned :
(1) Contact device
(2) Flow rate transmitter
(3) Quantity pre-setting device
The detailed illustration will be given in the following paragraphes for these three kinds of the devices to the Kolben-flowmeter :

(1) Contact device

The contact device is a certain kind of transmitters for tele-indicating the total flow quantity passed through the flowmeter. This device consists of a transmitting part and the reduction mechanism part, and has such a construction that, as shown in the Fig. 7, the reduction mechanism is fixed on above the measuring part, that the transmitting part is set above the reduction mechanism part, and that the immediate reading integrator is placed above the transmitting part of the device, respectively.

In this device, the reduction mechanism consists of the gears for a proper and adequate reduction of the rotating speed of the Kolben itself.

The transmitting mechanism employes such a systm as producing an impulse at every certain rotation number of the Kolben. The construction of this mechanism is given by the Fig. 8. It consists of the two main parts, one of which is the cam and the other is the mercury switch.

As shown in the Fig. 8, the cam is a cylinder with a slit of a mountain-like shape arround it. In this slit, there is inset a pin at the end of the lever secured to the mercury switch. And, the Fig. 9

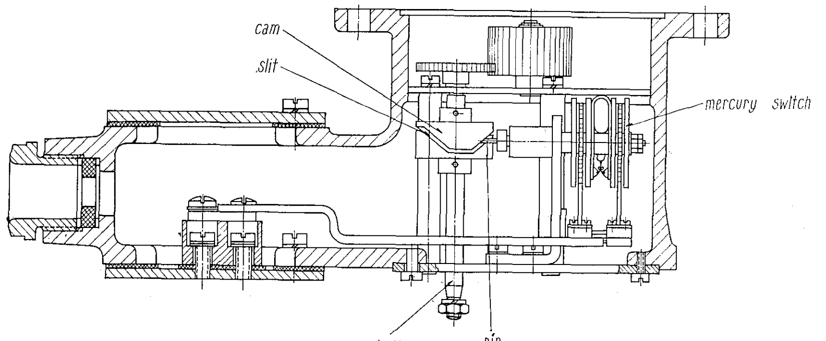

Fig. 8. Construction of contact device

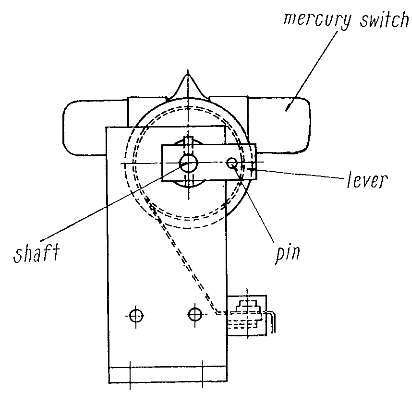

Fig. 9. Construction of mercury switch part

gives the construction of this mercury switch which has a construction of being able to revolve arround a shaft in its center. Therefore, as the cam turns, the pin inset into its slit will move up-and-downwards guided by the slit; and the up-and-downward movement of the pin makes the mercury switch inclined into the left and right sides of its shaft as a center. Corresponding to this inclination, the mercury within the mercury switch moves toward left and right sides. On its way of movement, the mercurry makes a short-circuit at the contact in the middle way of the above movement, so as to produce an impulse.

As the rotary shaft of the cam is connected to the Kolben through the reduction mechanism and the magnetic coupling, every one impulse is to be despatched at a certain rotation number of the Kolben, or at a constant quantity of the fluid passing through the Kolben.

There are two types of the device, the C 2 type and C 10 type; the former is to transmit two impulses at every one round turning of the cam, while the latter is to produce ten impulses at every one rotation of it. The C 2 type has one highest point (crest) and one lowest point (trough) of the cam, while the C 10 type has five highest points (crests) and the five lowest points (troughes) of the cam, respectively. The C 2 type is mainly applied for measuring a comparatively large flow rate and the C 10 type is used for measuring rather a small flow rate.

Thus the type classification of the transmitting part is limited to the above-mentioned two types, both of which are designed to fit commonly to every size of the meter itself. Therefore, the adjustment of different various sizes of it can be made by changing the reduction mechanism in accordance with its size.

The fluid quantity corresponding to one impulse can, in principle, be made any volume by using an adequate reduction mechanism, but it cannot be

Table 4. Volume for one impulse

Size / Type of contact device	32 mm	50 mm	80 mm
	Volume for one impulse	Volume for one impulse	Volume for one impulse
C 2 type	5 l	50 l	500 l
C 10 type	1 l	10 l	100 l

very much small in practice, because of the instrumental friction, pressure losses and its accuracy. The table 4 is to show a standard value of today.

As the receiving apparatus for this transmitting part, the electro-magnetic type integrator is employed. The Fig. 10 will illustrate the electric measuring circuit of the above flowmeter applied.

Within the applicable measuring range, its accuracy is $\pm 0.5\%$ of the total value.

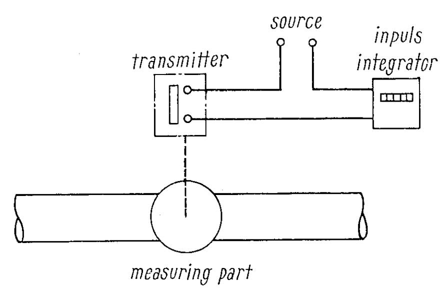

Fig. 10. Measuring circuit of integrated flow by contact device

(2) Flow rate transmitter

As have been described under the Section II, it is an total quantity of any fluid that can be indicated in an immediate way by the Kolben-flowmeter. However, the rotating speed of the Kolben is relating to the flow rate of the fluid, so that this speed can be made a measuring unit of the flow rate of a fluid applied. The construction of the measuring part of the Kolben-flowmeter is as illustrated in the Fig. 3, and the outside cylinder of the Kolben has a certain thickness, so that the volume of the fluid at a unit of angle of the measuring room might vary in accordance with the position of the Kolben itself against this measuring room and, as a result, an angular velocity of the Kolben might not always be held at a constant value for a constant quantity of the fluid. The above-mentioned point shall deserve to pay special attention and to take consideration. Now, assuming that $dV/d\varphi$ of the fluid quantity and $dV_m/d\varphi$ of the mean fluid quantity, both being of the measuring room at a unit angle in any given position of Kolben, are given; and that ω of the angular velocity of Kolben and ω_m of the mean angular velocity of it are also given in case of the flow rate Q; then, the following equations can be composed :

$$\omega=\frac{d\varphi}{dt} \quad \cdots\cdots\cdots\cdots(1)$$

$$Q=\frac{dV}{dt}=\frac{dV}{d\varphi}\cdot\frac{d\varphi}{dt}=\omega\frac{dV}{d\varphi} \quad \cdots\cdots(2)$$

Therefore, in case of Q=constant, the Kolben is to revolve quicker than the mean angular velocity ω_m, in such a position as $dV/d\varphi<dV_m/d\varphi$; and it is to revolve slower than ω_m, in such a position as $dV/d\varphi>dV_m/d\varphi$. In other words, the angular velocity of Kolben will vary periodically, just as a solid line of the Fig. 11, which expresses the deviation of the angular velocity ($\Delta\omega=\omega-\omega_m$) in the percentages for ω_m.

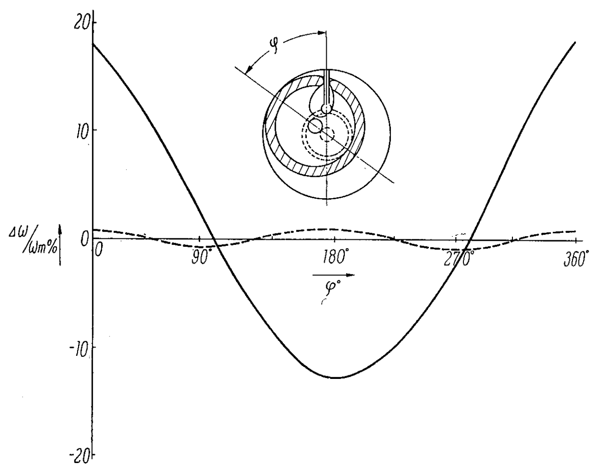

Fig. 11. Angular velocity of Kolben

As have been stated above, the angular velocity of the Kolben changes its value in accordance with the position of the Kolben, so that the indication of the tachometer may result in vibration, when the movement of the guide pin Z of the Kolben be connected to the tachometer, after it has been taken out in an immediate way. Therefore, an eccentric driving mechanism between the Kolben and the tachometer has been fitted in order to prevent the indication of the tachometer from producing vibration.

The dotted line of the Fig. 11 will represent a certain effect of the eccentric driving mechanism in such a case as above. Without this mechanism, the deviation of $\Delta\omega$ from ω_m is around $\pm 15\%$ approx.; but it can be reduced to such a small value as $\pm 0.4\%$ approx., of which variation becomes out of any question, if this mechanism is to be fitted.

The flow rate transmitter of our Company is a rotary magnet type, three-phase a-c generator consisting of the rotor of a permanent magnet and the six stator windings in a star connection, of which

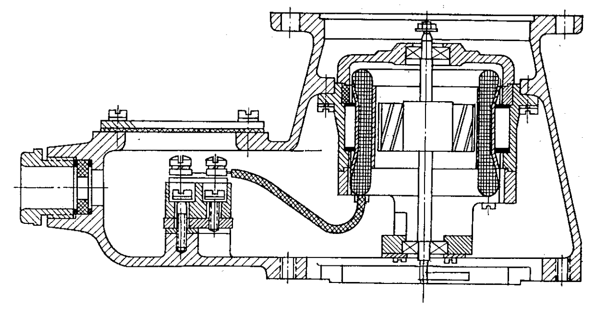

Fig. 12. Construction of the flow rate transmitter

construction is given by the Fig. 12. This transmitting device is set above the meter itself with an eccentric driving mechanism and its rotary shaft is connected, through gears, to the other rotary shaft of magnetic coupling taking out the rotary movement of the eccentric driving mechanism. Above the transmitting device, the immediate reading integrator is fitted. The Fig. 13 shows the appearance of the Kolben-flowmeter with this flow rate transmitter.

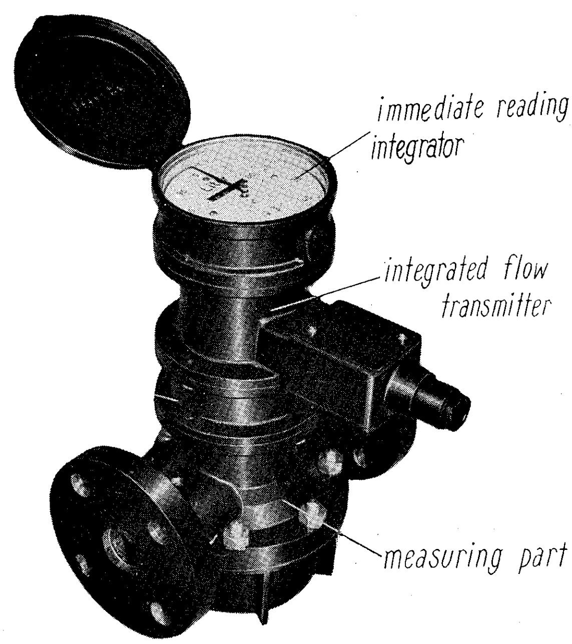

Fig. 13. Kolben-flowmeter with the flow rate transmitter

The output of this transmitter is as large as 5 mA and 8.5 V approx. at the rotation of 500 rpm. The generating voltage and the optimum output of this transmitter is given by the Fig. 14. The three-phase a-c output current is to be connected to the receiving meter, after being rectified with the rectifier. The Fig. 15 will give its measuring circuit of flow rate. For the receiving meter, there will be used the moving coil type meter and the eletronic self-balance type meter and so forth. Its

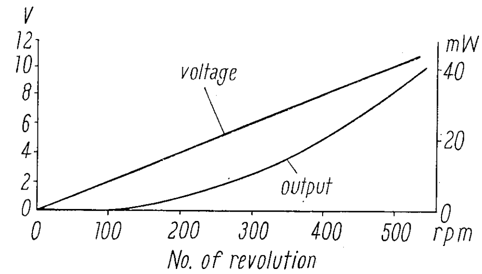

Fig. 14. Generating voltage and optimum output of flow rate transmitter

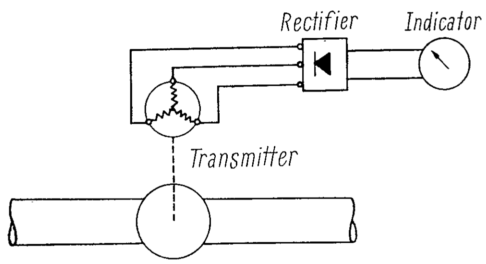

Fig. 15. Measuring circuit of flow rate by flow rate transmitter

consolidated accuracy is to be the maximum value of $\pm 2.5\%$ in case of the Class 1 meter used for the receiving meter, while in a case of the Class 0.5 meter, this accuracy becomes $\pm 2.0\%$.

(3) Quantity pre-setting device

The pre-setting device is one type of such a mechanism or device as measuring the fluid quantity of a pre-determined volume, which is aimed at measuring a fluid of a certain volume repeatedly, just as in the filling work into the drum can of any liquid. Among those pre-setting devices which employ a volume type flowmeter, there is the type of closing or opening the valves in an electric way or in air pressure operation.

Our pre-setting device consists of the setting part and the quick action valve, and is to open or close the valve in a purely mechanical way by synchronizing mechanically the setting part and the valve altogether. Just as the above-mentioned two transmitters, the setting part is fitted to above the measuring part, while the quick action valve is fixed at the flange of the outlet of the main body of the flowmeter. The Fig. 16 illustrates the Kolben-flowmeter with the pre-setting device, i.e. the pre-setting device and the quick action valve.

a) Construction of the quick action valve

The Fig. 17 will show the construction of the quick action valve. The valve disc is always pushed upwards with the spring, and the valve is

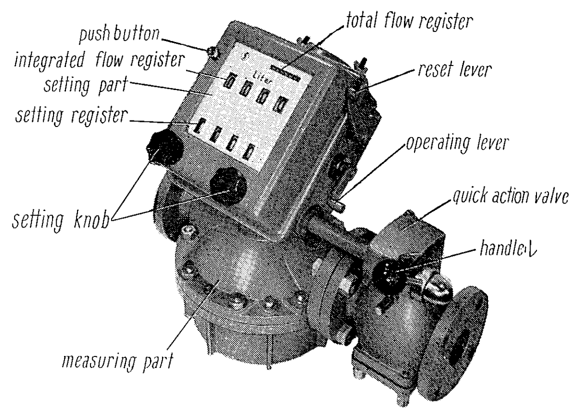

Fig. 16. Kolben-flowmeter with the pre-setting device

closed at any time when the handle is in a free state. If the handle is pushed upwards, it turns the shaft, and a lever fixed to this shaft pushes downwards the top end of the valve stem, so that the valve disc may be pushed downward to open the valve. This shaft is connected with the lever in the setting part. So, if the shaft is to turn, the lever of the setting part also turns along with the shaft to hang on a claw, keeping the valve an opened state. If this lever drops from the claw, the valve will automatically close with the force of the spring.

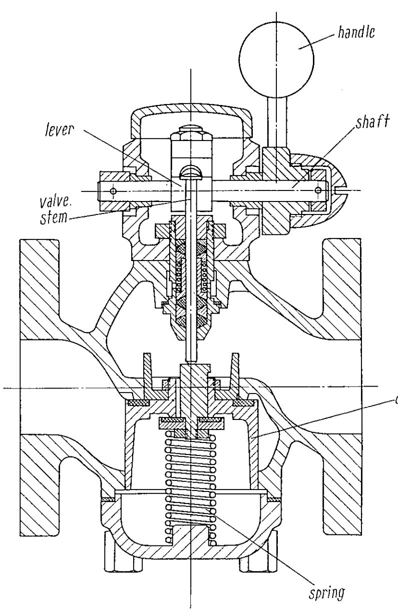

Fig. 17. Construction of quick action valve

b) Operation of the pre-setting device

As shown in the Fig. 16, the setting operation of a desirable fluid quantity is to be carried out by turning the operating lever towards the side indicated in the Figure and by turning the knob for setting in the front of the device. The setting of the volume is made by the left knob in the larger two units and by the right knob in the smaller two units. Thus, the pre-setting quantity is indicated on the setting register. Unless the valve were kept closed, the setting of the flow quantity shall not be done. Therefore, in order to set the fluid quantity on the setting register, by turning the knob for setting, it is required to hold the operating lever turend in the direction designated by the Fig. 16. On the other hand, in case of the valve being kept opened, the mechanical interlock makes the operating lever impossible to turn in the above-designated direction. Furthermore, in case of the operating lever being kept unturned in the above-designated direction, the setting register does not turn even with turning the knob for setting. Such a device is aimed at preventing the setting of the fluid quantity from making any error, even if any mistaken turning of knob for setting is made during the measuring.

After setting the fluid quantity, the valve can be opened by returning the operating lever to the former position and by pushing upwards the handle of the valve. In this case, the handle of the valve would not be moved by the interlock if the operating lever should not be returned completely to the former position. This is the device preventing any mistaken operation before the setting of the fluid quantity does not yet finish.

When the valve is opened and the fluid begins to pass through the flowmeter, the integrated register starts integrating the passing quantity of the fluid through the meter, and at the same time the setting register begins to turn from the set value to zero. At every time when the larger figure of each unit becomes zero by the turning of the setting register, the valve is closing gradually; when the entire units of the above set figure become zero, the lever within the setting part departs from the claw to close the valve entirely. At this time, the setting register indicates the zero in all the units, and the integrating register indicates the pre-set fluid quantity so that the confirmation of the quantity measured may become possible. In the state that the setting register indicates the zero in all the units of the figure, the lever of the setting part is interlocked mechanically in order to make the handle of the valve impossible to push upward. This is aimed at preventing from opening the valve by any error in operation, before the re-setting of the quantity is to be made.

In order to return the indicated figure to zero, for re-setting or re-measuring of the flow, the figure of the integrating register shall be returned to zero by means of the inner lever and cam mechanism, with pulling before-hand the lever for returning to the zero towards the former position. At that time, the meshed state of the driving gears between the main body of the flowmeter and the integrating register are set free with the function of the clutch, any unreasonable load can not be born to the main body of the flowmeter.

In case of the re-setting of the fluid quantity after any one-round measuring was finished, the operating lever has only to be turned beforehand and the knob for setting has only to be also turned adequately. Particularly, if the setting of the same quantity as before is to be made, again the same quantity as that of the previous time is pre-set on the setting register only by turning the operating lever beforehand and returning it in the former position, of which function is carried out by the inner lever and cam mechanism.

The small register illustrated in the upper right side of the Fig. 16 is to show such a one as without the register returning to zero, but indicating the total integrated fluid quantity.

The push button illustrated in the upper left side of the case in the Fig. 16 is to be used for emergency. By pushing this button, the valve can be entirely closed at any time during the measurement.

c) Capacity of the pre-setting device

The Table 5 is to show a setting range of this device and the flow range of the applicable fluid is just the same with that of the measuring part of the Kolben-flowmeter. Its accuracy is ±1.0% of the set value within the flow range of the applied fluid.

Table 5. Setting range of quantitative equipment

Size	Setting range	Minimum setting quantity
32 mm	1～ 9,999 *l*	1 *l*
50 mm	10～99,990 *l*	10 *l*
80 mm	10～99,990 *l*	10 *l*

The reference will be made to the following data on this Article:

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(By Shōkichi Kikuzawa, Designing Div., Toyoda Works.)