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FUJI INTEGRATING WATT-HOUR METER (IV)

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The earlier issues of this journal having dealt with fundamental points of our integrating watt-hour meters and our single phase integrating watt-hour meter in particular, the present issue describes the three phase three wire integrating watt-hour meter.

Electric power in a three phase three wire unbalanced load circuit can be measured by a two watt-meter method.

Assuming that the connection is laid as shown in *Fig. 66* and defining the voltage and current of the whole as in the figure,

$$e_{12}+e_{23}+e_{31}=0$$

and, defining the instantaneous value of electric power as p,

$$p=e_{12}\dot{i}_1-e_{23}\dot{i}_3$$

and, consequently, the mean value in a cycle of the three phase power may be described as:

$$P=P_1-P_2$$

and, since $P_1=\frac{1}{T}\int_0^T e_{12}\dot{i}_1 dt$ and $P_2=\frac{1}{T}\int_0^T e_{23}\dot{i}_3 dt$ therefore, by determining the direction of winding

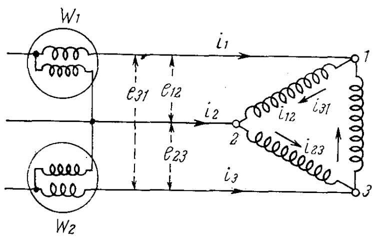


Fig. 66 Messuring method by two watt-meter

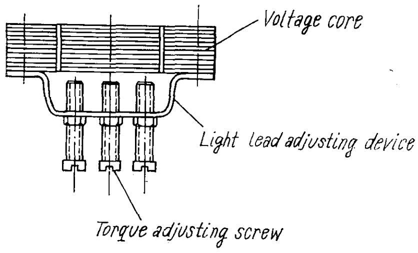


Fig. 67 Torque balance adjusting device

as in the figure, the symbol of P_2 is reversed and

$$P=P_1+P_2$$

As a result, the electric energy in a three phase circuit may be measured by having the driving torque of a driving element of two single phase integrating watt-hour meters work upon a single common shaft and having one register to count the number of rotations.

However, inasmuch as this counting is bound to present error unless the driving torque of these two driving elements is balanced in a situation when an equal amount of electric power is applied to both driving elements, it is essential that these two driving elements should be perfectly balanced. With this necessity in mind, the Fuji three phase integrating watt-hour meter is equipped with a driving torque balancing device to both driving element of which construction is illustrated in *Fig. 67*. Under this system, the effective voltage flux is adjusted by regulating a torque adjusting screw fitted to the central section of yoke of the voltage element with a view to making fine adjustments of torque.

It is desirable that for proper adjustment the three adjusting screws should protrude to about the same extent, because an inconsistency in the protrusion of these screws would give rise to voltage creeping and will vary errors under a light load. It is also necessary to avoid alternate insertion of the adjusting screws of both elements for lowering the torque and to see, instead, that one of the elements be taken as the level standard and the other element torque set thereto.

In addition, each driving element should be correctly given a power-factor adjustment, because inaccurate power factor adjustment of each driving element of the three phase watt-hour meter is bound to produce the registration error.

The following mathematical formula represents errors arising out of maladjustment:

D_1......Lagging element torque
D_2......Leading element torque
ε_1, ε_2......Errors for criterion torque
δ_1, δ_2......Out of angle from 90° internal phase angle
k......Proportional constant

Under these conditions of definition,

$$D_1=k\ (1+\varepsilon_1)\ EI\ \cos\ (30^\circ+\varphi-\delta_1)$$
$$D_2=k\ (1+\varepsilon_2)\ EI\ \cos\ (30^\circ-\varphi+\delta_2)$$
$$\begin{aligned}D_1+D_2=&kEI\{\cos\ (30^\circ+\varphi)+\sin\ (30^\circ+\varphi)\ \sin\ \delta_1\}\\ &+kEI\varepsilon_1\{\cos(30^\circ+\varphi)+\sin(30^\circ+\varphi)\sin\delta_1\}\\ &+kEI\{\cos\ (30^\circ-\varphi)-\sin\ (30^\circ-\varphi)\ \sin\ \delta_2\}\\ &+kEI\varepsilon_2\{\cos(30^\circ-\varphi)-\sin(30^\circ-\varphi)\sin\delta_2\}\\ &\fallingdotseq\sqrt{3}\,kEI\ \cos\ \varphi+kEI[\{\frac{\cos\ \varphi}{2}(\delta_1-\delta_2)\\ &+\frac{\sqrt{3}}{2}\sin\ (\delta_1+\delta_2)\}\\ &+\{\frac{\sqrt{3}}{2}\cos\ \varphi\ (\varepsilon_1+\varepsilon_2)-\frac{1}{2}\sin\varphi\ (\varepsilon_1-\varepsilon_2)\}]\end{aligned}$$

φ: Phase angle.

Consequently, the comprehensive error ε_0 is:

$$\varepsilon_0=\frac{(D_1+D_2)-\sqrt{3}\,kEI\ \cos\ \varphi}{\sqrt{3}\,kEI\ \cos\ \varphi}\fallingdotseq\frac{\varepsilon_1+\varepsilon_2}{2}+\frac{\delta_1-\delta_2}{2\sqrt{3}}+\frac{1}{2}\tan\varphi\left(\delta_1+\delta_2-\frac{\varepsilon_1-\varepsilon_2}{\sqrt{3}}\right)$$

The Fuji three phase three wire type integrating watt-hour meter is, generally speaking, represented by the following four types:

1) D–170: A two element two disc type integrating watt-hour meter conforming to JISC–1214.
2) D–27: A two element one disc type integrating watt-hour meter conforming to JISC–1214.
3) D–16P: A two element two disc type precision integrating watt-hour meter conforming to JISC–1212.
4) D–25K3: A four element two disc type special precision integrating watt-hour meter with transmitting device.

The following space of the present journal will be expended on the description of these meters in outline.

X. FUJI THREE PHASE THREE WIRE SYSTEM INTEGRATING WATT-HOUR METER, MODEL D-170

1. Construction

1) Case

The case consists of a base made of a steel plate of high class finish and of hard glass or of a metallic cover and all the metallic sections are fully treated against corrosion so that it has ample weather resistant quality for outdoor use. A neoprene packing ensures air-tight closure of base and cover.

2) Frame

The frame is built of a combination of steel plates of high grade finish possessing a perfect strength and there is a magnetic shielding plate provided between the upper and lower driving elements lest there should be any magnetic interference between them. The frame is screwed in the base interior and to this frame are fitted main composite parts of meters

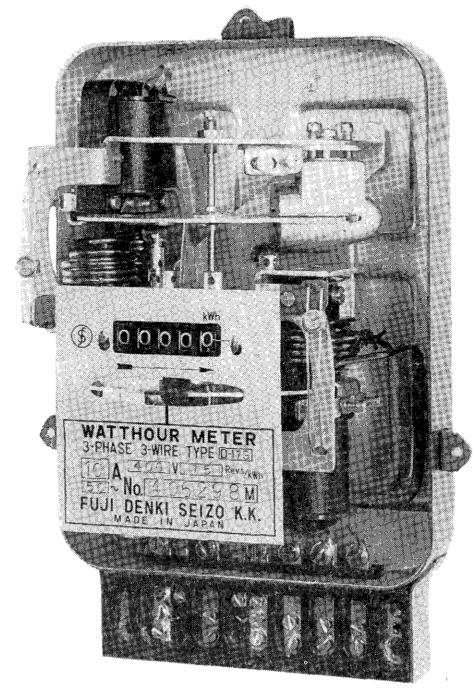


Fig. 68 Three phase 3-wire watt-hour meter, Model D–17G

such as driving elements, braking magnet, upper and lower bearings, register and rotor in such a manner that their interrelational positions will not go out of order.

3) Rotor

The rotor is constructed of an aluminum disc measuring 1.2 mm in thickness and 95 mm in diameter with the two discs die-cast onto a shaft. Since

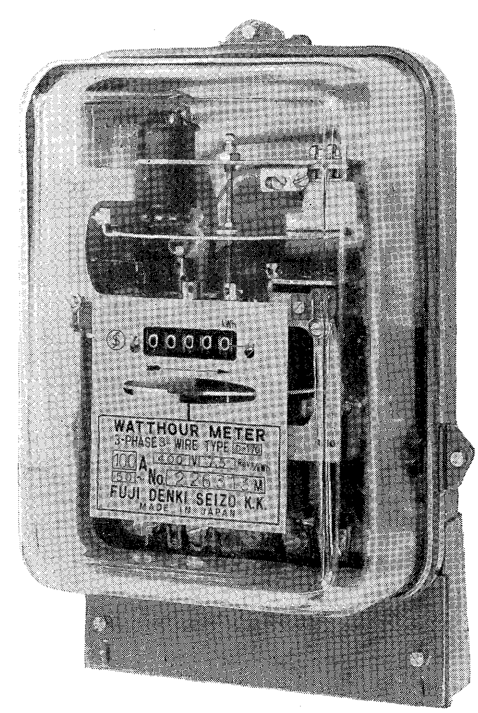


Fig. 69 Internal construction

high quality material is used, a high torque is obtainable for a relatively small weight. The periphery of the disc is divided into a hundred equal divisions and 250 equal stroboscopic slits so that it is possible to test it on either master meter of the stroboscopic method.

4) Bearings

The upper bearing is a needle bearing, while the lower bearing is a pivot and jewel bearing whose construction is the same as that of the single phase integrating watt-hour meters. However, since the rotor weight is relatively heavier than the weight of the single phase meters, the size of various parts is larger in order to fully withstand the rotor weight by giving these parts higher mechanical strength.

5) Braking magnets, register, voltage element and current element are almost identical with those in use in the single phase integrating watt-hour meters, model E–71. Braking magnets are of Alnico steel magnet, while the register is furnished with a 5–digit cyclometer with a number wheel made of drawn out aluminum sheet.

2. Adjusting Devices

1) Torque balancer

Adjustment of driving torque balance is effected through adjusting the effective voltage flux by turning the three torque balance fine adjustment screws in either left or right direction which are located in the central portion of yoke of the upper and lower voltage elements. Variation of the driving torque following the turning of these adjusting screws is as shown in *Fig. 70*.

2) Full load, light load and inductive load adjusting devices

These adjusting devices are fitted to the upper and lower driving elements respectively, and their structure and adjusting method are the same as those of the foregoing single phase integrating watt-hour meter model E–71 and whose range of adjustment is as shown in *Figs. 71~73*.

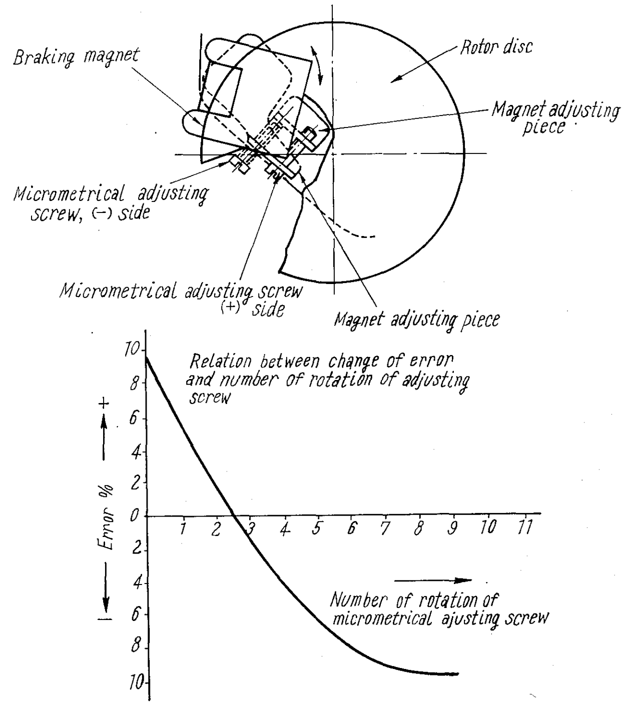


Fig. 71 Full load adjusting device

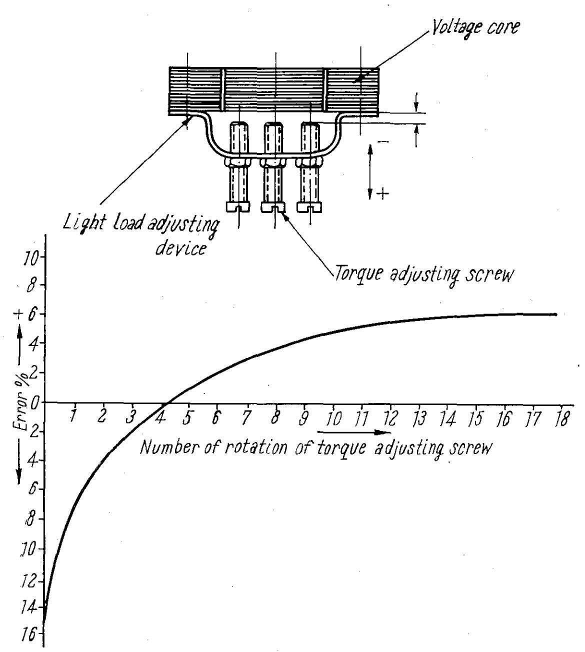


Fig. 70 Torque balance adjusting device

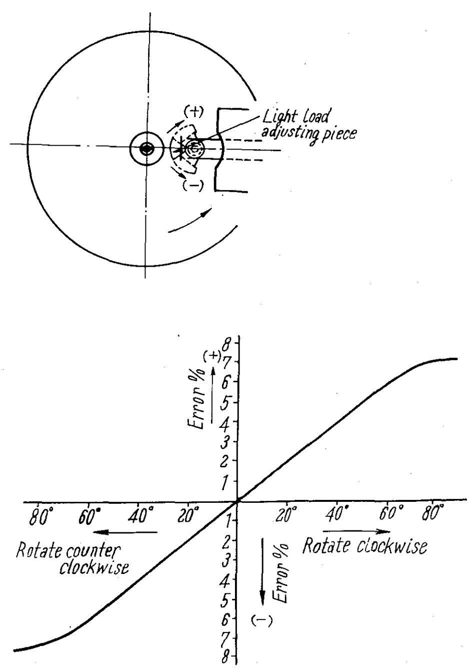
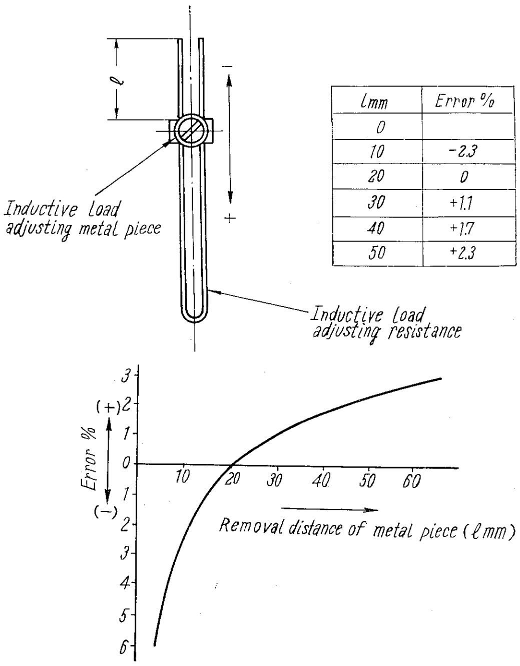


Fig. 72 Light load adjusting device



ℓmm	Error %
0	
10	−2.3
20	0
30	+1.1
40	+1.7
50	+2.3

Fig. 73 Inductive load adjusting device

3. Compensating Devices

1) Temperature compensating device

This meter has an excellent temperature characteristic because a magnetic compensating alloy of our own manufacture is fitted to the voltage element to compensate for variations in errors as a consequence of ambient temperature changes.

2) Compensation for load characteristic

Because current core is of high quality laminated steel sheet and the magnetic shunt core is provided between both poles of current core, load characteristics is compensated over a wide range.

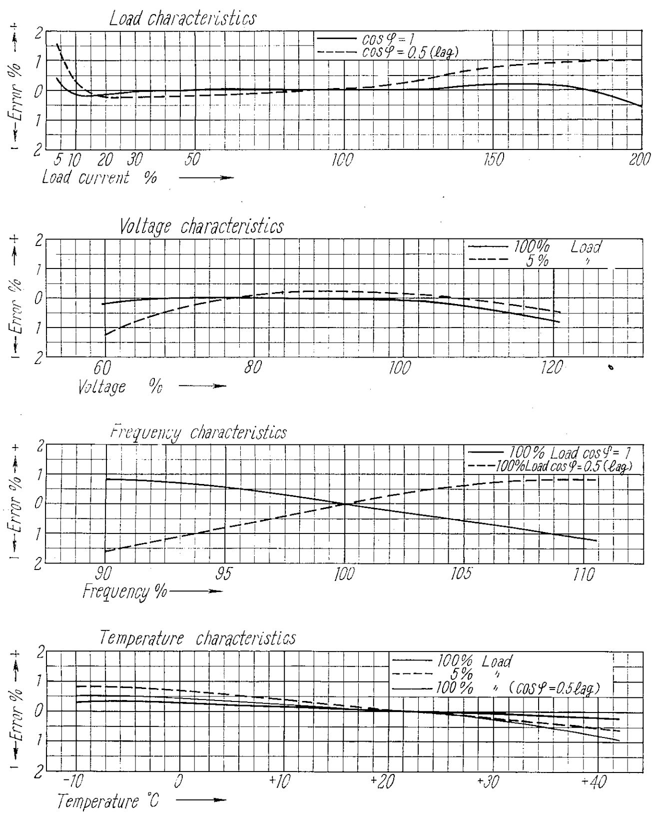


Fig. 74 Characteristic curves

4. Characteristics

The characteristics of this meter are shown in *Fig. 74.*

5. Technical Data

Rpm at full load: 13.86∼17.32 rpm
Full load torque: 12.8∼16 g-cm
Rotor weight: 59 g
Torque/rotor weight: 0.217∼0.271
Electric circuit invariables (at 100 v, 10 (5) amp)

	Voltage circuit	Current circuit
Apparant power	2.7∼3.1 va	0.88 va
	0.75∼0.8 w	0.75 w

Starting current: The rotor starts and continues running when the meter carries 0.5% of the rated current at the rated voltage and at unity power factor.

Voltage creeping: Rotor will not rotate more than once at no load when the meter voltage circuit alone is energized at the 110% of rated voltage.

Insulation resistance: Measured on d-c 500 v values between electric circuits and between electric circuits and earth are over 10 Mohm.

Insulation strength: Can withstand a-c 2000 v, 50 or 60 c/s, between electric circuits and earth for one minute.

XI. FUJI THREE PHASE THREE WIRE SYSTEM INTEGRATING WATT-HOUR METER, MODEL D-27

1. Outline

Model D–27 is a two element one disc type integrating watt-hour meter which has the features of being small in size and very light in weight. On the other hand, since it is so built that both driving elements act on a single disc, there arises mutual interference between both elements through the disc, which gives rise to the necessity of taking special steps to compensate for the theoretical error induced by this interference. As measures to compensate for mutual interference, the following are thought of:

1) Make slits on the disc in a radial direction to lessen the eddy current that contributes to mutual interference;

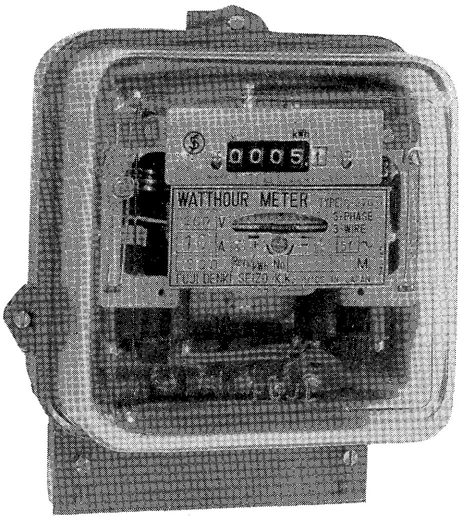


Fig. 75 Three phase 3-wire watt-hour meter, model D-27G

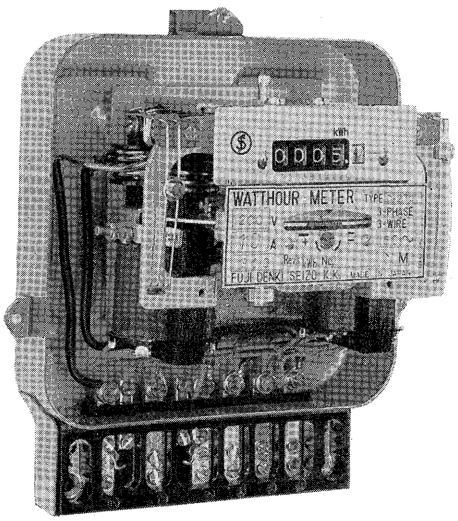


Fig. 76 Internal construction

2) Wind some compensating coil around both voltage elements and alternately arrange them in a series connection to cancel the torque due to respective interferences.

The former, of necessity, is bound to sacrifice the driving torque and badly affect other characteristics, whereas the latter will permit a radical reduction in mutual interference if its design is made reasonably. For the reason just mentioned above, our company adopts the latter system.

Mutual interference may be divided into the following three subdivisions:

a) Mutual interference between voltage flux and current magnetic flux;

b) Mutual interference between voltage flux and voltage flux;

c) Mutual interference between current flux and current flux.

While the mutual interferences between voltage elements and between current elements cannot be checked at all by compensatory coils, they can be avoided by balancing their geometrical positions. So that what forms the main body of mutual interference is that which exists between the voltage element and the current element as in a) above.

As shown in *Fig. 77,* the compensating principle with the use of compensatory coils is as follows: Fit on the same iron core of the first voltage element a compensatory coil a_2N_2 along with the main coil N_1 and, likewise, fit a compensatory coil a_1N_1 in addition to the main coil N_2 to the second voltage element and by alternately connecting them the torque of mutual interference between P_1 and q_2 is compensated for by the magnetic flux of (a_1N_1) and the reverse torque occasioned by q_2 and, in a like manner, the torque of interference between P_2 and q_1 is offset by the magnetic flux of the compensatory coil (a_2N_2) and by the reverse torque caused by q_1.

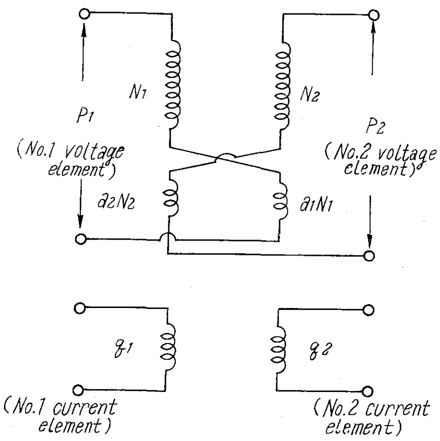


Fig. 77 Mutual interference compensating coil

2. Construction

1) Case

The case is small in size for it is two elements and a disc type. The base is pressed out of steel plate of high grade finish and both exterior and interior surfaces are given elaborate anti-rust treatment so that it may fully withstand all weather for outdoor use. The cover is either of glass or of metal and the interior surface of the glass cover is treated against clouding. A synthetic packing is provided between cover and base for perfect air-tight closure.

2) Frame

The frame is constructed of a combination of steel plates of high grade finish with anti-rust treatment and in such a manner that it may be fitted geometrically symmetrically the driving element and other against the disc.

3) Voltage element

The voltage element consists of a voltage core, a main voltage coil and a compensatory coil. The voltage core is made of high quality laminated silicon steel sheet. The head of the iron core is provided with a metal ring for compensation of interior phase angle and a piece of magnetic compensating alloy. The main voltage coil and the compensatory voltage coil are wound on the same bobbin with a high rate of insulation.

4) Rotor

The rotor consists of a disc of high quality aluminum and a rotor shaft. The periphery of the disc is divided into a hundred equal graduations and 250 equal stroboscopic slits.

5) Braking magnets

For the braking magnets, Alnico steel magnets die-cast with aluminum alloy are used and they have a large coercieve force. These magnet do not demagnetize when heated, shocked or placed in external disturbance field. Because of their stabilized characteristics, their durability is tremendously enhanced.

6) Other

The current element, register and other parts are the same as with model D–170.

3. Adjusting Devices

1) Full load adjusting device

In order to vary the braking torque of magnet and to effect fine adjustment of load, loosen the stop screw of the full load adjusting device and turn the full load adjusting device in the front either to the left or to the right.

Variation of errors arising out of turning of the adjusting screw is as shown in *Fig. 78*. This system has the feature of having the screw turning and error variation change in a linear manner, thus the adjusting may be easily done.

2) Other adjusting devices

Both structure and adjusting method of the light load adjusting device, torque balancing device and power-factor adjusting device are the same as those of model D–170. The range of adjustment is shown in *Figs. 79~81*.

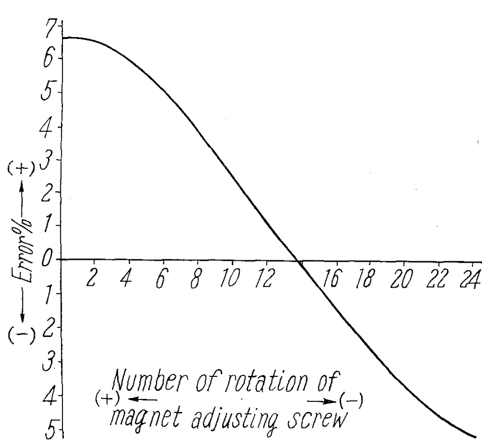


Fig. 78 **Full load adjusting device**

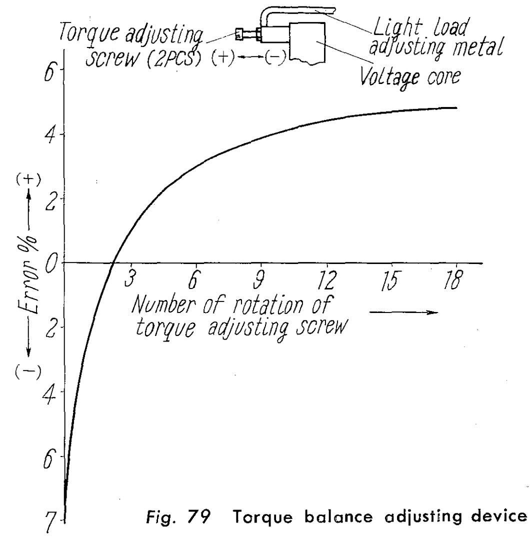


Fig. 79 **Torque balance adjusting device**

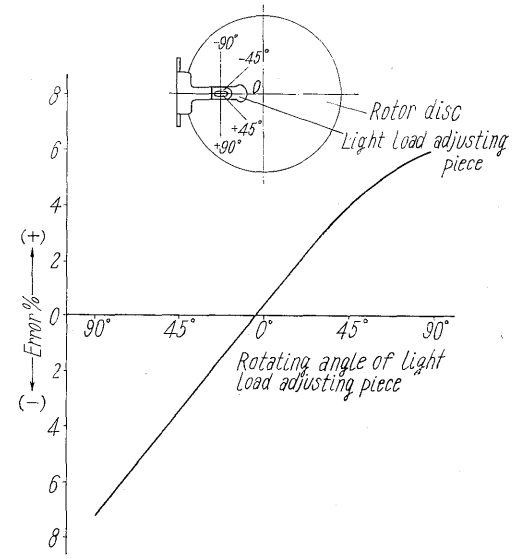


Fig. 80 **Light load adjusting device**

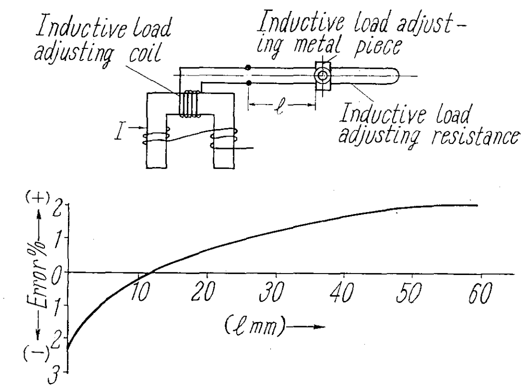


Fig. 81 **Inductive load adjusting device**

4. Compensating Devices

1) Full load compensating device

A magnetic shunt iron core is provided between both poles of current core and by means of this the load characteristics is compensated over a wide range.

2) Voltage compensation

The head of voltage iron core in 50 c/s meters is provided with a magnetic shunt for compensation of voltage characteristics through a plate of support and compensates for voltage characteristics.

3) Temperature compensation

As with the single phase integrating watt-hour meter, model E–71, this carries out temperature compensation for both unity power factor and low power factor.

4) Mutual interference compensation

On the same core as that of the main voltage coil is a mutual interference compensation coil as connected in *Fig. 82* and the mutual interference compensation plate is equipped as in *Fig. 83* which is fixed upper and lower side of the rotor at the frame bottom plate. Both of those compensate for interference between both elements.

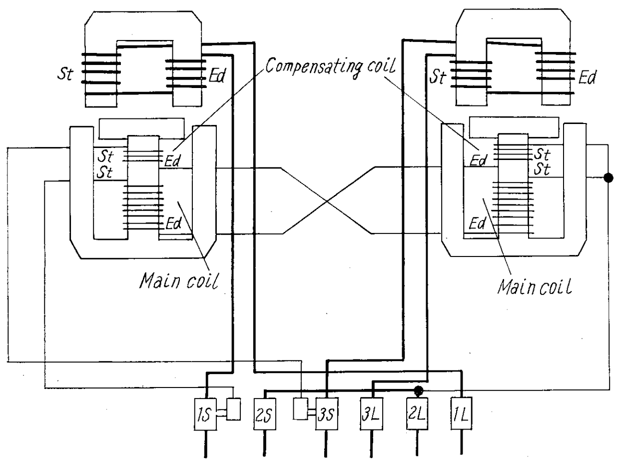


Fig. 82 Internal connection

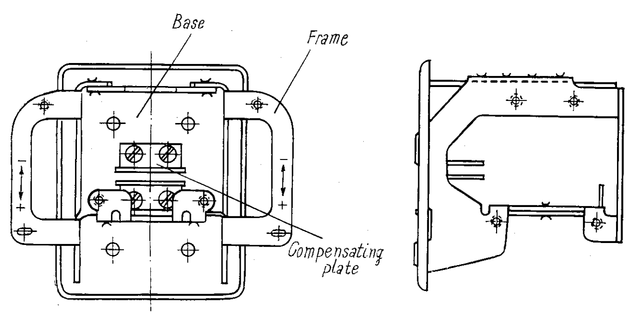


Fig. 83 Mutual interference compensating plate

5. Characteristics

The characteristics of this meter are as shown in *Fig. 84*.

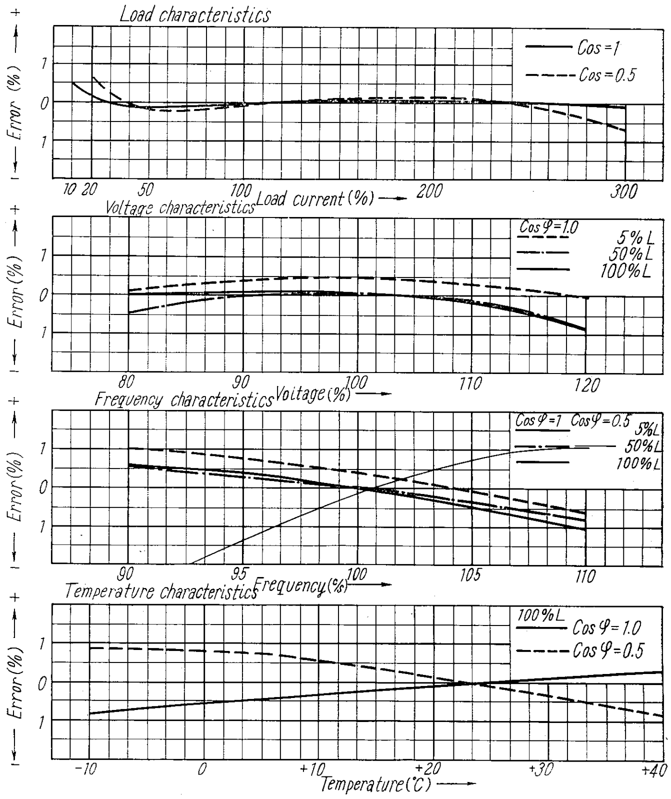


Fig. 84 Characteristic curves

6. Characteristic Invariables

Rpm at full load: 34.65 rpm

Full load torque: 14.5 g-cm

Rotor weight: 25 g-cm

Torque/rotor weight: 0.58

Electric circuit invariables (at 100 v, 10 (5) amp)

	Voltage circuit	Current circuit
Apparent power	3.04∼3.65 va	—
Power loss	0.7∼0.9 w	0.41 w

Starting current: Under 0.25% of rated current

Voltage creeping: At no load, no more than one turn under 110% of rated frequency and rated voltage

Insulation resistance: Measured on d-c 500 v, the value between the electric circuit and earth is over 10 Mohm.

Insulation strength: Can withstand a-c 2000 v, 50 or 60 cycles, between electric circuit and earth for one minute.

Weight: Under 20 (10) amp 2.95 kg, over 60 (30) amp 4.0 kg.

XII. FUJI PRECISION INTEGRATING WATT-HOUR METER, MODEL D-16P

1. Outline

The precision integrating watt-hour meter, model

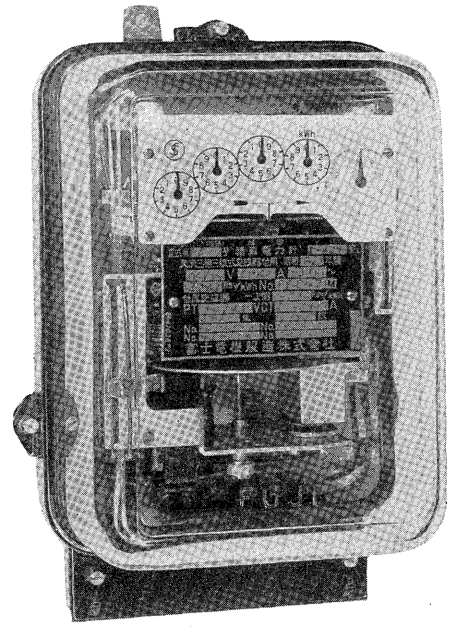


Fig. 85 Precision three phase 3-wire watt-hour meter,

D–16P, is a meter so manufactured as to meet the requirements of the standard for precision integrating watt-hour meters under JIS C–1212. Since this particular type is intended to be used for accurate measuring of a huge amount of electric power in combination with an instrument transformer or for more accurate measuring of load mean power-factor along with a var-hour meter, it has structurally and characteristically high accuracy and long service life. In short, this is an integrating watt-hour meter suitable as a precision instrument.

Inasmuch as the precision integrating watt-hour meter is, as a rule, always used in combination with an instrument transformer, the rated current value is only 5 amp. The rated voltage may, however, be manufactured to any specification upon request. By the very purpose for which the precision meter is used, the comprehensive error as combined with the transformer is of greater importance than the value of the meter alone. In this sense, it is desired that the transformer of 0.5 class be made standard. And even if adjustment is made when both are combined, the meter should be as accurate and stable as possible.

2. Construction

1) Case

The case is constructed with the base made of a steel sheet of high grade finish and the cover made of a hard glass or aluminum sheet. The base and the metallic cover are given full and special treatment against rust. The base and cover are totally enclosed through highly weather-resistant synthetic rubber and humidity-proof packing. This meter is so compactly built, so small in size and so light in weight that it is easy to handle it. The exterior size is almost the same as the three phase integrating watt-hour,

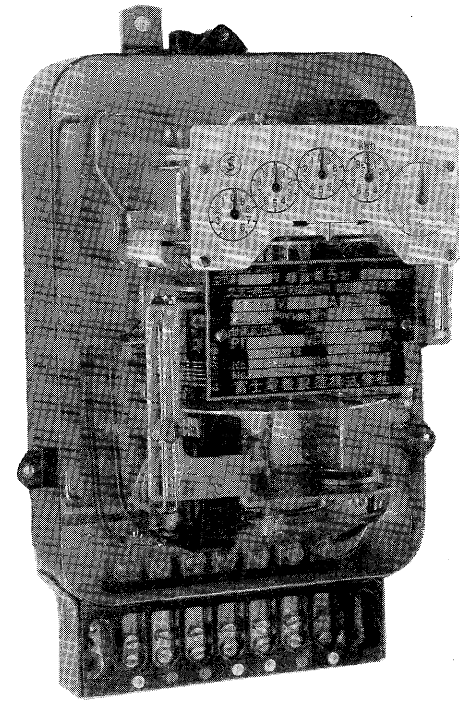


Fig. 86 Internal construction

model D–170G.

2) Rotor

The rotor is built particularly small in size and light in weight (with model D–170 weighing 59 grams and model D–16P 44 grams) and, coupled with the high torque attribute, the mechanical factor of merit is better and stability and life tremendously increased. The periphery of the disc is graduated into a hundred equal divisions, so that the testing of the meter can be easily carried out.

3) Register

The register is of pointer type and a large dial (outside diameter 18 ϕ) is fitted for easy reading of the dial. When it is necessary to read the lowest level accurately, the diameter of the dial for this level is made larger (outside diameter 28 ϕ). In addition, it is possible to manufacture resisters with a hundred equal graduations. The register is divided into the transmission gear mechanism section and the register section itself and these two sections are connected by a special coupling mechanism. For this reason, checking, putting in order, dismantling, repairing and confirming of gear meshing can be greatly facilitated.

The fit accuracy is elaborately attended to so that no repetition of loading and unloading of the register mechanism will alter the fitting position and, consequently, errors resulting from that are rendered non-existant.

At the transmission gear section especially, the worm is placed in the second stage as it has a large friction and the first stage is fitted with a spur gear which has a very small friction and by these mechanism

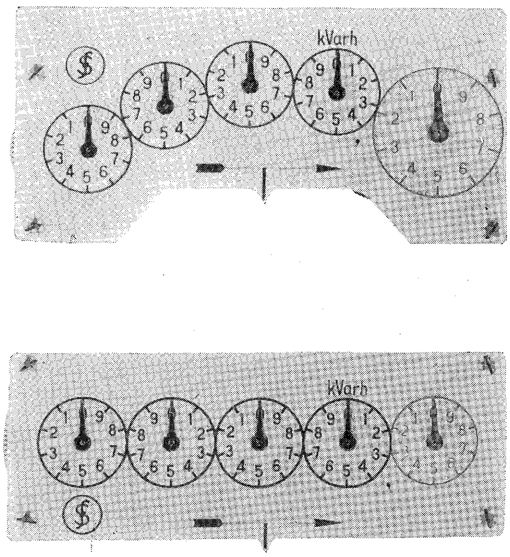


Fig. 87 **Resister dialplate**

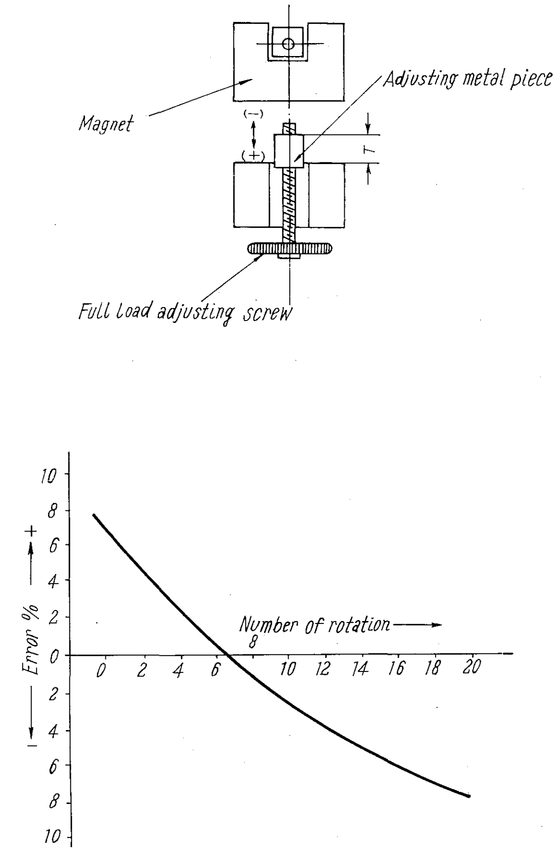


Fig. 88 **Full load adjusting device**

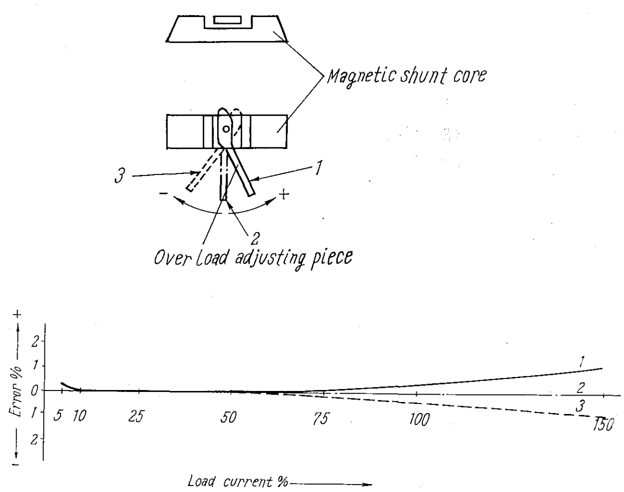


Fig. 89 **Range of overload adjustment**

torque increase is accomplished. Further, the bearing section uses a jewel to reduce possible aging changes. (All these contribute to making register friction smaller and to stability of register). In addition to this, the material of the first stage spur gear is bakelite with clothes, thereby making for the lightness of weight and smallness of friction as well as prevention of noise.

4) Bearings

The upper bearing is a needle bearing as referred to in one of the preceeding paragraphs and the lower bearing is a double jewel bearing to guarantee good characteristics.

5) Driving elements

Both voltage and current elements are of carefully selected material and the cores of those elements are made of high quantity to increase the stability and torque and to improve the characteristics.

6) Braking magnets

For the braking magnets, Alnico steel magnets with a large coercive force are used. As this magnet is so stable that there is hardly demagnetization owing to heat, sock, external disturbance field, etc., it is suitable for case of usage continuously for long period.

3. Adjusting Devices

1) Full load adjusting device

Adjustment is done by turning the adjusting dial to the left and right for the braking magnets. It is necessary to tighten the locking screw firmly after this adjustment. The relation between the number of turns of the adjusting screw and meter error is shown in *Fig. 88.*

2) Overload adjusting device

Adjustment of overload is performed by shifting the overload adjusting lever fitted to the yoke section of the upper and lower voltage elements. The relational variation of lever shifting position with reference to meter errrors is indicated in *Fig. 89.* Locking such as screw fastening after the adjustment is unnecessary.

3) Other

The torque balancer is exactly the same as that of model D–170, while the structure and adjusting method of the light load adjusting device, and the inductive load adjusting device are the same as those of model E–71 and the range of adjustment is shown in *Figs. 90～91.*

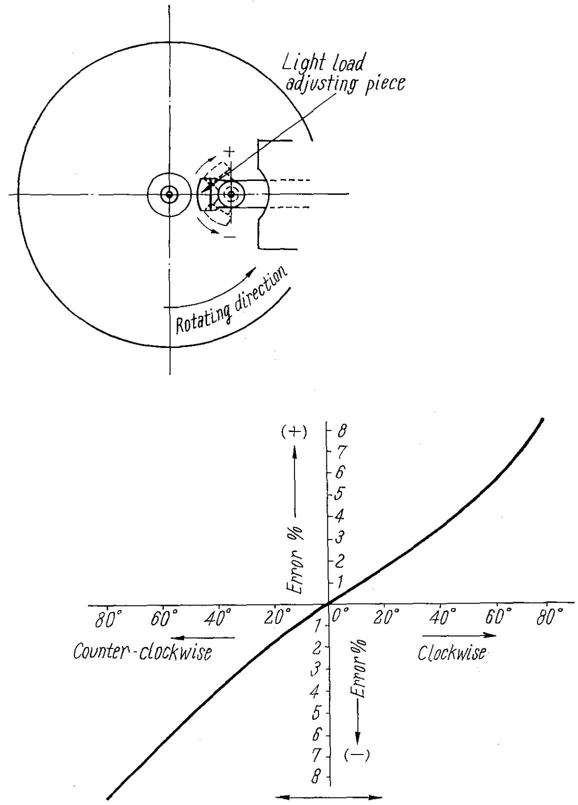


Fig. 90 **Light load adjusting device**

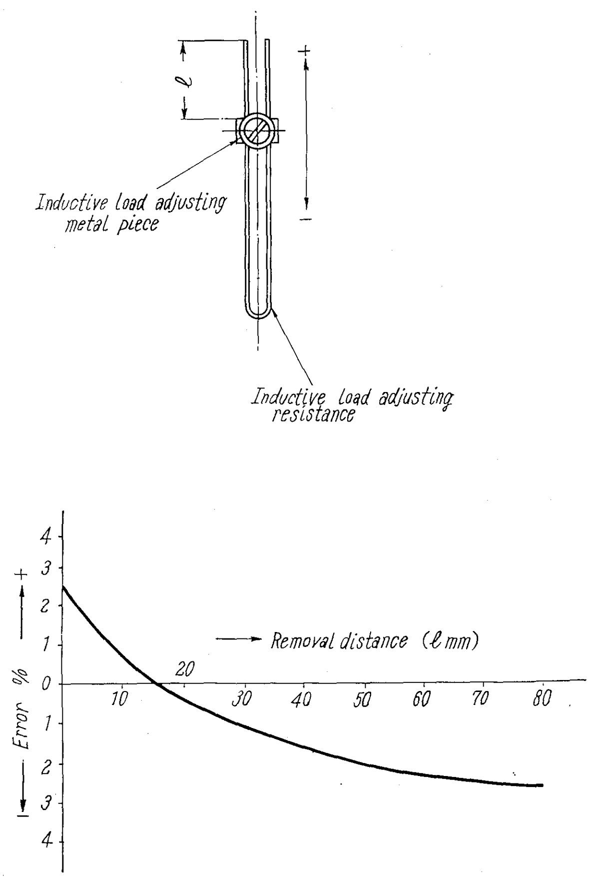


Fig. 91 **Inductive load adjusting device**

4. Compensating device

This meter is provided with each characteristic compensating device for the load voltage, temperature self-heating and other mutual interference which all contribute to the improvement of various characteristics.

5. Characteristics

This meter thoroughly satisfies JIS C1212, whose characteristics are as shown in the following figure:

Characteristic constants:

Rpm at full load: 28.86

Full load torque: 18.0 g-cm

Weight of rotating parts: 44

Torque/rotating parts weight: 0.41

Electric circuit constant (on 100 v, 5 amp)

	Potential circuit	Current circuit
Apparent power	4.3～4.6 va	4.7 va
Power loss	1.1～1.2 w	2.1 w

Starting current: Will start and continue its rotation under rated current and power factor 1 and under 0.25% of rated current.

Voltage creeping: Under 110% of rated frequency and rated voltage, at no load, meter armature

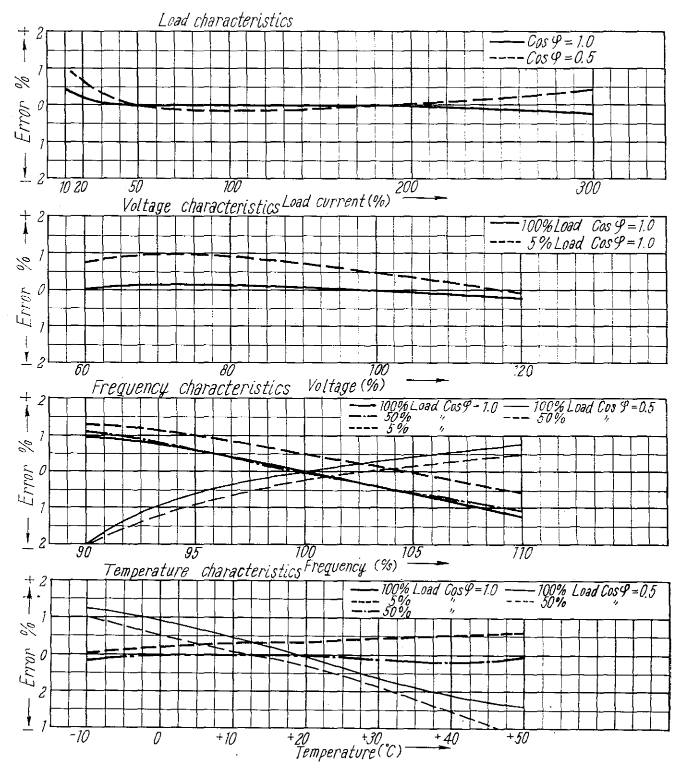


Fig. 92 **Characteristic curves**

Insulation resistance: When measured with d-c 500 v, value will be maintained above 10 Mohm for both between electric circuit mutually and between electric circuit and earth.

Insulation strength: Meter can withstand a-c 2000 v, 50 cy or 60 cy between electric circuit and earth for one minute.

XIII. FUJI SPECIAL PRECISION INTEGRATING WATT-HOUR METER WITH TRANSMITTER, MODEL D-25K3

1. Outline

For registration of a huge amount of electric energy such as is exchanged between power companies, generating stations and substations or is sent to consumers of much electricity, an integrating watt-hour of as high accuracy as possible is required. Heretofore, a precision intergating watt-hour meter had been used as this type of instrument but since even very small errors had a far-reaching effect, a more accurate and more reliable meter had been desired. To meet this need, our company carried out all kinds of experiments and research and explored a special precision integrating watt-hour meter on the order of 0.3% which fulfills these requirements.

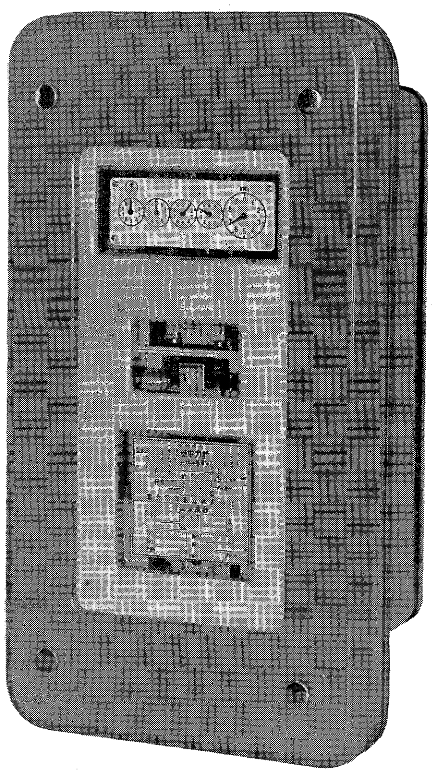


Fig. 93 Special precision three phase 3-wire watt-hour meter, Model D-25K3

2. Construction

1) Case

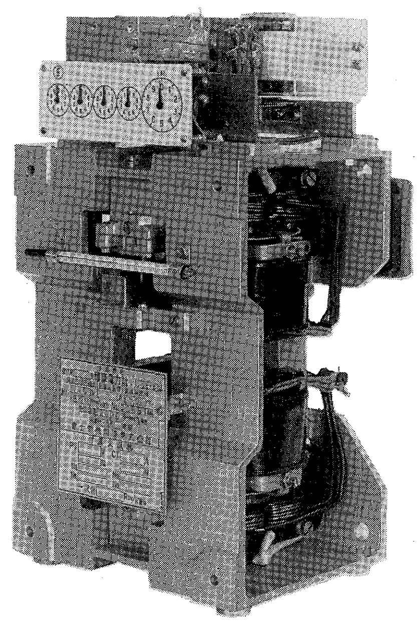


Fig. 94 Internal construction

The base is of aluminum alloy casting which can accommodate the frame firmly and at the front on the upper stage are glass sights for resister; on the middle are thermometer, level, revolution indicator, and on the lower is one for a nameplate. The front and rear covers of the case are made of steel plate which protect the meter itself from outside force and magnetic field in a perfect manner. The front cover has a large glass sight window at the front to enable one to see the meter, thermometer, level, rotation of disc and name plate. The front cover fixing screws are made in such a way as to seal the installation parts on the board. The rear cover is provided with a glass sight window for the photo electric testing equipment and since there is provision for a fixture to mount and dismount this testing equipment it is easy to take pulses for testing quite separately from the pulse transmitting circuit for the register. By the sealing screws fitting on the back cover the meter itself is sealed.

2) Frame

The frame of the box formation is made of aluminum alloy diecast in order to fix it firmly vis-a-vis the interior structural parts of the meter. In particular the driving elements fitting part, in particular, of inlaying system may be fitted to any desired position by inserting which prevents inconsistencies in characteristics arising from the mode of fixing and, at the same time, ensures excellent characteristics against vibration from shock.

3) Construction of measuring elements

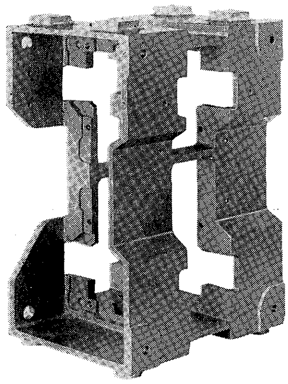


Fig. 95 Frame

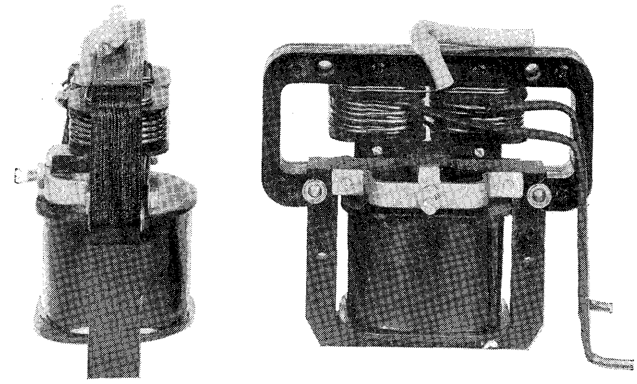


Fig. 97 Driving element

This meter uses four driving elements and braking magnets respectively. These are arranged in halves on two discs, two each, as shown in *Fig. 95.* They are arranged symmetrically against the rotor shaft. The driving elements are connected to the same phase of two voltage elements arranged on the same rotating disc in parallel and of the current coil in series. This system of measuring elements structure gives a couple of the driving torque and braking torque to the rotor shaft thus shutting off the lateral thrust as well as preventing harmful parasite vibration for improved stability.

4) Driving elements

Since the driving elements are the most important part which influence upon various characteristics of a meter, they are most elaborately manufactured. Because more quantity of core and copper is used in this meter than the meters in the past, and because the elements themselves are liberally constructed, they are capable of high torque and at the same time of improving various characteristics. By constructing the voltage and current elements in a body, magnetic and mechanical stability of the meter is ensured, so that there is hardly any effect such as vibration or shock.

5) Rotor

It is hoped that one of the way of keeping aging changes at a minimum is to have the rotor light in weight and the torque great. Stability against aging is assured by making the disc diameter larger to increase torque, making the disc thickness thin to lighten the weight and by using a sturdy aluminum alloy bar for the rotor shaft to lessen its weight. Jewel is employed for the needle bearing at the top of the shaft to prevent wear. The shaft has an oil chamber which provide lubrication oil.

6) Braking magnets

Braking magnets are made of two sets facing each other, of U-shaped Alnico steel magnets die-cast with aluminum alloy in a so-called double pole construction. The magnets used are high grade magnets with an ample allowance for aging and are considered stable against aging or outside demagnetizing action. Each magnetic pole of this double pole construction is equipped with a magnetic compensating alloy for the temperature compensation at unity power factor.

7) Pointer type register and pulse transmitter

By combining the vane wheel and the auxiliary motor for the pulse transmitter, the transmission of rotation after the vane wheel is done not by the driving torque of the meter rotor but by the auxiliary motor, and, at the same time the friction torque from the rotor to the vane wheel is offset and compensated for. Jewel bearings are used throughout from the

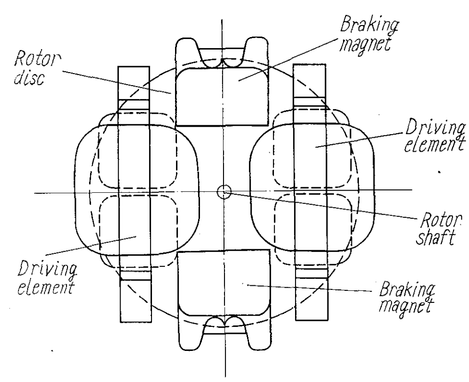


Fig. 96 Position diagram of driving elements and braking magnets

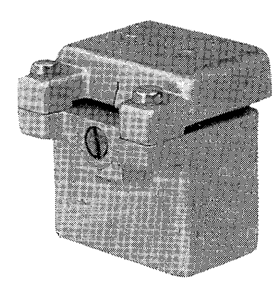


Fig. 98 Brake magnet

rotor to the vane wheel on the rotating shaft. So coupled with the above-mentioned friction torque compensation, stabilized transmission is obtained.

This device being of all mechanical transmission system is not affected by such physical conditions as temperature, light or magnetic field and accurate pulse transmission can be effected. As a mercury switch having large contact capacity is used, many kinds of transmitting devices may be simultaneously fitted and connected. The resister device is synchronized with the transmitter, and the friction does not affect the integrating watt-hour meter. Moreover, in order to facilitate dial reading, the lowest level is designed particularly large and is provided with a hundred equal graduations. Both the register and the transmitter are, through the function of the vane wheel of non-reversing register construction.

8) Bearings

The upper bearing, like model E–71, is a needle bearing, while the lower bearing is a double jewel bearing.

9) Other

A level and an inclination correcting device are housed so that it is easy to fit the meter in a vertical position.

Temperature inside the meter is read from the thermometer mounted on the frame.

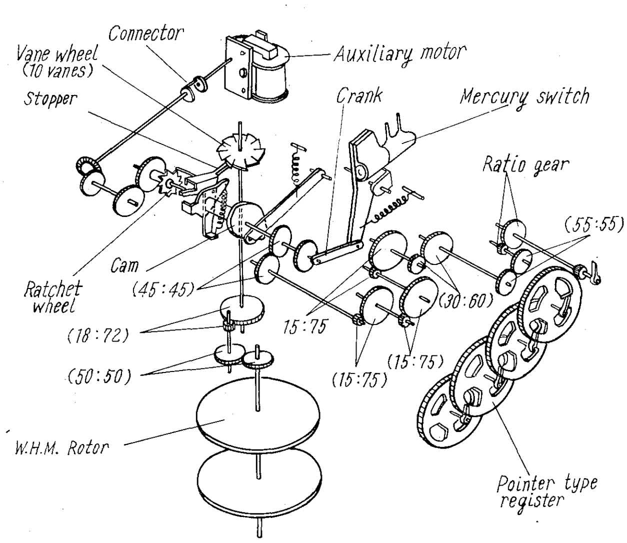


Fig. 99 Register and pulse generating device

3. Adjusting Devices

This meter is capable of full load adjusting, light load adjusting, phase adjusting, etc. but since it is an extremely accurate meter it is, as a rule, not to be adjusted after it has been delivered to the place of use. For this reason, all adjusting devices are locked so that it will not be likely that they are to be tampered with thoughtlesely after delivery.

4. Compensating Devices

1) Load characteristic compensation

Compensation on this meter is also taken care of by a magnetic shunt provided between both pole of current core. Since with this meter the disc rotary speed is slower than with other general meters, its self-braking action by current flux is little and, consequently, the degree of compensation through magnetic shunt is small. For this reason, the extent of compensation of shunt core is lessened and the uniformity of characteristics attained.

2) Voltage characteristic compensation

Compensation of voltage characteristic is made by a magnetic shunt for voltage characteristic compensation fitted to the tip section of the voltage iron core. Since with this meter the meter constant is reduced and voltage and current cores are in a single body, on almost perfect magnetic closing circuit is formulated and it has extremely good characteristics even without voltage compensation but the characteristic are much bettered by this magnetic shunt.

3) Frequency characteristic compensation

The driving elements employ a great quantity of core and copper and the voltage coil, in particular, has big wires wound scantly to lessen d-c resistance. At the same time, the rotating disc is made as thin as possible to lessen the shading effect of the rotating disc. Thus, frequency characteristics are compensated for under a low power factor situation.

4) Temperature characteristic compensation

a) Compensation for unity power factor

Magnetic compensating alloy is fitted between magnetic poles of the braking magnets to compensate for the temperature characteristics in a high power factor.

b) Compensation for lagging power factor

The thermister having negative resistance and the manganin resistance wire are connected to the voltage coil of the voltage element in series which, by the variation of temperature and internal phase angle, serves to compensate for the temperature characteristics in a low power factor.

5) Compensation for light load error variation and stability

Stability is greatly enhanced by the compensation for the total friction torque applied to rotor shaft by utilizing the vane wheel and auxiliary motor, dynamically and geomtrically well-balanced arrangement of measuring elements, employment of double jewel bearing, use of jewelry for the upper bearing and the bearing section of the register equipment, light rotor, monobloc constrution of the voltage and current elements, frame box formation, etc.

5. Characteristics

The characteristics of this meter are superior as shown in *Fig. 100.*

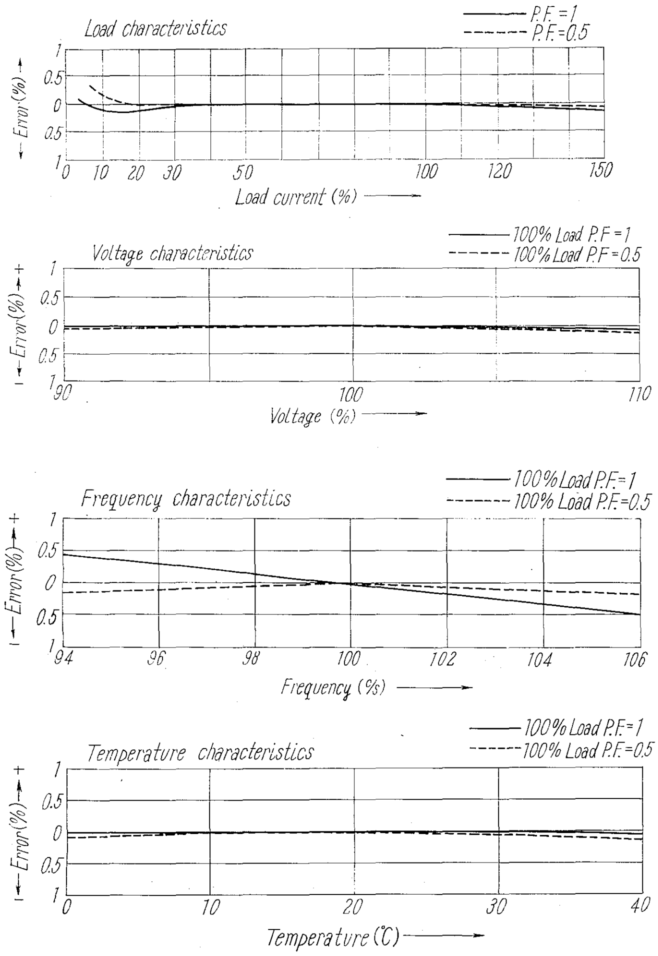


Fig. 100 **Characteristic curves**

6. Technical Data

Rpm at full load: 0.212

Full load torque: 36.5 g-cm (50 c/s), 32.5 g-cm (60 c/s)

Rotor weight: 43.0 g

Rotary power/Rotor weight: 0.85 (50 c/s), 0.76 (60 c/s)

		Potential circuit	Current circuit
Apparent power	(P_1)	15.4 va	
	(P_3)	18.7～19.8 va	2.68～2.89 va
		(including motor circuit)	
Power loss	(P_1)	3.15～3.23 w	1.73～1.84 w
	(P_3)	5.32～6.22 w	
		(including motor circuit)	

Starting current: under 0.15% of rated current

Voltage creeping: Rotor does not creep at no load on 110% voltage of the rated frequency and rated voltage.

Insulation resistance: When measured on d-c 500 volts, value will be maintained above 100 Mohm for both between electric circuits and between electric circuit and base.

Insulation strength: Meter can withstand ac voltage of 2000 v, 50 cy or 60 cy between electric circuit and base for one minute.

Total weight: 16.5 kg.