

# RECENT FUJI WATT-HOUR METERS

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## I. INTRODUCTION

Fuji Electric has 35 years experience in the production of watt-hour meters which started in 1936 and at present, the total number produced has reached 15 million meters and they occupy about 50% of Japanese watt-hour meter exports. The performance of Fuji watt-hour meters is especially high and various types of meters have been developed which fulfill such specifications as the BSS, (Fig. 1) VDE and NEMA standards. These meters have been exported and used all over the world including Southeast Asia, Middle and South America and the Near and Middle East. In Japan, in 1968 a revision of the Japanese Industrial Standard (JIS) was completed in 1968. In the new JIS, watt-hour meters are classified into three types: ordinary meters, precision meters and high precision meters. These meters possess the same accuracy as the 2.0, 1.0 and 0.5 classes of the IEC standards. Fuji Electric has completed the development of meters which satisfy these new standards. The performance, stability and reliability of this new watt-hour meter have been thoroughly studied and it is sufficient for future watt-hour meters of a higher level. It not only conforms to JIS standards but also satisfies the various standards of other countries.

The summation metering system for multi-circuit power reception and the automatic centralized meter-

ing system for power metering in factories and high density locations such as buildings have been developed and put into use in keeping with the recent demands for the systemization of watt-hour meters. This article will give an outline of the latest trends in Fuji watt-hour meters and the new series, especially those for export.

## II. FUJI WATT-HOUR METER SERIES

The Fuji watt-hour meters include the former type series and the newly developed series in terms of construction, as well as the universal series (ordinary domestic use) and the large demand users' series. In order to meet recent requirements for wider measuring ranges and higher accuracy, a new series has been developed which has a higher level of performance and reliability than the former series. The over load range is of the 600% class and the accuracy is of the 2.0 class. Table 1 shows the meters of these series. A series of utility meters has been completed based on the new JIS revised in 1968. Since most of the utility meters used in Japan are of the pulse type, the main Fuji Electric series is of the pulse type with power meters having transmitter attached.

## III. WHOLE CURRENT WATT-HOUR METERS

### 1. Foreign Standards and Conforming Meters

The main foreign standards related to watt-hour meters are as follows:

- ASA (American Standards Association)
- BSS (British Standards Specification)
- CSA (Canadian Standards Association)
- IEC (International Electrotechnical Commission)
- JIS (Japanese Industrial Standards)
- NEMA (National Electrical Manufacturers Association)
- VDE (Verband Deutscher Elektrotechniker)

The E and D series of meters which are the most popular for export at the present, will be introduced along with the completely new FA, FD and FF series which were developed on the basis of the former series.

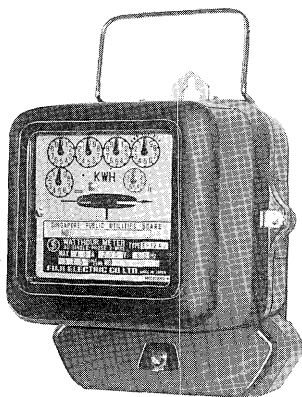


Fig. 1 Fuji watt-hour meter type E-12AJ for single-phase 2-wire

**Table 1 List of whole current watt-hour meter**

Conforming specification		Over load (% of basic current)				
		200%	300%	400%	500%	600%
JIS C1211 (1968)	1-element 2-wire	E-71(G)	E-71(G) FA13	FA14	FA15	FA16
	2-element 3-wire	D-27(G) FD12	D-27(G) FD13	FD14	FD15	
	3-element 4-wire	D-28(G) FF12	D-28(G) FF13	FF14	FF15	
BS 37 (1969)	1-element 2-wire		E-12A(J) FA13(J)			
	2-element 3-wire	D-27(G) FD12				
	3-element 4-wire	D-28(G) FF12				
VDE 0418	1-element 2-wire			E-18A(J) FA14(J)	E-18A(J) FA15(J)	E-18A(J) FA16(J)
NEMA	1-element 2-wire 3-wire					E-18A(J) FA16(J) FA16S
IEC PUB 43	2-element 3-wire 3-element 4-wire			D-27(G) FD14(G) D-28(G) FF14(G)	FD15(G) FF15(G)	

Note: Type FA, FD, FF are new model.

### 1.1 The E-71, D-27 and D-28 Series

#### 1) Single element watt-hour meter: type E-71 (Fig. 2)

This meter is the basic one in the E-71, D-27 and D-28 series. This meter conforms to JIS C1211/1965 and has sufficient tolerance in its characteristics to be used at long ranges. Therefore, it also satisfies other standards such as the BS and VDE standards. The base of the meter is made of iron plate and there are two types of covers: aluminum and glass. The connection system can be either the Japanese or the European system. The terminal cover can be either a short cover or an extended cover and the register can be either the cyclometer type and the pointer type. The meter can be used by combining these various types arbitrarily in accordance with the specifications, etc. of the customer. The features of this meter are as follows:

- (1) Since the driving torque is large, erroneous changes are small and the meter's life is long.
- (2) The number wheel of the cyclometer type register is an aluminum type developed especially by Fuji Electric which makes it very light weight. Light load characteristics and meter life are especially good.

- (3) The brake magnet is made of ALNICO metal which has a high coercive force and because of the twin double pole construction, the meter is stable with timed and no parasitic oscillation arise in the disk.
- (4) Since the driving element is attached on the side surface, inspections and overhaul when the effective certified period is over are very easy.
- (5) Because temperature compensation is complete, erroneous changes caused by alterations in the ambient temperature are very few.
- (6) The construction is weather-, earthquakes- and shock-proof construction. The meters are elec-

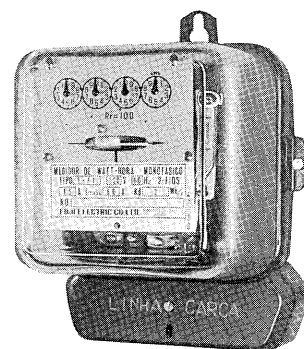


Fig. 2 Type E-71 for single-phase 2-wire

trically stable and mechanically durable.

2) Two-element watt-hour meter: type D-27

This meter has two elements for single-phase three-wire, two-phase three-wire or three-phase three-wire circuits. It is widely used in various types of industries and can be employed for highly accurate power measurements in both balanced and unbalanced circuits.

This meter conforms to the JIS C1211/1965 standard and the electrical characteristics are normally stable. The same types of base, cover, coupling system and terminal cover as in the E-71 type can be combined arbitrarily to meet customers' specifications, etc. The features of this meter are as follows:

- (1) The meter is compact and lightweight since the two elements are combined in one disk.
- (2) The effects of mutual interference are completely compensated by a system originated by Fuji Electric.
- (3) The various control devices employ a micro-adjustment system which means simple adjustments with no mutual interference.
- (4) Construction is weather-, earthquakes- and shock-proof construction. The meters are electrically stable and mechanically durable.

3) Three-element watt-hour meter: type D-28

The three-phase four-wire meter is used in various types of industry and is capable of highly accurate power measurements in unbalanced circuits. The meter conforms to the JIS C1211/1965 standard and because of its large driving torque, it can also be used in long range applications. Its characteristics also satisfy BS and VDE standards. The following are the main features.

- (1) The effects of mutual interference are completely compensated by a system originated by Fuji Electric.
- (2) Registers of either the cyclometer or the pointer types can be easily attached. The registers are made of aluminum so that the weight is decreased and there is almost no influence due to friction.

## 1.2 New series of watt-hour meters

Because of the high quality, high reliability and wide measuring ranges demanded recently for watt-hour meters, developed a completely new driving element. This element has been specially developed to have a small watt loss and a large driving torque. The new series of watt-hour meters using this new drive element are as follows.

1) Single-element watt-hour meter FA series (Fig. 3)

These meters have an overload capacity of 300 to 600% and are of the 2.0 class for two-wire use. By changing the case, cover and terminal arrangements, these meters can be made to conform with major international standards such as BS, VDE, ASA, CSA, NEMA and IEC standards. In order to assure stability, the various parts are riveted or screwed to a light alloy die cast frame. The equipment is

designed so that the positions are determined for the various parts and any shifts in position are prevented. It is possible to attach all of the parts with the special specifications described hereinafter to this meter depending on the requirements. This meter possesses the following features.

- (1) All parts including the lightweight alloy die cast frame are durable so that stability is high.
- (2) The brake magnet is a three-pole formed magnet (tromalit magnet) which has a high coercive force and is stable against external conditions.
- (3) All of the control devices can be fine-adjusted from the front of the meter.
- (4) All of the various devices with special specifications can be easily attached.

2) Two-element watt-hour meter FD series (Fig. 4)

These meters have an overload capacity of 300 to 600% and are of the 2.0 class with two elements in one disk. The influence of mutual interference in meters with two elements in one disk is minimized by making the disk diameter large and separating the elements as much as possible. Complete compensation is provided by the compensation device. These meters have the following features.

- (1) Stability is high since all parts including the lightweight alloy die cast frame are very durable.
- (2) The brake magnet is made of ALNICO metal with high coercive force and the double pole construction is employed. These ensure high stability.
- (3) All of the control devices can be fine-adjusted

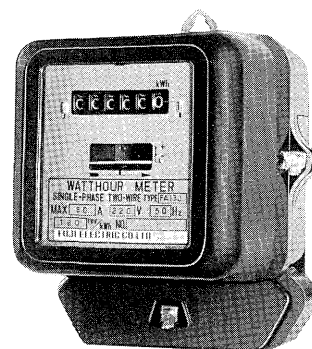


Fig. 3 Type FA-13J for single-phase 2-wire (new model)

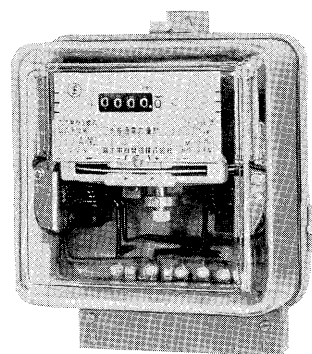


Fig. 4 Type FD-13 for three-phase 3-wire (new model)

from the front surface.

- (4) These meters are compact since they contain only one disk.

### 3) Three-element watt-hour meter FF series

This meter has an overload capacity of 300 to 600% and is of the 2.0 class with two disks and three elements. It is for use in unbalanced load four-wire circuits. The driving elements are arranged with a holder system so that there is a minimum of mutual interference. The brake magnet has been arranged so that improper moments in each of the disks are kept to a minimum. In this meter, the case, cover and terminal arrangement can be changed and various attachments can be added so that the meters conform to BS, VDE and ASA standards. This meter has the following features.

- (1) Stability is high since all parts are durable including the light alloy die cast frame.
- (2) Because of the appropriate driving element and brake magnet arrangements, there are very few errors due to mutual interference and improper moments in the disks.
- (3) The brake magnet is a three-pole (tremalit magnet) which has a high coercive force and is stable against outside influences.
- (4) All control devices can be fine-adjusted from the front surface.
- (5) Attachment of various devices with special specifications is easy.

## 2. Devices with Special Specifications

By combining the following special devices with standard meters, it is possible to manufacture meters conforming to various specifications.

### 2.1 Bearings

The bearings are of two types: the double jewel bearing and the magnetic bearing.

#### 1) Double jewel bearing

The Fuji double jewel bearings employ steel balls and jewels which have been strictly quality controlled. Since high quality lubricating oil is used, the meters error change is very little with time. Because of the dust-proof construction, the bearing maintains excellent characteristics with no penetration of dust even when used under rigorous conditions.

#### 2) Magnetic floating bearing (Fig. 5)

The magnetic bearings are of two main types: the suspended type and the repulsion type. Fuji magnetic bearings are of the repulsion type and the main feature of this construction is that the rotor position is relatively stable in respect to changes in the magnetic force of the magnet. For example, in the suspension type there is a tendency for the N and S poles to be separated by the weight of the rotor and there is relative instability since the attractive force of the magnet decreases rapidly. However, in the repulsion type, stability is maintained since the repulsion force increases as the poles

approaches when the magnetic force decreases. The Fuji magnetic bearing has a ring shaped magnet inserted in the top of the bearing screw so that the

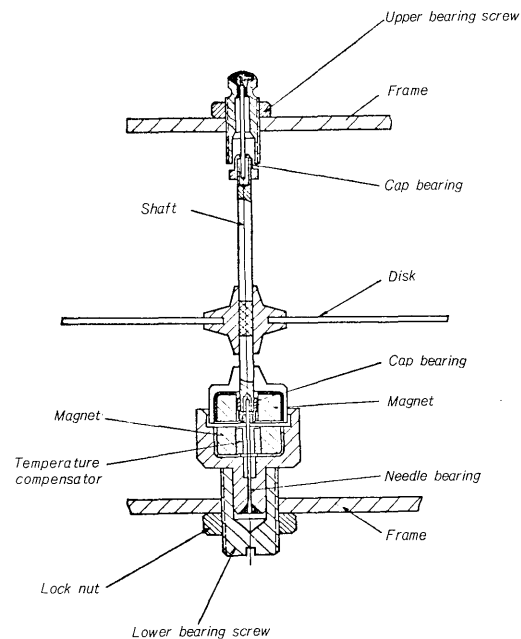


Fig. 5 Construction of magnetic floating bearing

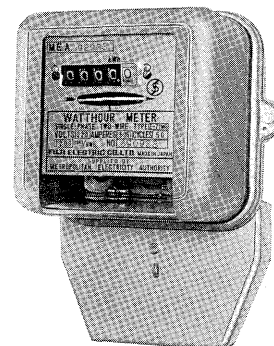


Fig. 6 Magnetic floating bearing watt-hour meter type E-71MG for single-phase 2-wire.

rotor is floated by the repulsion force with the magnet at the top of the rotor. There are also cap bearings provided at both ends of the rotor and support is provided in the radial direction by the shaft pins. The magnets have temperature compensation caps and thermo-alloy so that magnetic force changes due to temperature changes are compensated. Fig. 6 shows E-71MG type including magnetic floating bearing. The Fuji magnetic bearing has the following features.

- (1) Because of the repulsion type, the gap remains stable even when there is a change in the force on one of the magnets. This eliminates erroneous changes in the meter.
- (2) Even when magnetic bodies such as iron are inserted near the magnets of the bearing, there is no effect since the poles are not bridged due

to the fact that the opposite poles are of the same polarity.

- (3) Since the stability of the barium ferrite magnets is high and suitable temperature compensation is provided, the rotor operation is stable in respect to ambient conditions.
- (4) Changes with time are very slight since there is almost no friction variation.
- (5) The magnets are especially treated for protection against shock, etc. during transport or handling.
- (6) Because barium ferrite magnets are used, the coercive force is high and there is almost no reduction in the magnetic force due to mechanical or magnetic shocks. The magnets are also chemically stable, they have a high electrical resistance and there are no eddy currents.

## 2.2 Registers

### 1) 5-figure and 6-figure cyclometers

The number wheel of the cyclometer is made of aluminum so that it is light in weight and friction especially when the figure is advanced is slight. Therefore, there are few erroneous changes during light loads and since the increase of the friction torque with time is slight, almost no erroneous changes arise in the register. Because of the aluminum plate, the high temperature characteristics are excellent and there are no deformations in the number wheel even when the meter is used outdoors exposed to direct sunlight.

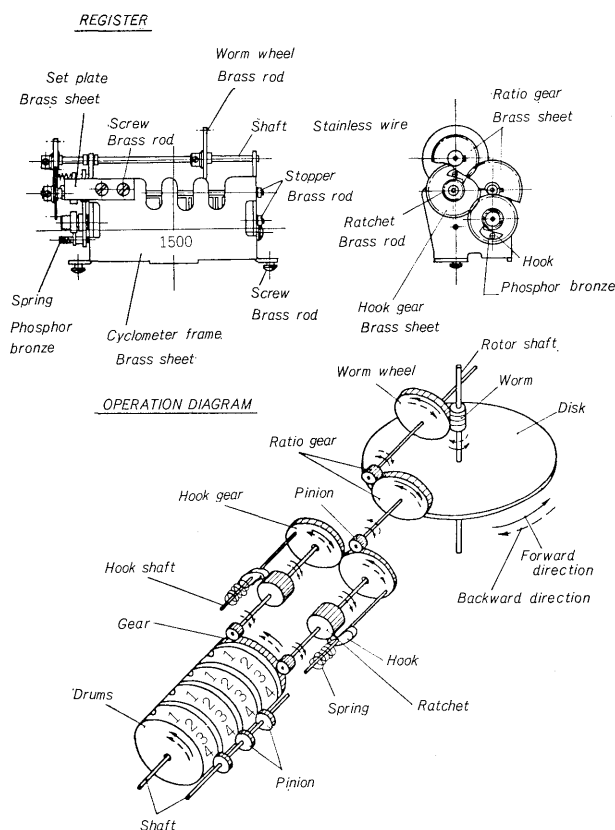


Fig. 7 Uni-direction cyclometer type register

### 2) Jumping cyclometer

In the jumping cyclometer, the figures on the number wheel are large and easy to read in order to prevent misreadings. In order to prevent increases in the friction torque because of the large number wheel, the number wheel is made of a light weight plastic molding and a jumping type advancer is used for frictional compensation when the number wheel is advanced.

### 3) Uni-directional cyclometer (Fig. 7)

The uni-directional cyclometer employs a ratchet mechanism which provides readings in a single direction for both forward and reverse turning. Improper measurements performed at will by the user can thus be prevented. The ratchet mechanism consists of gears with little backlash and the idling time during forward/reverse operation changeover is short so that correct measurements can be obtained.

### 4) Pointer type registers

The pointer type registers are of the 4 dial, 5 dial and 6 dial types which can be used according to the specifications. The dial diameters of each type are large and the dials are independent and with letters so that reading is easy. The pointer type registers has a long life and has little effect on erroneous changes in the meter. In all types, the pointers can easily be returned to zero so that such meters can be used for measurement tests, etc.

### 5) Uni-direction pointer type register

The uni-direction pointer type register is the same as the uni-directional cyclometer type in that it uses a ratchet mechanism which provides readings in a single direction for both forward and reverse turning. As in the cyclometer type, the ratchet mechanism consists of gears with little backlash so that the idle time during forward/reverse operation changeover is short so that correct measurements can be obtained.

## 2.3 Case

There are various types of cases available depending on the application and the specifications. The main types are the metal case, mold case and ceramic cover.

### 1) Mold case

The mold case which is made of molded insulation materials employs thermosetting plastic so that it is highly resistant to heat and non-inflammable. This means that there is stability even if a short circuit should occur. Since this case is also chemically resistant, it can be used outdoors, even in atmospheres where harmful gases are present. The case for the single-element meter and the three-element meter are manufactured in accordance with BS37 (1969).

### 2) Reflector cover

The reflector cover which is ceramic coated on the inner surface of the glass cover by a special process is patented in Japan. It is highly effective in blocking solar radiation in meters used outdoors. Since this cover inside the meter 15 to 20°C below

the normal value, the meter is protected against deterioration of the lubricating oil and insulation due to high temperatures.

#### 2.4 Weather-proof construction (Fig. 8)

This completely weather-proof type watt-hour meter has been strengthened by surface treatment related to the outside case which is coated with double layer of paint after zinc plating. Since the surface is treated with silver grey metallic paint, weather-proofing is excellent. All of the parts such as the attachment parts and screws where rust can easily occur are made of stainless materials. The outer

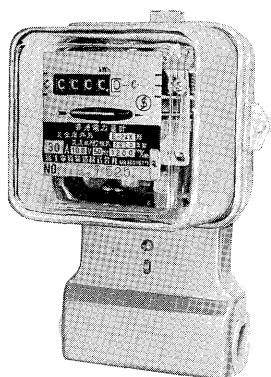


Fig. 8 Weather-proof type E-24X for single-phase 2-wire

side of the terminal cover has been extended to keep out water and prevent drops in the insulation resistance. Improving the form of the packing, there is absolutely no chance for water which can deform the packing, etc. to enter the meter. The surfaces of the sealing screws have been nickel-chrome plated to improve corrosion resistance. When this meter is used completely outdoors, it can be used for 10 years without any spreading of rust.

### 3. Meters for Special Applications

Two or three of the meters which have been developed for saving labor, rationalization, power control rationalization, etc. will be introduced here.

#### 1) Double-tariff watt-hour meter (Fig. 9)

This meter contains two registers and a auxiliary relay for switching. Measurements are made separately of the amount of power used during the day and the amount used during the night. Changeover between the day and night measurements is performed by a separate time switch or a ripple control receiver. Since the same meter can be used for both day and night measurements, the measuring accuracy remains the same, relay power consumption is low, the register which is not measuring is not disturbed because a lock device is provided. In addition to these features, the meter is compact and highly reliable. The meters with the double tariff register are of the following types:

System	Type
Single-element for two-wire	FA-13-T <sub>1</sub>
Two element for three-wire	FD-13-T <sub>1</sub>
Three element for four-wire	FF-13-T <sub>1</sub>

#### 2) Excess watt-hour meter

This meter contains two registers and is used for separate indication of the total power and the excess power used when a set power limit is exceeded. If a higher tariff than normal is charged for the excess power used, the user can adjust the load since he can make sure the load used is within the power limit. Since the excess amount is recorded separately, it can be used as data for making changes

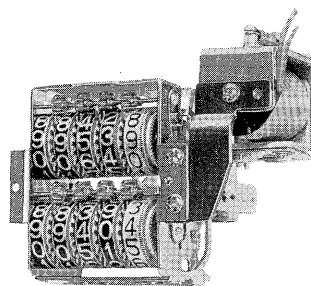


Fig. 9 Double tariff register

in the contracted power. In the excess watt-hour meter developed by Fuji Electric, the constant speed due to the hysteresis motor and the meter rotor speed are compared by the differential gear and when the rotor speed becomes greater than the speed equivalent to the power limit, only the excess amount is measured on the excess register.

The power limit can be changed freely by changing the gear. These meters can make accurate measurements of the excess power. Since a 16-pole hysteresis motor is used, stability is high and life is long. This meter has the following types:

System	Type
Single-element for two-wire	FA-13-T <sub>3</sub>
Two-element for three-wire	FD-13-T <sub>3</sub>
Three-element for four-wire	FF-13-T <sub>3</sub>

#### 3) Maximum current 200 A whole current watt-hour meter

When the rated maximum current is of the 200 A class, it is often necessary to use a current transformer but this FD23G type meter can be used to measure 200 A directly. Since this meter has a large rated current a special construction is used for the terminals in order to prevent heat due to loose lead wire connections, etc. This construction is such that when the lead wire is connected securely, it will not come

loose with time. If this meter is used, the price is cheaper than if a current transformer must be employed. In addition, the accuracy is good and storage is easy. The type of this meter is as follows:

#### IV. UTILITY METERS

High accuracy measurement for large power volumes and appropriate as well as rational control in accordance with the maximum demand, power factor and separate time band measurement are required. Since the utility meters described here were developed on the basis of the new JIS standard published in 1968, they can also be used for these types of control as well as ordinary uses. Since these meters are especially meant to handle large amounts of power, they have been designed and manufactured on the basis of high reliability and high accuracy.

##### 1. Impulsing Watt-hour Meter

The impulsing watt-hour meters generate an electrical pulse which is proportional to the amount of power. These meters consist of three types: the precision type, the high precision type and the ordinary type. The electrical pulse is utilized for drive of a pulse form demand meter, drive of a print-out type recorder, a pulse form counter, a data logger, etc. The impulsing devices are of the following types.

###### 1) Type K7, K8 impulsing device

This impulsing device is of the static type consisting of an oscillation disk attached to the meter rotor shaft, and LC oscillator thyristor switching circuit. Since there are no parts subjected to friction, the life is long and reliability is high. Since there are no friction parts, there is absolutely no effect on the meter body. The signal can be generated even at overloads of over 300%. This type of impulsing device is attached to the FH03K7R high precision watt-hour meter, and the FP03K8R precision watt-hour meter.

###### 2) Type K9 impulsing device

The type K9 impulsing device contains two LC oscillators and a circuit to distinguish between forward and reverse. The pulse is generated only when the rotor is turning in the forward direction. This type of impulsing device is used in var-hour meters where there are many possibilities of comparative repetition of forward and reverse operation and in watt-hour meters employing tidal current circuits. It is attached to the FH03K9R high precision watt-hour meter and the FV13K9R var-hour meters.

###### 3) Type K10 impulsing device

The K10 impulsing device consists of a reed switch and a permanent magnet attached to the cyclometer register. The features of this device are simple construction, high reliability and no influence on characteristics of the meter. In particular there is

no influence of the external magnetic field. This type of impulsing device is used with ordinary class watt-hour meters and can be utilized in a centralized metering system. The meters employed are the 1 $\phi$  2 W FB03K10 and the 3 $\phi$  3 W FD13K10 types.

##### 2. Maximum Demand Meters

The maximum demand meters consist of two types: the pulse type with an impulsing watt-hour meter and a maximum demand indicator accommodated in separate cases with a pulse circuit between them, and the other type in which the maximum demand indicator is attached to the watt-hour meter with both accommodated in the same case. There are pulse types for one circuit and for two circuits.

##### 3. Var-hour Meters (Reactive Energy Meters)

Var-hour meters for measuring the average power factor are classified according to their element structure. However, Fuji Electric had already manufactured the D-24BWGR type 0 meter in which there were theoretically no errors. From that time, new types of higher accuracy and reliability have been developed. These var-hour meters have the same accuracy as the precision watt-hour meters. A meter has also been developed for attachment of the K9 type impulsing device so that it can be used as a pulse type.

Var-hour meter .....Type FV13R

Impulsing var-hour meter.....Type FV13K9R

110 V, 5 A with transformers

two-element for three-wire system

##### 4. Multi-circuit Summation Metering System (Fig. 10)

The multi-circuit power receiving system is used to increase the reliability of power supply. The summation metering system is employed for control in this and other such systems. This metering system consists of the current transformer totalized system and the pulse totalized system using pulse type meters. Fuji Electric uses the pulse totalized system and it can measure two or more circuits of total-watt hours, total demand or total var-hours. The totalized system has no effect on mutual interference among the circuits and makes highly reliable measurements at all loads. Remote measurements can be made economically. It is also easy to make changes in the circuits. The types are as follows:

Summation meter

SUM2-2K mechanical type for 2 circuit

SUM2-3K mechanical type for 3 circuit

Impulsing watt-hour meter, var-hour meter

Auxiliary power supply device

#### V. AUTOMATIC CENTRALIZED METERING SYSTEM

(Fig. 11)

Considerable attention has been given recently to labor saving and rationalization measures because of

the labor shortage and high wages. There is also urgent necessity for labor saving and automation in the metering field. Automatic centralized metering systems are used mainly in the supply of electricity, gas and water. Fuji Electric anticipated such expansion and started to develop an automatic centralized metering system some time ago. This system has now been completed for use in billing utility

costs for tenants in office and apartment buildings and for controlling consumption in the various sections of factories. This system can be classified under four basic types which can be selected in

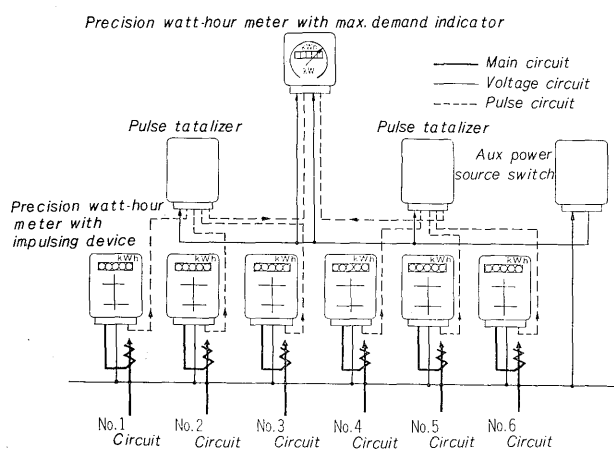


Fig. 10 Multi-circuit summation metering system

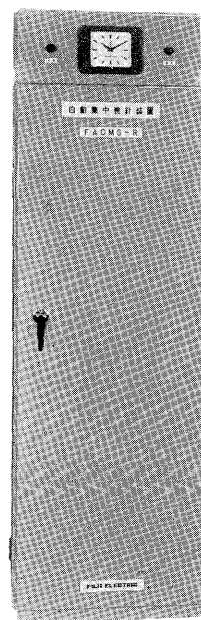


Fig. 11  
Overview of FACMS-R  
(automatic centralized  
metering system)

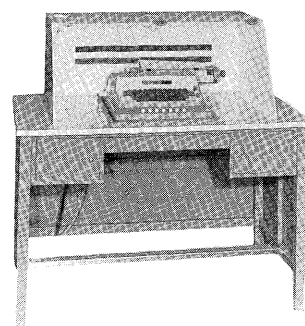


Table 2 Fundamental classification of Fuji automatic centralized metering system

Type	System	Function		
		Indicating	Recording	Billing
FACMS-C	Counter indicating system	○		
FACMS-R	Typewriter recording system	○	○	
FACMS-T	Tape punching system	○	○	※
FACMS-O	On line realtime system	※※	○	○

※ Disposal with off-line  
※※ Installed with option

accordance with the degree of labor saving, the number of measurements, economy, etc. Table 2 shows these four systems.

## VI. CONCLUSION

This article has given an outline of the watt-hour meters recently developed by Fuji Electric and in particular those meters for which demands are expected to increase in the future. However, new techniques appear all the time for the design and manufacture of such meters, and customers continue to demand higher accuracy and reliability. Studies

are being made by customers for the rational utilization of power and more rational and labor saving metering. This has resulted in demands for higher performance and quality, and more variety of watt-hour meters. Fuji Electric is earnestly working to develop watt-hour meters to meet these requirements and also to improve the quality of existing meters. The value of watt-hour meters is thus increasing. The specifications for watt-hour meters exported depend on the country but Fuji Electric has made a detailed study of these various requirements and is manufacturing a wide range of watt-hour meters to meet all of these demands.