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FUJI STANDARD SMALL HYDRAULIC TURBINES

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I. FORWORD

Triggered by the first and the second energy crises, developments of domestic energy were advocated, and as one of the projects related to such energy developments, a variety of study and research were called for developments of substitute energy. Among such projects, it is the development of small hydraulic power plant that has shown steady achievements and that is also expected to provide more achievements in the future, althrough the scale of power generating capacity is rather limited.

When the oil energy cost which was used to be less than 1 yen/Mcal (ca 0.5 cent/Mcal) was skyrocketed to 5 yen/Mcal (2.5 cent/Mcal) in Japan, small hydraulic power plant so far neglected because of its unprofitablity has become comparable with petroleum thermal power generation, and its development is seen in steady progress at present partly thanks to the positive subsidiary policy of the government, etc.

In Japan with respect to possible locations and hydro resources for domestic hydraulic power plants, various kinds of modifications and corrections have been made on the basis of the results of the 4th hydro resource survey. In addition, the 5th hydro resource survey has been conducted under auspices of the New Energy Foundation of Japan. Details of the results of such surveys have been made know to public in various forms. According to the data and information made available by these surveys, it is known that developments of hydraulic power plants for more than 600 MW are planned for every year in Japan. Among such projects are included the projects related to many small-scale hydraulic power plants whose outputs are no more than 1,000 kW. Even in the case of the projects started during 1981 fiscal year, the average projected outputs are reported to be less than 10 MW.

Generally, Fuji Electric Co. calls hydraulic power plants of less than 20 MW "small hydraulic power plants". In the case of such small hydraulic power plants of less than 5,000 kW inclusive of so-called "mini-hydro" power units of less than 2,000 kW, it is necessary to employ more economical turbines, generators, and auxiliary equipment, althrough their power generating cost of "Small hydraulic power plant" has become somewhat comparable with that of the existing thermal power generation.

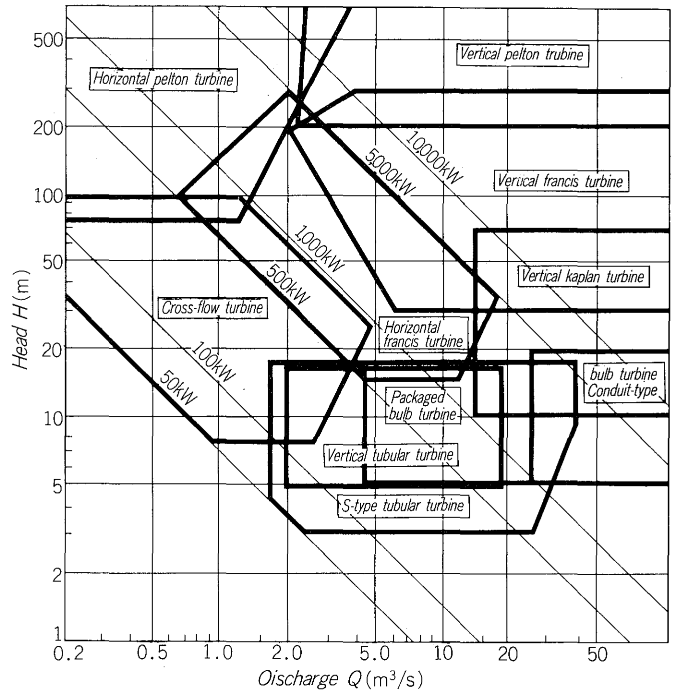

Fig. 1 Selection chart of Fuji standard hydraulic turbine

In the case of small hydraulic power plants, it is general that they are constructed in combination with water utilization or irrigation facilities in most cases. Also, it cannot be denied that they can become profitable with some types of multi-purpose facilities combined. For this reason, conditions of water utilization for the turbines are, in most cases, not for power generation itself. Even when the conditions of water utilization are for pwoer generation, most of the power generating plants are so-called "run-off-river" type power plants. Thus, water flow and the head are creating very undesirable conditions for turbine. Under such conditions, it is a problem how to effectively recover the water potential energy as electric energy. In order to efficiently recover all kinds of potential water energy as electric energy, inclusive of low head water energy of which utilization has been so for unconceivable, Fuji Electric Co. has made available various kinds of turbines for samll hydraulic power generation as shown in *Fig. 1*.

II. OPERATING CONDITIONS AND STANDARDIZATION

1. Types of Turbines and Specifications

In the case of a small hydraulic power plant, the turbine of the optimum type and optimum size is to be selected out of standardized turbines available in series, instead of designing an optimum turbine anew according to the each hydraulic conditions as in the case of conventional hydraulic power plants.

More specifically, in the case of a conventional hydraulic power plant, the optimum turbine is designed according to a given head and discharge, and the performance characteristics of the designed turbine are tested and verified by means of a model turbine. In the case of a small hydraulic power plant, however, a turbine of the optimum type and optimum size having the optimum performance characteristics is to be selected out of the standardized turbines of various types available in series.

With respect to the generator, not only the generator itself of either synchronous machine or asynchronous machine (induction generator) but also the required excitation equipment and AVR are to be selected out of those standardized and available in series. In other words, through employment of mass-produced devices for general use as the circumstant permits, the power plant can be constructed at less cost maintenanced easily and made the most economical plant available from an overall point of view.

2. Operating Conditions and Equipment

In general the prime objict of a small hydraulic power plant is to recover electric energy from the surplus head of various kinds of hydraulic systems. Therefore, a necessity is generally not conceivable for maintaining the frequency of the associated electric power network by controlling demand and supply of power or placing the plant under and isolated operation. Also, the penstock which provides water to the turbine is designed as water supply pipe for irrigation, etc., and is not specifically designed and installed as the pipe for supplying water to the turbine. Therefore, the allowable strength of the pipe is relatively low, and such a necessity very often occurs that the value for water pressure rise ΔP is to be set to an abnormally low value at the time of load damping of the turbine.

Because of such conditions as cited above, there are many cases where and asynchronous machine (induction generator) is employed for a generator for a small hydraulic power plant if the conditions of the electric power network permits. In case fo using asynchrounous machine and no necessity for an isolated operation, acceleration time constant fo rotating portions (Tj) can be freely set to a smaller value irrespective of the wate inertia time constant of penstock (Tw = L.v/H.g), and therefore the inertia (GD2) of the generator can be designed at a smaller value. In many cases only the value of pressure rise ΔP is held within the allowable range of values at the time of load damping, but the value of speed rise Δn is up to a run-away speed with no specific limit.

In the case of a small capacity, it is natural that the size of the generator is proportionately small, and thus there is no particular difficulty to withstand a run-away speed operation continuously if some considerations are given to the bearing. Fuji Electric Co. has already made available more than 10 units of such facilities that are capable of withstanding continuous operations at a run-away speed, inclusive of plants whose capacity exceeds 10,000 kW.

3. *Standardization*

In the case of a small hydraulic power plant, such a turbine whose size and type are optimum to the conditions of the water system is to be selected out of turbines of standardized types. Therefore, it is necessary to make available turbines of various types and sizes to sufficiently meet the conditions of deversified water systems.

As seen from *Fig. 1*, Fuji Electric Co, is manufacturing turbines of various types so that turbines for small hydraulic power plants may be available for wide range of heads and discharge of various kinds.

Of the turbines of the types shown in *Fig. 1*, the turbines of following (1) through (7) are especially for small hydraulic power plants. Of these seven types of turbines, the four types of turbines other than (4) Horizontal Francis Turbine, (5) Horizontal Pelton Turbine and (7) Small Vertical Francis Turbine are those that have been closed up in conjunction with the recent rise of requirements for small hydraulic power plants.

(1) Cross-Flow Turbine
(2) Packaged Bulb Turbine
(3) S-Type Tubular Turbine
(4) Horizontal Francis Turbine
(5) Horizontal Pelton Turbine
(6) Vertical Tubular Turbine
(7) Small Vertical Francis Turbine

III. USING CONDITIONS AND TYPE OF TURBINE

The types of turbines suitable to each discharge and head of small hydraulic power plants are as shown in *Fig. 1*. In the boundary of applicable types, two or three types of turbines are oaverlapped. In this case, the type of turbine to be employed is determined according to various kinds of conditions at each specific plant. In addition, there is a possibility that a turbine of a type not matched to the range shown in *Fig. 1* is to be selected because of some special specific conditions at each plant. In the following will be explained the characteristics and outline of each of the seven types of turbines of Fuji Electric standard for small hydraulic power plant mentiond above.

1. Cross-Flow Turbine

This turbine is of very simple structure as seen from *Fig. 2*. Its wicket gate can be divided into two portions. Both portion of the divided wicket gate can be operated separately or simultaneously.

A cross-flow turbine functionally comes in an impulse turbine rather than a reaction turbine. As seen from *Fig. 3*, the water flowed into the runner is applied twice to the runner blades and is discharged into the tailrace after giving energy to the runner.

A coss-flow turbine has been primarily designed as a turbine for small hydraulic plant which is operated by small amount of water and a medium and low head. Because its structure is simple and its maintenance is relatively easy, it is available at a relatively low price. The following are Fuji Electric standard specifications of a cross-flow turbine.

Output: 50~1,000 kW
Flow: 0.15~5.0 m^3/s
Head: 7.5~100 m (Head at the turbine center)
Speed: 100~1,000 rpm (50 Hz)
100~1,200 rpm (60 Hz)
(Note: In principle, the speed of the generator is rasied to 1,000 rpm or 1,200 rpm by the gear)
Runner Diameter: 315, 400, 500, 630, 800, 1,000 mm

The features of a cross-flow turbine lies in its simple structure and its high efficiency at a relatively light load. The wicket gate can be divided into two portions, each of which can be operated separately. Thus, when the length of the wicket gate is divided at a rate of 1 : 2, smaller wicket gate are to be opened for up to 1/3 of the discharge, and smaller wicket gates are closed and larger wicket gates are opened for 1/3 to 2/3 of discharge. For more than 2/3 of flow, both smaller and larger wicket gates are to be concurrently opened. This operation is essentially the same as the efficient operation of a Pelton turbine through control of operating nozzles. *Fig. 4* shows the efficiency of a cross-flow turbine by means of this control of opening the wicket gates. From these features, it can be said that a cross-flow turbine is most suited for application in the case where the variation of head is small even if the variation discharge is large at a head of less than 100 m.

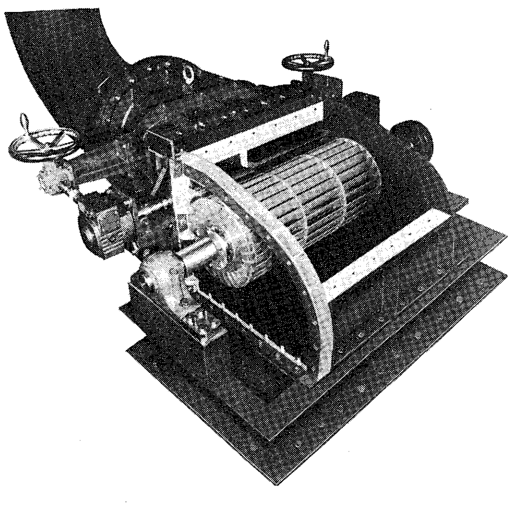

Fig. 2 Cross-flow turbine

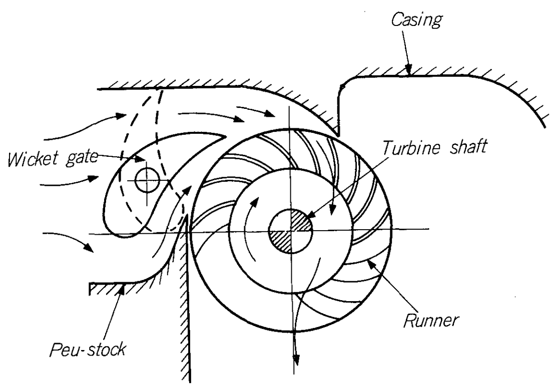

Fig. 3 Water path of cross-flow turbine

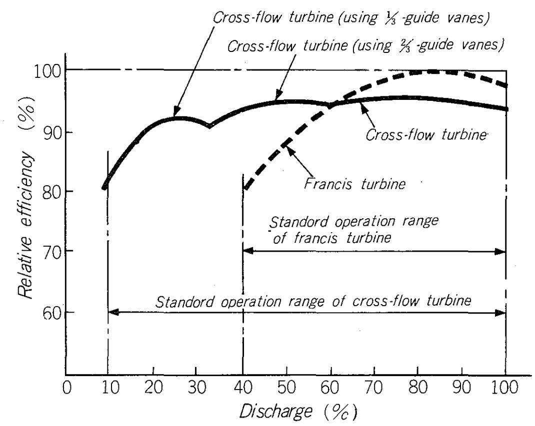

Fig. 4 Efficiency of cross-flow turbine

2. Packaged Bulb Turbine

A packaged bulb turbine is a turbine to be used in a case where the discharge is larger and the head is smaller than those in the case of a cross-flow turbine. *Fig. 5* shows a sectional view of the atructure of a packaged bulb turbine.

As seen from *Fig. 5*, this turbine is most suitable for recovering the surplus head of water service pipe as electric energy. However, as the generator is housed within a rather narrow bulb, use of the turbine is not desirable in a case where the relatively long penstock requires a large inertia to the generator and there is a necessity for isolated operation. Of the bulb turbines of small capacity, the runner diameters are standardized to the following five, as packaged bulb turbines, The following are the standard specific-

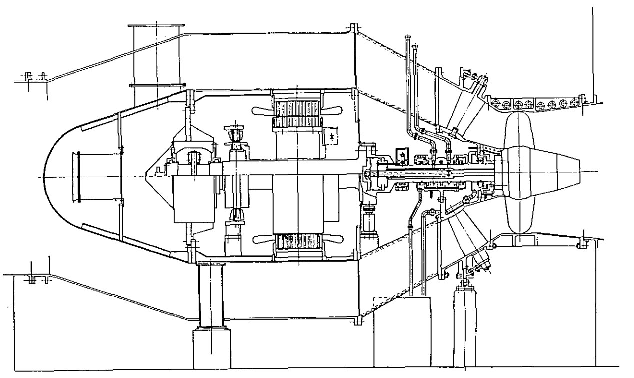

Fig. 5 Section of package type bulb turbine

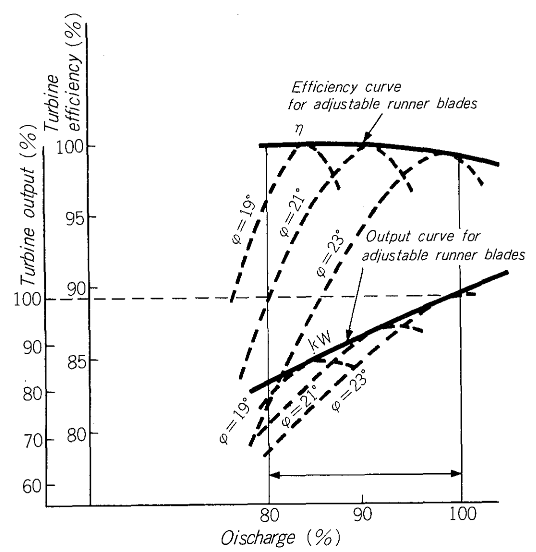

Fig. 6 Efficiency of package type bulb turbine

ations of packaged bulb turbines.

Output: 150~3,500 kW
Discharge: 4~25 m^3/s
Head: 5~18 m
Speed: 187.5~500 rpm (50 Hz)
180~514 rpm (60 Hz)
Runner Diameter: 1,250, 1,400, 1,600, 1,800, 2,000 mm (See Note below)
Number of Runner Blades:
5: in case the head is higher than 9 m
4: in case the head is lower than 9 m

(Note: In the case of 1,600 to 2,000 mm, the runner blades are adjustable; in the case of 1,250 mm and 1,400 mm, the runner blades are semi-adjustable).

The wicket gates and the runner blades are both adjustable (Runner blades of certain diameters are semi-adjustable. See the specifications above), and this turbine shows very excellent performance against variations of discharge as seen from *Fig. 6*.

In principle, in the case of runner blades whose diameter is larger than 1,600 mm, the runner blades are automatically positioned at the optimum point by means of so-called Kaplan device. In the case of runner blades of 1,250 mm or 1,400 mm, they are semi-adjustable and are to be manually positioned to the optimum point by stopping the turbine.

3. S-Type Tubular Turbine

The runner of the S-type tubular turbine is designed in essentially the same way as that of a bulb turbine, but the turbine draft tube is bent into the S-shape. The turbine shaft is run through the S-shape turbine draft tube and connected to the generator externally installed. Because of this design feature, the conditions for the design and installation location of the generator are very flexible. Also, as seen from *Fig. 1*, its applicable range includes all the applicable range of packaged bulb turbine and can be applicable widely to ranges from cross-flow turbines to conduit-type bulb turbines.

Fig. 7 shows a sectional view of the S-type tubular turbine, and the following are the standard specifications of the S-type tubular turbines.

Output: 50~5,000 kW
Discharge: 1.5~40 m^3/s
Head: 3~18 m
Speed: 120~750 rpm
(Note: In principle the speed of the generator is raised to 750 rpm or 730 rpm by gear.)
Runner Diameter: 800, 900, 1,000 1,120, 1,250, 1,400, 1,600, 1,800, 2,000, 2,250, 2,500 (mm)

The wicket gates and the runner blades are both adjustable, and the performance characteristics of the turbine are exactly similar to those of the packaged bulb turbine shown in *Fig. 6*. However, in the case of the S-type tubular turbine, the conditions with respect to the generator is increased to either 750 rpm (50 Hz) or 720 rpm (60 Hz) by use of a gear, and the size of the generator can be reduced. At the same time, the inertia moment required by the turbine can be easily met. Also, a flywheel can be installed with ease even if required. Further, in case the speed of the turbine is as high as 514 rpm (60 Hz) or 450 rpm (50 Hz), the speed of the generator is matched to the speed of the turbine, thus the turbine and the generator can be directly connected.

4. Horizontal Francis Turbine

Among various types of turbines, Francis turbines are used in a very wide range from high head to low head, from a large capacity to a small capacity. In addition, its structure is simple and its maintenance is easy. From these features, Horizontal Francis turbines are being used as the most general type turbines. In addition, Horizontal Francis turbines being used as the turbines for small hydraulic power plants outnumber the turbines of any other type being used for the same purpose.

Horizontal Francis turbines for small hydraulic power

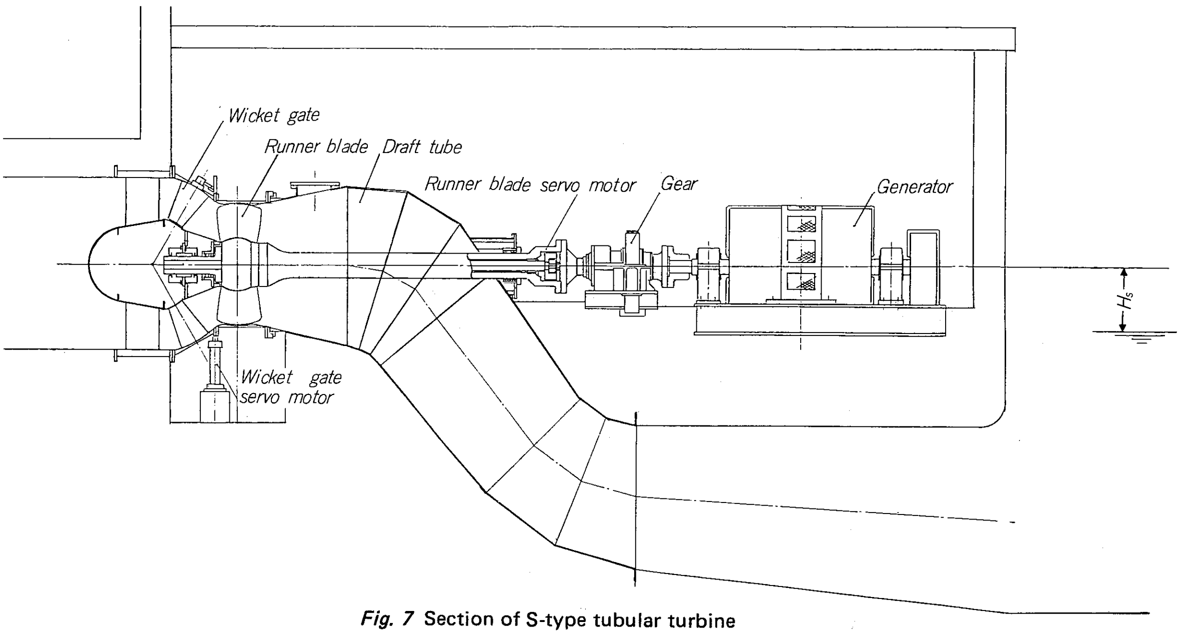

Fig. 7 Section of S-type tubular turbine

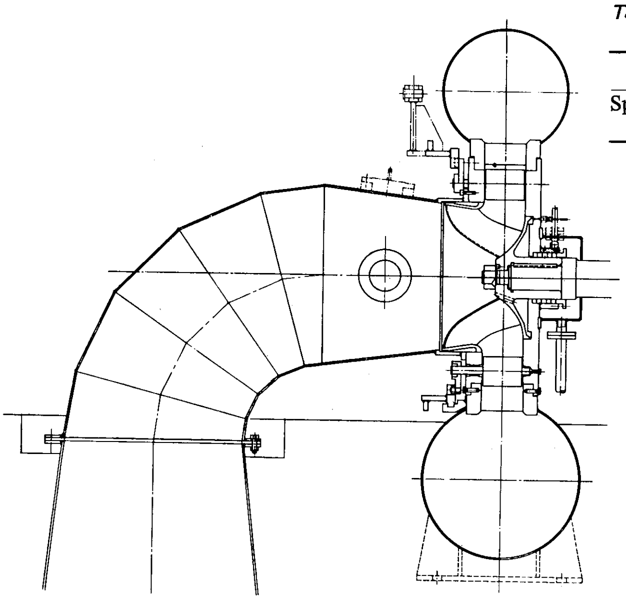

Fig. 8 Section of standard horizontal single flow Francis turbine

Table 1 Table of model and specific speed

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Specific Speed ns (m.kW)	300	266	236	209	186	165	146	130	115	102	90	80	71	63

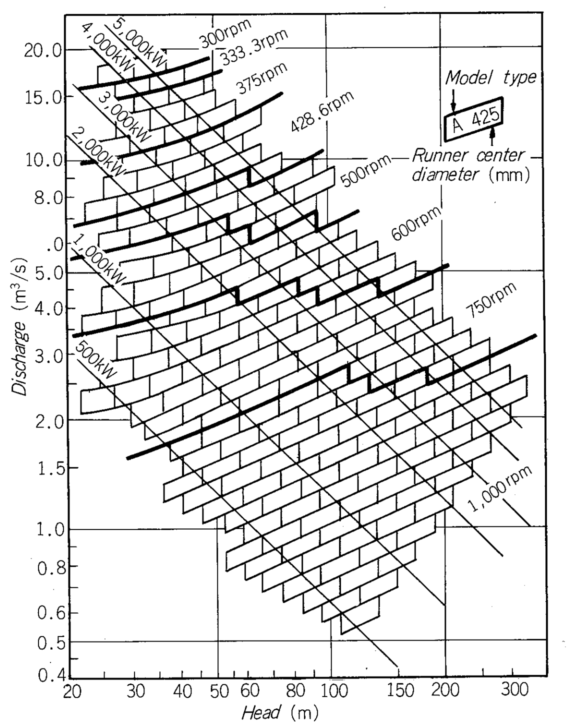

Fig. 9 Selection chart of standard horizontal dingle flow Francis turbine (50 Hz)

plant are standardized by use of 14 kinds of models within the range of the following specifications. The standard Horizontal Francis turbine is designed as a single flow turbine, and *Fig. 8* shows a sectional view of a standard horizontal single flow Francis turbine.

Output: 500~5,000 kW
Flow: 0.6~17 m^3/s
Head: 20~300 m
Speed: 300~1,000 rpm (50 Hz)
300~1,200 rpm (60 Hz)
Specific Speed n_s: (m-kW)
Runner Center Diameter: 375~1,250 mm; 41 kinds

In the case of standard Horizontal Francis turbines, they are standardized by combinations of 41 kinds of runner center diameters with 14 kinds of models from A through N shown in *Table 1* (in the case of 50 Hz), and thus standard types as shown in *Fig. 9* are determined with respect to each discharge and head. A capital letter A through N of the designation of a standard type represents the model type, and following letters by a number represent a runner center diameter as in A 425, for instance.

5. Horizontal Pelton Turbine

Generally, Pelton turbines are used when the head is high (higher than 200 m). However, in the case of a Horizontal Pelton turbine for a small hydraulic power plant, its applicable head range is being extended down to as low as 75 m.

In case where variation of head is small even if variation of discharge is large, a Pelton turbine has a small drop of efficiency and maintains the good operating performance at light lood. Because of these features, use of a Pelton turbine is suited to a run-off-river type power station whose head is high and variation of head is small and variaties of discharge is large.

As specifications for standard Horizontal Pelton turbines, the following are under consideration.

Output: 100~5,000 kW
Flow: 0.2~3 m^3/s
Head: 75~400 m
Speed: 120~1,000 rpm (50 Hz)
120~1,200 rpm (60 Hz)

In some of small hydraulic power plants, there may be such a case where a Pelton turbine needs to be used because of the hydraulic condiitons even if the head is low. In such a case, the speed of turbine inevitablly becomes low, the turbine is coupled to the generator via a gear as in the case of the cross-flow turbine or the S-type tubular turbine. *Fig. 10* shows a sectional view of a Horizontal Pelton turbine.

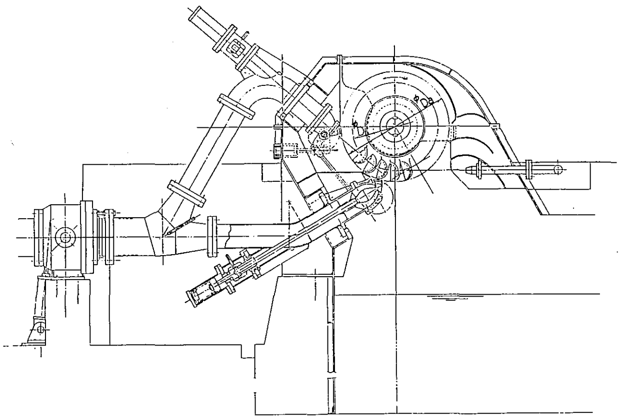

Fig. 10 Selection of horizontal Pelton turbine

6. Vertical Tubular Turbine

A vertical tubular turbine is a kind of S-type tubular turbine which is vertically installed (or obliquely sometimes), and thus the characteristics are basically the same as those of the S-type tubular turbine. In principle, the runner blades are fixed blades, and the turbine is directly coupled to the generator. As its application range, it is best suited to the range of a relatively high head and low flow among the applicable range for S-type tubular turbines. When compared with the S-type tubular turbine, the housing for a vertical tubular turbine can be smaller, and thus energy recovery can be made profitable by minimizing the overall cost inclusive of the construction.

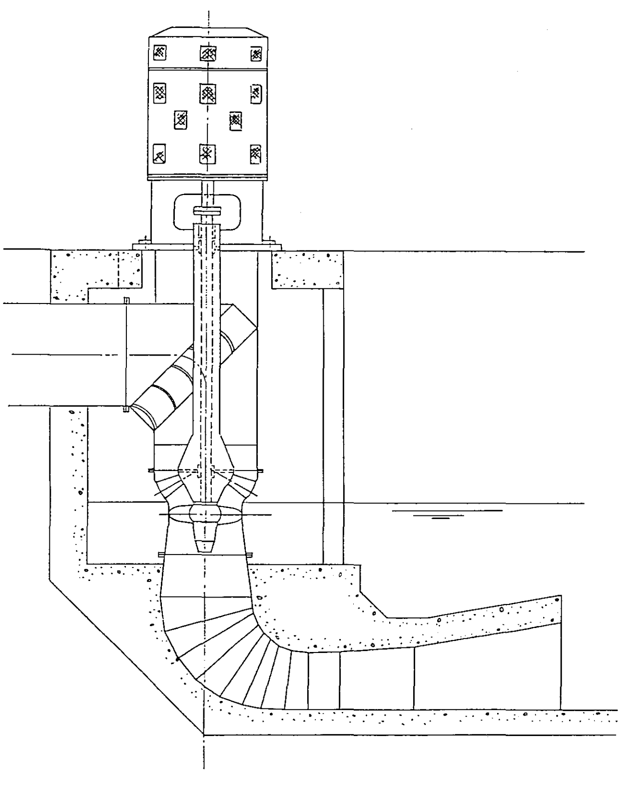

Fig. 11 Vertical tubular turbine

Fig. 11 shows a view of a vertical tubular turbine, and its standard specifications are shown below. Under a certain specific circumstance, this turbine can be applied to a smaller flow and a smaller head than those of the standard specifications. If necessary, this turbine can be settled on the gate of a dam as a gate-type turbine which moves up and down with together the movement of the gate. Also, when there is a sufficient space downwards, a straight bugle-shape tube can be used as the draft tube.

Output: 100~2,000 kW
Flow: 2~20 m^3/s
Head: 5~18 m
Speed: 300~750 rpm
Runner Diameter: 800, 900, 1,000, 1,120, 1,250, 1,400, 1,600 mm

The generator to be used with this turbine should be an asynchrounous machine (induction generator) in principle. The runner blades are fixed blades and the wicket gates can be adjustable. In case, however, the synchronizing operation to the network is possible by the inlet valves or others, the fixed wicket gates should be employed as much as possible.

7. Small Vertical Francis Turbine

The structure of a small vertical Francis turbine for a small hydraulic power plant is essentially the same as that of a regular vertical Francis turbine of large/medium size. However, in the case of small vertical Francis turbines, the standard models and he standard sizes are determined as in the case of horizontal Francis turbines, and the optimum one is to be selected out of such standard models and sizes according to the each conditions.

IV. GENERATOR

As the turbine generator for ordinary hydraulic power plants, synchronous machines are generally used. But for a small hudraulic power plant asynchronous machines are used in rather many cases. The small hydraulic power plant is a carecely operated and controlled to maintain the frequency and voltage of the network at predetermined values. Especially, in the case of a so-called mini-hydro power unit whose output capacity is rated at less than 2,000 kW, it is general that such operation and control are never involved. Therefore, as long as the electric network, or other conditions permit to use an asynchronous, machine (induction generator) it is general to employ an ansynchronous machine and reduce the cost of power plant.

Most of turbines for small hydraulic power plants are horizontal turbines, and their speeds are within the same ranges as those of standardized diesel generator. Therefore, a synchrounous machine (induction generator) of hydraulic power plant is basically the same as that of the standard diesel generator, and in the case of an asynchrounous machine, it is basically the same as that of the standard induction motor of general use. However, in the case of a hydraulic turbine generator, it is required to withstand a speed increase at the time of load damping. Further, it is sometimes required to withstands a run-away speed continuously. Also, in case the turbine is a bulb turbine, the S-type tubular turbine, or a Francis turbine, the generator is required to be equipped with thrust bearings which support hydraulic thrust load of the turbine excepting a case where the geare is used.

The exitation system for a synchronous generator, is employed standard brushless excitor is normally employed as standard.

Table 2 shows the standard specifications for standard horizontal generator for a small hydraulic power plant.

V. CONTROL EQUIPMENT

Not only for a hydraulic power plant but also for any other system, the control equipments and/or supervisory equipments are required to match the control functions of

Table 2 Standard specifications of small hydraulic turbine generator

Item	Synchronous Generator	Induction Generator
Type	3-phase rotating-field synchronous generator	3-phase cage rotor induction generator
Degrees of Protection	Screen Protected Type	Screen Protected Type
Cooling System		
1,000kVA 1,000kW Less than	Free circulation type	Free circulation type
1,000kVA 1,000kW More than	Outlet pipe ventilated system	Outlet pipe ventilated system
Rating	Continuous	Continuous
Voltage	3.3 kV or 6.6 kV	3.3 kV or 6.6 kV
Frequency	50 Hz or 60 Hz	50 Hz or 60 Hz
Power Factor	0.9 (lagging)	–
Speed	100~1,200 rpm	100~1,200 rpm (synchronous = speed)
Class of Insulation	Class F	Class F
Insulating Treatment	Epoxy Resin Vacuum Impregnation	Epoxy Resin Vacuum Impregnation
Exciting System	Brushless Excitation	–
Temperature Rise		
Stator (Embeded temperature detection)	100°C	100°C
Rotor (Resistance method)	110°C	–
Applicable Standard	JEC-114 (1979)	JEC-37 (1979)

the system, despite the scale and size of the system to be controlled or supervised. In the case of a small hydraulic power plant, it is also required that not only the control equipment and/or supervisory equipment themselves but also the control system and supervisory system must be simplified for the purpose of accomplishing cost reduction. In the case of such a small hydraulic power plant whose output capacity is rated at larger than 5,000 kW and that is required to maintain the network by supplying electric power to the network by isolated operations in an event of a trouble of the network, the control equipment and the supervisory equipment of exactly the same levels as those being used in an ordinary hydraulic power plant are required. However, in the case of so-called mini-hydro power units whose output capacity is rated at less than 2,000 kW, such operating functions as mentioned above are not required in general, and thus both the control equipment and the supervisory equipment are as much sumple as possible.

1. Governor and Operating Mechanism

In case a small hydraulic power plant is required of the same operations and the same control fujctions as those in the case of an ordinary power plant, both the wicket gates and the runner blades are to be operated by pressure oil system as in the case of an ordinary turbine. However, in the case of a so-called mini-hydro power unit or in the case where the wicket gates can be controlled using a long time without causing any specific problem as a result, governing machianism with motor-driven wicket gate is used as the standard arrangement.

1) Pressure Oil Operation Governer and Pressure Oil System

When the wicket gate (runner blades) are operated by pressure oil system and the governor is required of the same functions as in the case of an ordinary hydraulic power plant, TU type hydraulic turbine governor is used. This governor detects the turbine speed digitally and position of the wicket gates electrically. Although it is not provided with auxiliary distribution valve nor with auxiliary servo-mechanism, it is a hydraulic turbine governor having excellent performance characteristics satisfying requirements of dead band 0.02% and dead time 0.25 sec. In case induction generator is used, the generator is not required to have a speed control function excepting the case of switch-on operation to the network, and is operated by output setting equipment. Thus, even in the case of pressure oil operation, the speed control function is not provided, but it is operated only by wicket gate position limiter (77).

As the pressure oil device, bladders with nitrogen gas sealed in by means of diaphrams are used in place of conventional pressure oil tank and compressed air supply device. Also, excepting the electric part, the governor inclusive of pressure oil pump and solenoid valves, etc. are mounted on top of the oil collector tank as the standard arrangement. Also, as the standard arrangement, the bladders of standard capacity are installed in as many as required according to the requirement.

Fig. 12 shows the system diagram and view of TU type hydraulic turbine governor and bladder type pressure oil system.

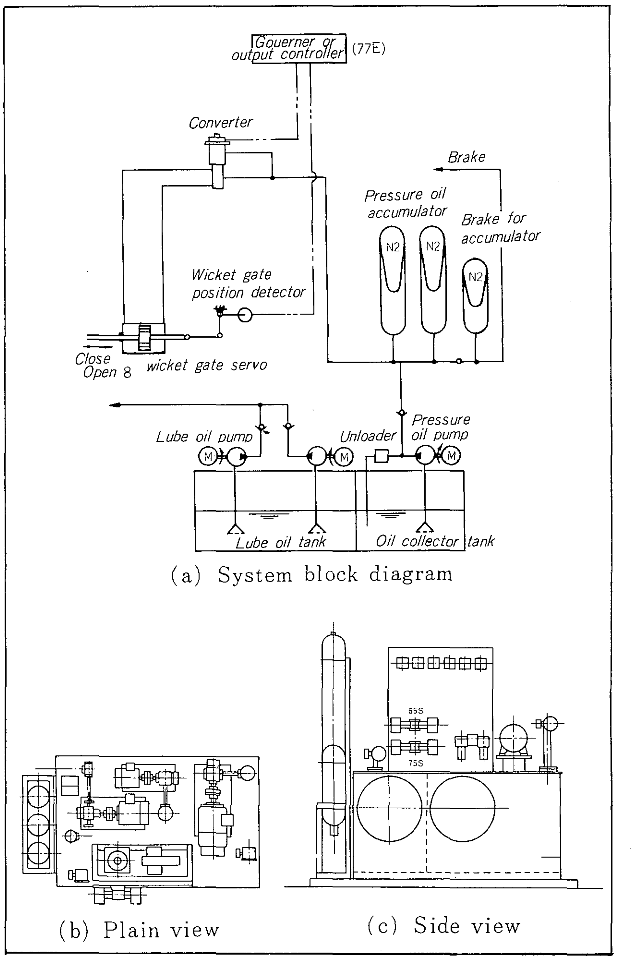

Fig. 12 TU type hydraulic turbine governor and bladder type pressure oil system

2) Motor-Driven Governor

The wicket gates of a cross-flow turbine and a vertical tubular turbine are driven by the motor. Also, in the case of a Francis turbine, an S-type tubular turbine, and a bulb turbine, its wicket gates are driven by the motor when speed control function is not required or when controlling of the wicket gates using a long time does not create any problem.

Normally induction motor is used as the drive motor. If necessary, however, the wicket gates can be driven by means of a DC motor. If the circumstance involved so requires, the wicket gates can be driven by both an induction motor and a DC motor; in other words, they can be driven by an induction motor normally, but they can be driven by a DC motor in an event of AC power supply failure.

Fig. 13 shows the control system block diagram for electric motor operating governor provided with circuit arrangements for both AC and DC operations. In *Fig. 13*, the drive circuits for the AC and DC motors are indicated by contact-type magnetic contactors, but semi-conductor

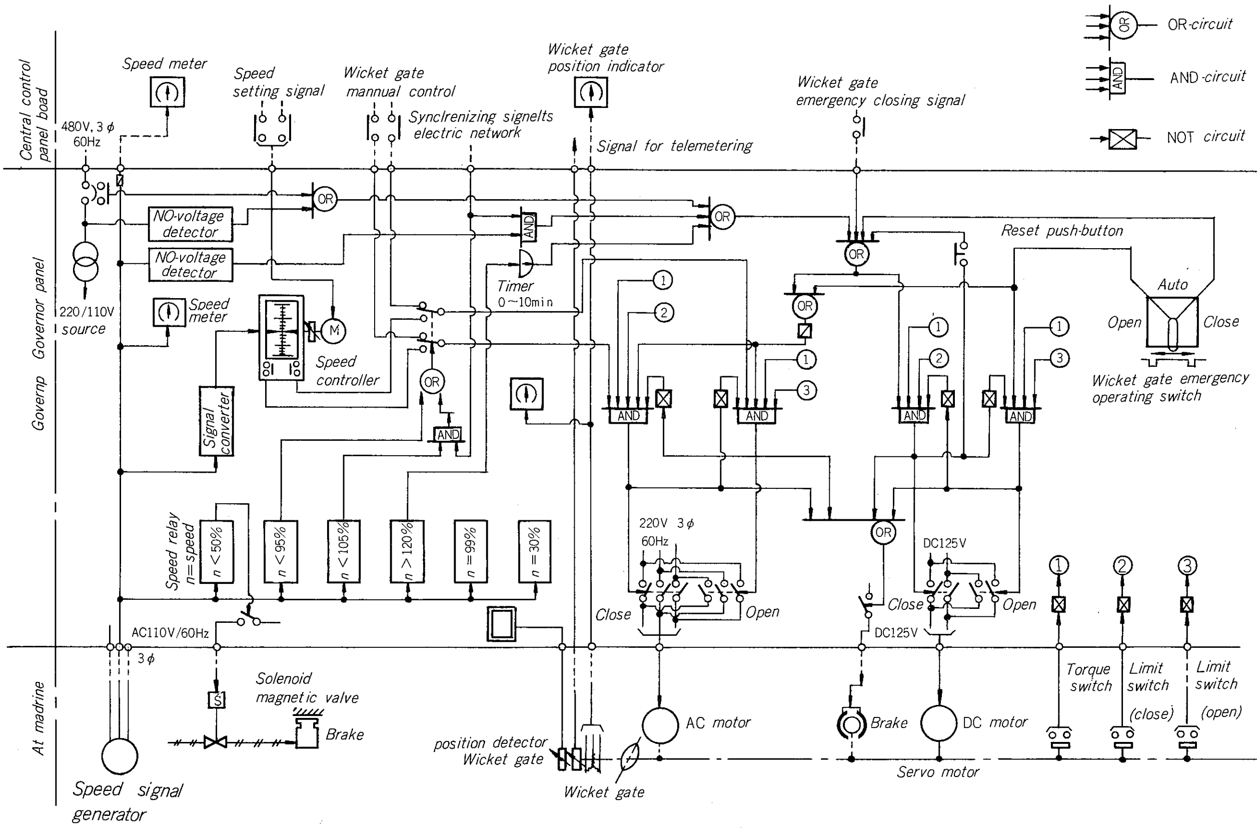

Fig. 13 Block diagram of control for electric motor operating governor

Table 3 Specifications of compact controller

Type of Equipment		Controller of electro current output type (PMK type) Controller of contact output type (PML type)
Input	Detected value (controlled)	DC 1~5 V
	Externally set value	DC 1~5 V or pulse input signal
	Auxiliary analog input	DC 1~5 V, 5 points
	Auxiliary binary input	4 points
	Opening position signal	10~100~10Ω 3-wire potentiometer or DC 1~5 V
Output	Control output signal	DC 4~20 mA or pulse output signal
	Auxiliary analog output signal	DC 1~5 V, 2 points
	Auxiliary binary output signal	8 points
Indication	Detected value, Set value	Plasma display, Accuacy 0.5%, Scale: 100 mm
	Operated amount	LED indication, Accuracy 2.5%, Scale: 60 mm

type switches circuits of thyristors or transistors can be used also in place of the magnetic contactors.

2. Automatic Voltage Regulator (AVR)

In many cases of higher than 2,000 kVA, a synchronous machine is used as a generator and the AVR function is also required in the same way as in the case of an ordinary hydraulic power plant. Thus, the standard AVR SSR-15 (or SSR-10) consisting of only one large-size printed circuit board equipped with all the required control function is used as the AVR.

In the case of a mini-hydro power unit rated at less than 2,000 kW, an asynchronous machine (induction generator) is used as long as the conditions permit.

The SSR-15 type (or SSR-10 type) AVR is using a digital counter as the voltage setting device (90R) in place of a sliding rheostat, thus eliminating a contacting failure in a case where a sliding contact rheostat is used.

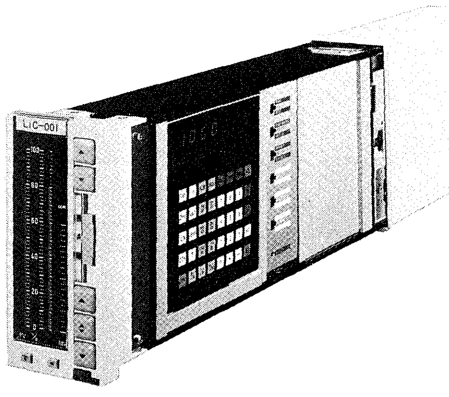

Fig. 14 Compact controller

3. Others

For controlling a hydraulic power plant, such controls as water level control of dam level APC, ALR, AQR and APFR are necessary in addition to the main control system such as a governor and the AVR. Sometimes, supervision on the operating ranges and/or operating of turbines, is required also. For these requirements, some general-purpose control devices with single function are used, or digital controller plural functioned such as control and supervision are required, with microprocessor is used. Whatever devices may be used, the control equipment and supervisory equipment for a small hydraulic power plant should be of simple system.

Table 3 shows the outline of the functions of the digital controller (COMPACT CONTROLLER type PMK and PML), and *Fig. 14* shows a photograph of its appearance.

VI. AFTERWORD

In this paper have been described the outline of the standard equipment related to a small hydraulic power plant to be provided by Fuji Electric Co., and the applications of such equipment. Fuji Electric Co. have standardized and made available all the types of turbines to be employed in all ranges of small hydraulic power plants. Since the description on each type of turbine is limited to its outline, it is suggested that, for the details of each individual type of turbine, each catalogue or explanation should be refered.

Hereafter, Fuji Electric Co. will continue and double its efforts to enhance the standardization and the functions of various kinds of equipment related to small hydraulic power plants, by accepting users' advice and opinions for further promoting developments of small hydraulic power plants and energy recovery.