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ENERGY SAVING TECHNIQUE FOR WATER AND SEWAGE WORKS

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I. FORWORD

Recently, the words "energy saving" have become a fixation and results have been obtained in various industrial fields.

Even in water and sewage works, substantial results have been obtained in energy saving by adding the newest electronics techniques to existing know-how.

The most part of the energy used to operate water and sewage plants is electric energy.

Conserving this energy and recovering and reusing the surplus energy are the cornerstone of realizing energy-saving. A typical example of energy saving is pump variable speed control technology. The newest techniques are introduced by emphasizing the recovery of the energy of the digestion gas generated in water and sewage plants and the water position energy recovery system.

II. ENERGY RECOVERY SYSTEM

2.1 SMALL TURBINE GENERATOR

2.1.1 Water power energy and its use

The surplus energy of water corresponds to the surplus pressure of the pipeline. The following equation gives the the possible electric output of a turbine generator.

$P = 9.8\, Q\, (H - \Delta H)\, \eta_T \cdot \eta_G$

P : Electric power (kW)

Q : Flow (m^3/s)

H : Static head (real head) (m)

ΔH : Loss head at pipeline, etc. (m)

η_T, η_G : Efficiency of turbine and generator

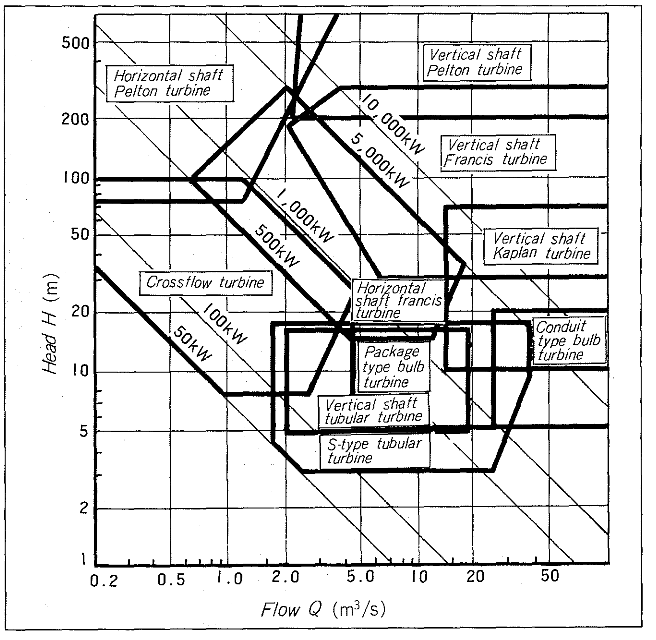
The flow Q and effective head $(H - \Delta H)$ determine the specifications of the turbine. In water and sewage works, a turbine which maintains high efficiency even when the flow and head change must be selected.

2.1.2 Turbine Types

Turbines having specifications suitable for water and sewage works are listed below. The Fuji Electric standard turbine types selection chart is shown in *Fig. 1*.

(a) Discharge side is open .... Cross flow turbine

Fig. 1 Fuji standard turbine type selection chart



(b) Discharge side is .... pressure pipe (1) Low head ... S-type turbine:
(2) High head... Horizontal shaft Francis turbine

The features of the small hydroelectric power generation turbines listed above are described below.

(1) Crossflow turbine

Construction is simple and efficiency is good at comparatively light loads.

Applicable when changes in the head are small even when the flow changes largely at heads of 100 m or less.

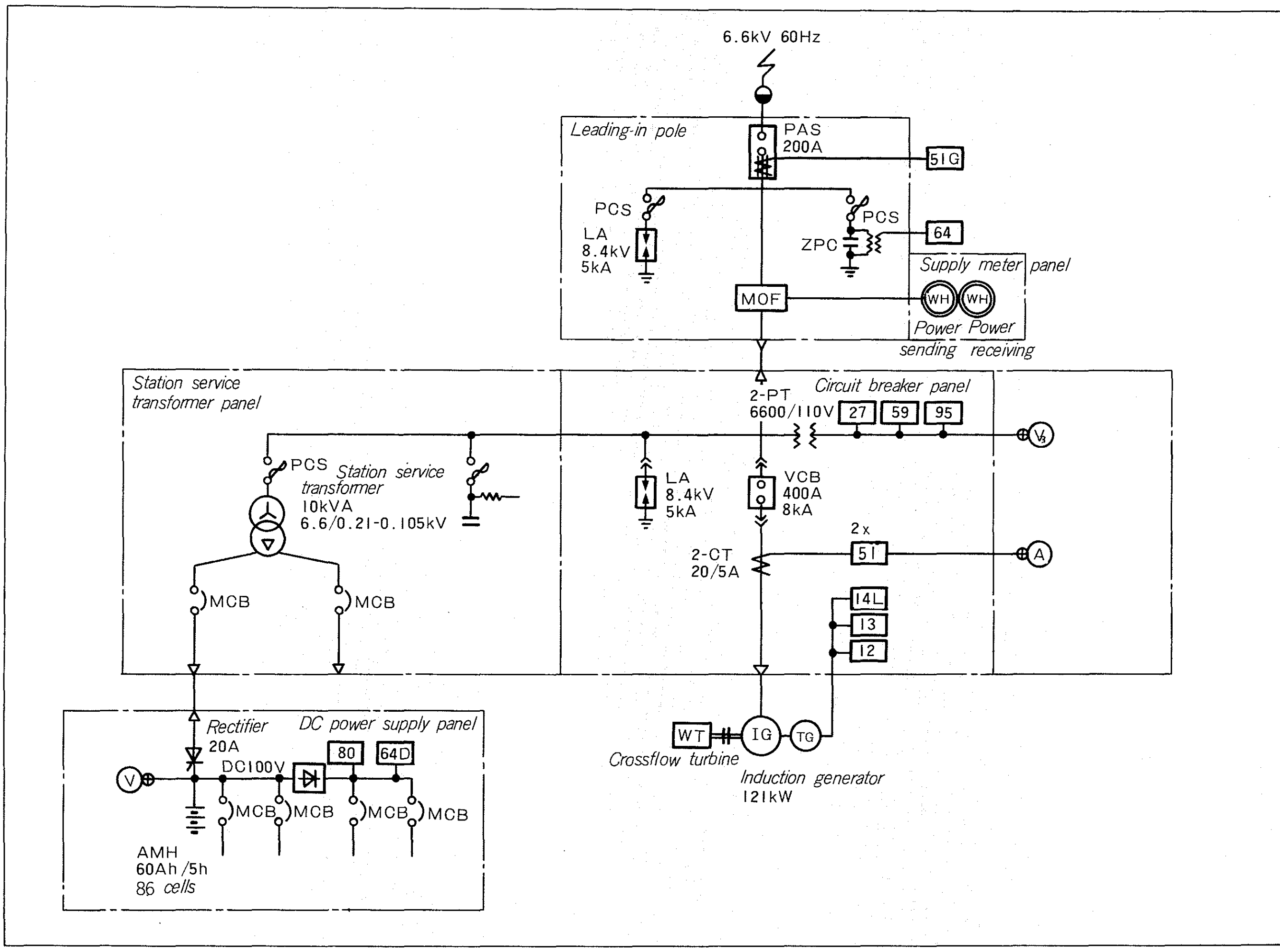
(2) S-tubular turbine

Both the guide vane and runner vane are movable and has excellent characteristics for flow and head changes. Applicable when the flow is larger and the head is smaller than that of the crossflow turbine.

(3) Horizontal shaft Francis turbine

Construction is simple and maintenance is easy. Most common turbine. Most widely used for hydroelectric power generation.

Fig. 2 Single line diagram using an induction generator



2.1.3 Generator

There are two kinds of generators: synchronous generator and induction generator. Because the system frequency and voltage are maintained at the required value, the output of small hydroelectric generators is almost never directly controlled. Since facilities of 2,000 kW or less, in particular, require such operation, construction costs are usually lowered by using an induction generator as far as the power system and other conditions allow.

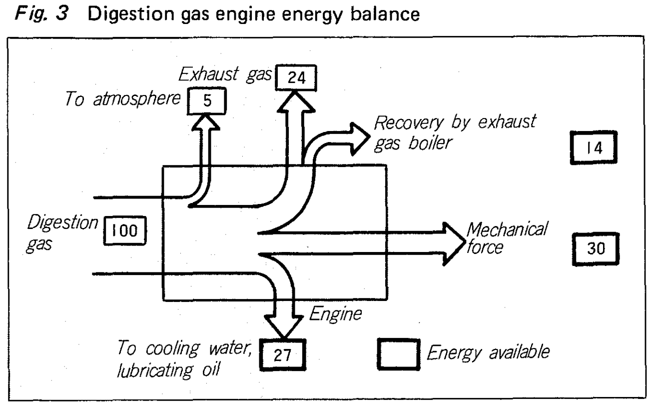
The single line connection diagram of a facility that uses an induction generator is shown in *Fig. 2*.

2.2 Sludge digestion gas generator

2.2.1 Digestion gas energy and its use.

From 60% to 70% of digestion gas is methane. Its calorific value is about 5,500 kcal/m^3. The amount of gas generated depends on various factors and also on the season. However, the sewage treatment plants in Japan generate gas equivalent to an calorific value per 1 m^3 of sewage of 240 kcal. Converted to electric power, this is equivalent to 0.28 kWh. This value is equivalent to the 0.2 to 0.3 kWh consumed per 1 m^3 of sewage. Digestion gas is used as heating fuel to keep the temperature of the sludge in the digestion tank at 30°C to 35°C. The energy balance when

Fig. 3 Digestion gas engine energy balance

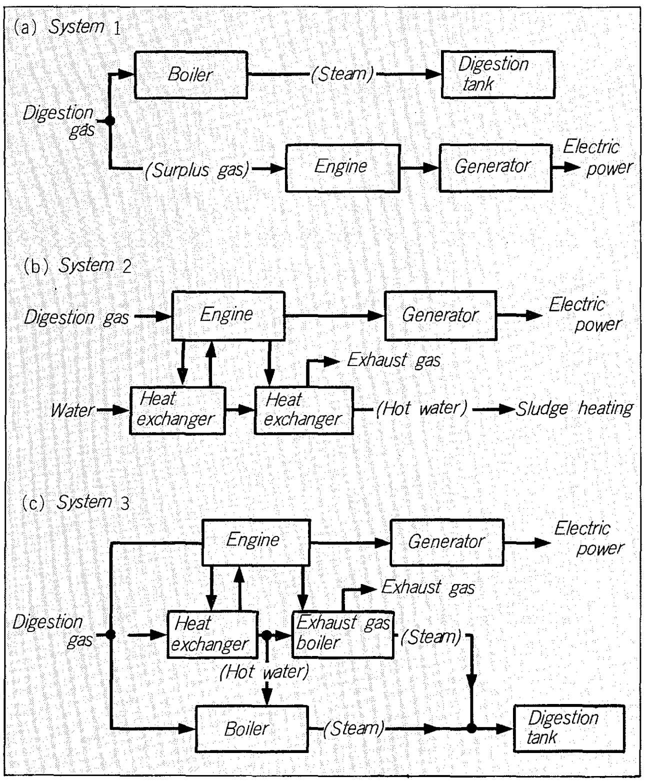


digestion gas is used by converting it to power with an engine is shown in *Fig. 3*. That is, a total of 70% can be used by generating electric power with this power and heating the digestion tank with the recovered surplus heat.

2.2.2 Digestion gas electric power generation system

Many systems are considered as total systems for digestion gas using a digestion gas electric power generating facility. Typical systems are shown in *Fig. 4*. System 1 of *Fig. 4* uses the surplus gas not used to heat the digestion

Fig. 4 Digestion gas use system



tank and power generation is voluntarily. For systems 2 and 3, since the sludge is heated with the recovered engine surplus heat, electricity is generated continuously and the load factor is determined by the calorific value needed for heating. Since the generator load factor can be arbitrarily set, parallel operation of the electric power generating facility and the commercial power line is indispensable at systems 2 and 3. Moreover, the capacity of an electric power generating facility operating single is usually determined by the voltage drop and the overload amount restraints at closing of a large capacity load, and is larger than the load capacity. However, if operated in parallel with the commercial power line, continuous operation at 100% load factor is possible, and is economically convenient even for system 1. The contract-power can be reduced by using a dual fuel type gas engine which can operate on heavy fuel without interruption even if the supply of digestion gas is stopped.

2.2.3 Policy for improving the total system efficiency

Development of gas electric generator waste heat recovery and improved efficiency technology is proceeding, but there is still a margin for improvment of sludge processing high efficiency technology.

Reducing the energy used in heating anaerobic digestion tank is effective in increasing the digestion gas used in electric power generation.

This can be achieved by condensing the sludge by filter condensation or centrifugal condenser. The energy needed for heating can be reduced to 1/3–1/5.

When a fairly large amount of heating energy is required in the winter in cold regions, recovery of the energy stored in the digestion sludge is also effective, and a system which permits an energy saving of about 20% (for heating amount of heat) is being developed.

Stable operation of the digestion tank is also important in increasing overall efficincy, and control for maintaining the best conditions without regard to load changes has been developed. This is different from the water quality analyzer widely used in conventional digestion state monitors and is a simple maintenance gas analyzer and a device which is digitally controlled with the gas generation amount as the index and performs stable operation control

2.3 Sewage treatment plant solar system

2.3.1 Solar heat energy and heat collection system

To use solar heat, first the solar radiation and the construction and heat collection efficiency of the collector used to collect it must be known. The solar radiation received at the earth's surface consists of direct solar radiation directly radiated from the sun and sky radiation scattered by the sky. The sum of these two radiations is called global solar radiation. (See *Fig. 5*.)

The solar radiation radiated on the horizontal surface of the earth is called the horizontal surface global radiation and is observed at the weather stations of each area. The solar radiation changes with the weather. Its approximate values are shown in *Table 1*. When designing a solar system, the solar radiation to an arbitrary heat collector mounting surface must be found with this horizontal surface data as the base. Fuji Electric has developed a computer program for this. The heat collector collects the solar radiation with a suitable absorber an passes the heat to the water flowing through the heat collector. When the temperature of the

Fig. 5 Solar radiation

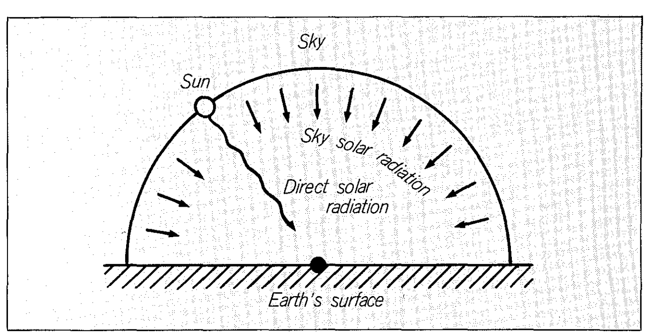
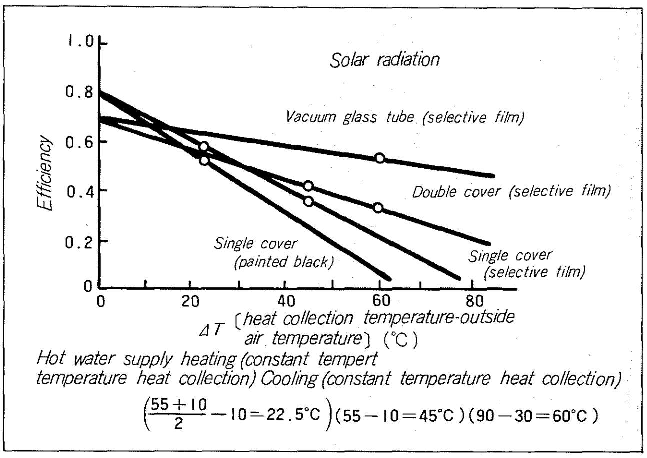


Table 1 Solar insolation

Units: kcal/m²h (860 kcal/h = 1 kW)

	Fair-clear	Fair-thin clouds	Cloudy	Rain
Direct solar radiation	700	400	0	0
Sky solar radiation	100	200	300	100
Global solar radiation	800	600	300	100

Fig. 6 Heat efficiency of various collectors



absorber rises, the amount of heat lost by conduction, convection, subradiation, and other self-dissipation becomes substantial. As a result, since the heat collection efficiency decreases as the temperature increases, a heat collector heat insulation construction is very important. A comparison of the heat collection efficiency by heat insulating construction is shown in *Fig. 6*.

2.3.2 Application to sludge heating

Digestion gas is used as a fuel to heat the sludge in a digestion tank. However, the amount of digestion gas and amount of heat generated differs with the treatment plant and also changes in a year. Depending on the treatment plant, there are periods when heat cannot be performed with only the amount of heat generated by the digestion gas and kerosene and heavy oil are used as supplementary fuels. This is where the use of solar heat in sludge heating is considered.

In trial calculation when the Fuji Electric vacuum glass tube type (with selective surface) heat collector was used, the unit heat amount for the conditions shown below is 1,100 ~ 1,400 kcal/m^2 . d. in the winter, 1,700 ~ 2,000 kcal/m^2 · d in the summer, and about 1,600 kcal/m^2 · d as the yearly average.

Heat collector installation conditions

Location; Tokyo, Direction; south, Angle; 20°

Atmospheric conditions: Conform to Tokyo standard weather data

Heat collector temperature conditions

Initial water temperature; 52.5°C,

Ultimate water temperature; 67°C

When the digestion gas use boiler efficiency is made 65%, from the annual average heat collection amount above, the effective heat collecting area of the heat collector to obtain the heating heat amount produced by 1 m^3 of digestion gas in one day is about 2.23 m^2

When using solar heat to heat sludge, combination with a digestion gas electric generation system is effective. The purpose of installing a solar system is not only to save the heavy oil used in heating and other supplementary fuel, but to also simplify operation of the electric power generation as a treatment plant. For example, the power consumption of the treatment plant is high in the summer, and since the contract power is determined by the maximum power consumption during this period. The contracted power is reduced by increasing the generated power by increasing the amount of surplus gas in the summer.

At the present time, most sludge heating systems are systems which blown steam into the digestion tank. However, for the digestion gas electric power generating system and solar system, heat recovery with hot water is very efficient. therefore, a hot water heating system which heats the sludge through a heat exchanger widely used in

Fig. 7 Fuji demand supervisory and control equipment

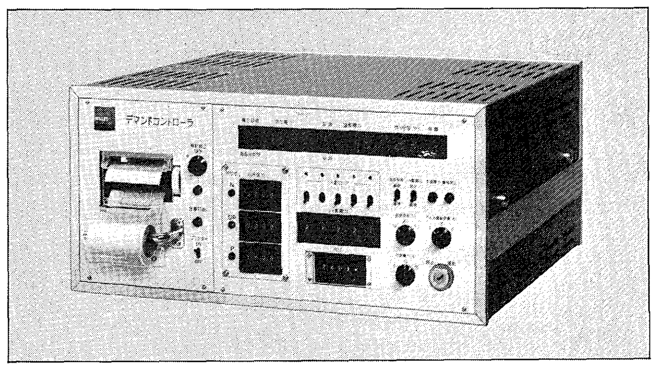


Fig. 8 Electronic instrumentation system FC series

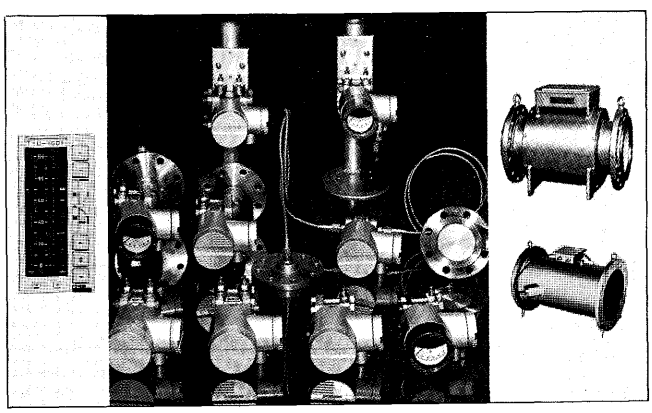
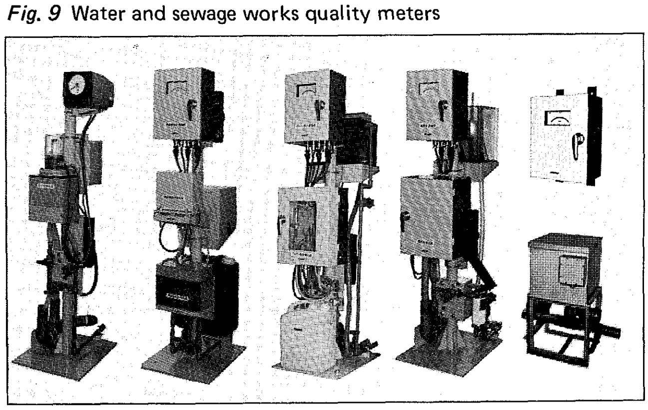


Fig. 9 Water and sewage works quality meters



Europe and America is desirable from the standpoint of energy-saving. However, there are many points which should be studied from the techniccal standpoints of maintenance management, plant basic planning, etc. and from the standpoint of cost.

III. ENERGY SAVING SYSTEM

Of the maintenance expenses in water and sewage works, about 40% is power cost, about 25% is personnel cost, and the remainder is chemical cost, repair cost. etc. Most of this power cost is electric power, and is expended by sanitary sewage pumps, feed and distribution pumps, blowers, etc. It is no exaggeration to say that in water and sewage works saving this electric power is the first step toward an energy saving system.

A Total Energy Saving system and operation example are introduced below as typical energy-saving system techniques.

3.1 Total Energy Saving system

To operate water and sewage works, water treatment, mechanical, electrical, measurement, and data processing total technology is necessary. Accurately grasping the plant information is step in Total Energy Saving and there are high performance, high accuracy power supervisory and control equipment, electronic instrumentation, water quality meter, etc.

Power supervisory and control equipment perform detailed power monitoring and unnecessary power elimination and smoothing are possible. Moreover, electronic instrumentation and water quality meters accurately grasp the water level, flow, pressure, water temeprature, turbidity, residual chroline, and other plant information and permit optimum control.

However, these only is insufficient, and telemeter and telecontrol equipment which transmit the positively grasped data accurate and quickly and microcontrollers for detailed distributed control have created the need for accurate processing of the information collected centrally by computer.

By designing such a Total Energy Saving system, energy saving in dosing control, activated sludge control, water distribution control, and distribution basin control has been attained effectively.

IV CONCLUSION

Part of the energy recovery system and energy saving system in water and sewage works has been introduced above. In water and sewage works enterprises, the amount of energy handled increases with the scale of the enterprise. Therefore, energy saving is a large theme in water and sewage works in any age. In the future, the demands of the age should be met and new energy saving technology developed based on the techniques described in this paper.