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CONSTITUTION OF INDUSTRIAL STEAM POWER PLANTS

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I. PREFACE

In the most modern commercial steam power stations in Japan, condensation turbines having steam conditions of 169 ata, 566°C and output per unit of 300 Mw have been adopted. The rise of steam conditions and output per unit are important in lowering the station cost, however, in the industrial plant, if it is planned in the type supplying process steam, in spite of a much lower output per unit and lower steam conditions, it will be possible to generate cheaper electric power than the commercial steam power stations. In the case of using no process steam under the proper conditions there are a number of cases where industrial power plants are profitable.

In commercial power stations the types are practically defined by their sole purpose. On the other hand, in industrial steam plants there are many types of electric power equipment since the energy circumstances of each industry vary.

Fuji Electric has constructed many industrial steam turbine plants in technical cooperation with Siemens-Schukertwerke Company of Germany. During this time we have encountered many types of plants established according to the characteristics of the particular enterprise that constructed it.

In this report we will describe various plant types and the considerations that we have encountered with them.

II. ESTABLISHED CONDITIONS OF INDUSTRIAL STEAM POWER PLANTS

In industrial power plants in addition to a steam turbine, a gas turbine, a free piston gas turbine, a diesel engine, etc., have been employed. However, in most power plants steam turbines have been adopted except in the case of a much lower output where diesel engines have been used.

The established conditions of industrial steam power plants are as follows:

1) When process steam is made use of in works
2) When thermal cost is cheap
 a) the utilization of remaining heat
 b) the utilization of combustible waste material
 c) steam power plants for coal mines.

Especially in the case of 1) above, the steam turbine is most suitable for industrial power plants. Steam is very convenient as a source of heat because temperature control is easy and the rate of reserve much thermal energy. Therefore, steam has been used frequently in industrial processes that require heat. It is not too much to say that process steam supply power plant adopted in such a case is the representation of industrial electric power plants. In the case of 2) above, the power generation of the utilization of remaining heat had often been affected but recently this has been gradually diminished by the improvement of the main productive process so that it has become difficult to capture enough heat to generate electric power. At present utilization of combustible waste material is accomplished in many factories, for example, utilizing blast furnace gas in iron works, thermal recovery done by the black solution boiler in pulp manufacturing, etc.

In a coal mine, as a link in the chain of rationalization, it is accomplished by using coal of a poor quality for power generation. The electric power demand of a coal mine itself is not so great, so the generated power must be sold to an electric company or used in related industries. Regarding this point, the steam power plant for a coal mine is somewhat different from other industrial power plants. *Table 1* shows the number and types of industrial power plants in Japan as of March 31, 1963. According to type the process steam supply power plant has been generally constructed and thus occupies the greatest number of establishments. Of the others, the steam power plants utilizing the exhaust gas in iron works are fairly numerous with a considerably high output.

III. BASIC TYPES OF STEAM TURBINES

1. Backpressure Turbine and Bleader Backpressure Turbine

Backpressure turbines and bleeder backpressure turbines, utilizing all of the steam that generate electric power in the turbine as process steam and

Table 1 **Number and kinds of industrial steam plants (as of March, 1963)**

Unit : kw

Item	Industrial classification	Condensation type		Backpressure type		Bleeder type		Bleeder-back-pressure type		Total	
		Number	Output	Number	Output	Number	Output	Number	Output	Number	Output
Process steam supply power plant	Chemical	5	44,700	38	168,850	21	146,520	16	123,250	80	483,320
	Chemical fertilizer			3	14,600	9	55,000			12	69,600
	Chemical fiber	4	32,156	18	72,740	22	104,900	8	33,150	52	242,946
	Natural fiber	3	5500	2	8000	6	14,400			11	27,900
	Paper & pulp			36	158,300	22	58,100	25	153,550	83	369,950
	Food	3	7100	20	44,180					23	51,280
Remaining heat utilization power plant	Mining & refining	6	11,540	1	5300					7	16,840
	Ceramic industry	60	378,970			5	4750			65	383,720
Exhaust gas utilization power plant	Iron & steel	41	605,400	7	65,190	9	144,610			57	815,200
Power plant for coal mine & other power plants	Coal	26	182,200	1	3000					27	185,200
	Machinery										
	Communication	2	135,000							2	135,000
	Water service	4	6960							4	6960
	Total	154	1,409,526	126	540,160	94	528,280	49	309,950	423	2,787,916

having no condenser radiation unlike a condensation turbine, have a high thermal efficiency even under comparatively low pressure and temperature. Therefore, they can oppose the most modern steam power station sufficiently. The electric power generated by backpressure and bleeder backpressure turbines is determined by the required quantity for process steam and there is no degree of freedom between electric power and the quantity of steam. Generally many generators are put in parallel operation with an external electric system and the power variation produced by the variation of the quantity of steam depends upon the external electric system in many cases, and in this instance thermal efficiency is highest. When parallel operation is impossible, the umbalance of electric power and the quantity of steam are controlled by supplying a portion of steam quantity from the by-pass or releasing exhaust steam in the air. In this case, however, thermal efficiency is lowered and as we will discuss in the next section, the bleeder condensation turbine would occupy a favorable position.

2. Bleeder Condensation Turbine

In the bleeder condensation turbine a portion of the steam is condensed so that thermal efficiency is lower than that of the backpressure turbine because of the radiation of the condenser. However, there are many degrees of freedom between the electric power and the required quantity for process steam so that constant electric power can be obtained by controlling the comparatively slight condensing steam without relation to the variation of process steam. Since the bleeder condensation turbine has less condensing steam compared withthe general condensation turbine, the size of the condenser is fairly small and the quantity of cooling water is small. When an ample supply of cooling water is not available the cooling tower provides for the circulation of the water. In special cases it is necessary to discuss provisions for the air-cooled condenser.

3. Condensation Turbine

When process steam is unnecessary the condensation turbine is used. As far as general fuel is concerned it is difficult to obtain a cheaper station cost per kilowatt-hour than buying electric power. Unless the fuel cost is cheaper it does not pay. However, steam conditions can be selected freely because there is no restriction on process steam.

IV. PROCESS STEAM SUPPLY POWER PLANTS

1. Selection of Basic Types

As illustrated by *Table 1,* there are many industrial process steam supply power plants. When such a plant is contemplated, first, the steam pressure and the required quantity for process steam are determined and then the type of steam turbine is determined by the relationship between these and the electric power demand. When the required quantity for process steam is fairly great and the variation of electric power depends upon the external electric power system, a backpressure or bleeder backpressure turbine is used. When the electric power is too great compared with the quantity of steam or when it is necessary to obtain a constant electric output, a bleeder condensation turbine is employed. The backpressure turbine or the bleeder backpressure turbine provide the cheapest station cost followed by the bleeder condensation turbine. In the case of the bleeder condensation turbine, thermal efficiency and construction costs vary greatly according to the condensing steam quantity and this in turn will influence the station cost. Thus the bleeder condensation turbine must be planned very carefully.

2. Improvement of Efficiency and Reduction of Construction Expenses

The improvement of thermal efficiency and the reduction of construction expenses are necessary in order to provide the cheapest possible station cost. However, these do not always coincide. In the backpressure turbine, the difference between the enthalpy of process steam and the enthalpy of boiler outlet steam becomes electric power. Therefore, if pressure and temperature, the required quantity of process steam, and the required electric power are determined then the turbine inlet steam conditions will almost be determined. When the process steam of point A (10 ata, 255°C) in *Fig. 1* is necessary, steam expansion line a is determined by the turbine internal efficiency and the turbine inlet steam conditions must be on this line. In the case of generating 100 kw electric power per steam 1 t/h, the enthalpy difference between turbine inlet steam and

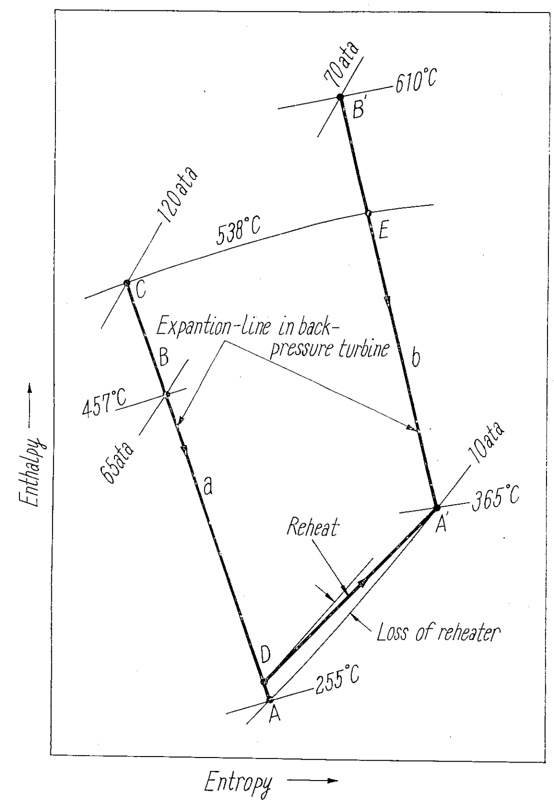


Fig. 1 Determination of inlet steam condition of backpressure turbine

outlet steam must be 86 kcal/kg. Assuming that the mechanical efficiency and generator efficiency is 1 so that, in practice, the enthalpy difference is greater than this; therefore, the turbine inlet steam conditions are determined to be point B (about 65 ata, 457°C). As the required electric power increases point B moves upward. Consequently, with the rise in temperature, Austenite must be used in construction of the boiler and this abruptly increases expenses and thus it becomes disadvantageous. Therefore, generally temperature is limited within 538°C. The pressure of the point where the temperature is 538°C on line a in *Fig. 1* is about 120 ata (point C).

The higher the pressure and temperature of process steam, the lower is the energy to be electric power so that the significance of the industrial steam power plant is lessened. In order to prevent this, it is necessary to raise the turbine inlet steam conditions as high as possible within the above mentioned limit. When process steam pressure is low and the temperature is high, the limit of steam temperature appears at a fairly low pressure. For example, when the steam of point A' (10 ata, 365°C) in *Fig. 1* is necessary and it is desirable to generate about 130 kw electric power per steam 1 t/h, point B' becomes about 70 ata, 610°C so that, in practice, it is difficult to realize this in temperature.

In such a case, if the inlet steam conditions are selected at 120 ata, 538°C. (point C) and steam is reheated to point A after expanding from C to D with the production of work in the backpressure turbine, it will be possible to satisfy the required conditions. In this case, the thermal efficiency is higher than the inlet steam conditions are selected at point E and the required output is supplied by the condensation turbine.

In boilers and turbines the types suited to high pressure and temperature must be selected. The boiler needed for such high pressure and temperature is a forced-circulation boiler and recently many of these of more than 70 kg/cm^2 have been constructed at numerous steam plants.

In turbines also, in order to apply high pressure and temperature many methods have been considered, for example, double casing or pot type casing without flanges in the high pressure part has been adopted in order to endure high pressure. The higher the pressure the more the casing of the turbine thickens and the thermal stress, depending on the variation of load, has been an important subject. *Fig. 2* and *Fig. 3* show the construction of the pot type turbine.

In order to increase the cycle efficiency steam conditions must be raised and at the same time the efficiency of the turbine itself must also be increased. In backpressure turbine plants, even though turbine efficiency is increased, cycle efficiency is not particularly increased, but it is very useful for the reduction of station service power and construction costs because it is possible to lower steam pressure. The

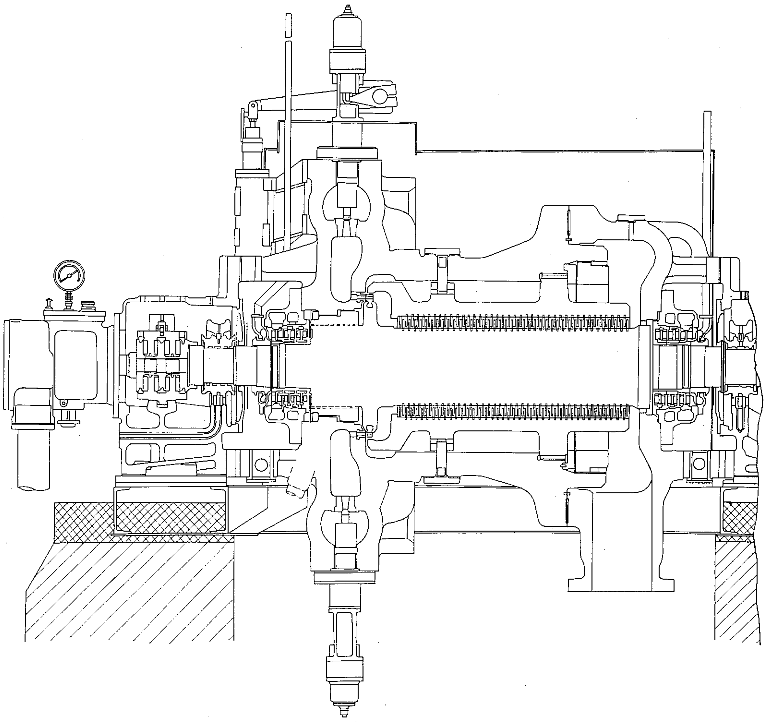


Fig. 2 Section of pot type turbine

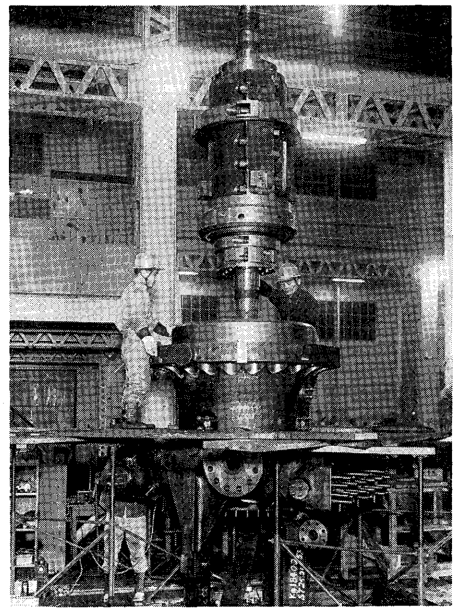


Fig. 3 Hang-up of guide vane holder of pot type turbine

effective method of increasing turbine efficiency is to increase the number of revolutions, for example, 3000 rpm backpressure turbine compared with 8000 rpm backpressure turbine with the same conditions (inlet steam 50 kg/cm², 480°C, exhaust pressure 10 kg/cm², output 3000 kw) and making the difference in turbine efficiency about 10%. Therefore, the high speed turbine is far more profitable than the direct coupling turbine even though the loss of reduction gear (about 2%) is taken into consideration. In addition, in the high speed turbine the number of stages of the blade is reduced and the diameter of the rotor is shortened, so that the weight of the turbine is lessened considerably and it is possible to reduce 20% of the weight including the gear weight.

Generally, insofar as the output is less than the required electric power of a factory, we can say that it is profitable to utilize high pressure and high temperature and plan the increase of power in the backpressure turbine plant. However, when the electric power requirement is not as great it is not always profitable to utilize high pressure and temperature. *Table 2* shows the calculation table of the station cost per kilowatthour in the bleeder backpressure turbine, bleeder 17 kg/cm²g, 5 t/h, exhaust 7 kg/cm², 60 t/h. According to this Table, the generator output is far greater using the high pressure method but the station cost is increased. Therefore, the method we adopt is decided by the demand of electric power and the cost of buying electric power.

3. Kinds of Process Steam Supply Power Plants

Generally, in paper-pulp plants, the backpressure or bleeder backpressure turbine has been employed. In the pulp manufacturing process, steam is used for digesting the materials such as wood, straw, rags, etc. The digesting pressure and steam consumption differ somewhat according to manufacturing systems but almost 2.5 tons per 1 ton of plup is used at approximately 7 kg/cm² pressure. In addition, in the paper making process steam is used for heating drying rolls. The pressure is 1～1.4 kg/cm² degree and almost 2.5 tons steam per 1 ton paper is used although the usage differs somewhat according to the kinds of paper.

Considering the daily output of the paper-pulp plant at approximately 300 tons, the rate as mentioned above, the digesting and paper making have a steam usage of nearly 30 t/h respectively so that the inlet pressure condition 50 kg/cm² bleeder back pressure turbine is possible to generate 6000 kw electric power. In the relation of paper manufacturing the inlet pressure of almost 50 kg/cm² has been generally adopted although recently high pressure of more than 100 kg/cm² has been adopted in many cases. In the industrial electric power plants at the paper factory, the black solution boiler is used for collecting sodium from black solution of plup manufacturing. In this case a portion of the required steam for the turbine is supplied by this boiler. Also in the sugar plants the backpressure turbines have been generally adopted. The beet sugar refineries are operated for three months of the year due to the availability of materials, and for this reason the burden of capital expenses per generated electric

Table 2 **Comparison of bleeder backpressure turbines with different steam conditions**

Item	Plan adopting low pressure	Plan adopting high pressure	Note
Specifications			
Steam pressure (kg/cm^2)	70	110	
Steam temperature (°C)	440	510	
Quantity of fresh steam (t/h)	87.4	89.8	
Generator output (kw)	9300	12,200	
Quantity of process steam			
at 17kg/cm^2-g (t/h)	5	5	
at 7kg/cm^2-g (t/h)	60	60	
(1) Rate of operation for a year (%)	85	85	
Electric energy for a year			
(2) At site electric power demand (Mw/year)	69,250	90,850	
(3) Power for station service aux. motors (%)	6.1	8.3	
(4) Sending end electric energy (Mw/year)	65,030	82,850	
(5) Process steam quantity per year (t/year)	484,000	484,000	
(6) Heat consumption per year (Mcal/year)	432,000,000	455,800,000	
(7) Total construction expenses (10^3 yen)	420,000	565,000	
(8) Annual running expenses (10^3 yen/year)	409,890	454,080	
Capital expenses (〃)	75,600	101,700	(7)×18%
Personnel expenses (〃)	12,000	12,000	
Mending price etc. (〃)	4200	5650	(7)×1%
Price of fuel (〃)	302,400	319,000	(6)×0.7 yen/Mcal
Price for feedwater (〃)	15,600	15,730	30 yen/t
(9) Cost of process steam (〃)	329,000	329,000	(5)×680 yen/t
(10) Net expenses per year (〃)	80,890	125,080	(8)-(9)
(11) Station costs (yen/kwh)	1.244	1.510	(10)÷(4)

power is fairly large compared with general installations. Nevertheless, industrial electric power plants have been constructed because it is felt that the high thermal efficiency of the turbine offsets the burden of capital expenses. Practically speaking, if the temporary electric power demands, as those mentioned above, are supplied by buying electric power it becomes relatively disadvantageous due to the power rates, therefore, the industrial power plants are sufficiently profitable. Of course it is necessary to restrain construction expenses for the power installations according to possible limits in consideration of the low operation degree. *Fig. 4* illustrates the backpressure turbine for the sugar plant.

In the petroleum plants a great deal of steam is used for distilling several different ingredients from crude petroleum. Further, the various processes which require steam are quite numerous, for example, colking for obtaining light oil and coke from heavy oil; viscosity-braking for changing high viscosity oil to low viscosity, etc. In the process steam supply power installations at the petroleum factory the particularly different character of general installations is not required since petroleum plants have all become of the outdoor type due to the harmful gases and also economical considerations. In view of this the outdoor type turbine has been adopted.

Fig. 5 illustrates the appearance of the industrial electric power plant for the Chiba oil refinery, Idemitsu Kosan Co., Ltd. The reduction of construction costs and shortening of the construction period were attained by utilizing the outdoor type. *Fig. 6* illustrates the heat flow diagram of this plant.

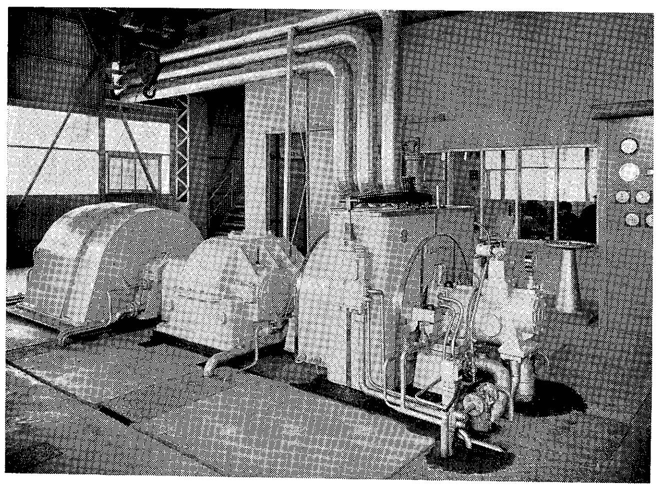


Fig. 4 1500 kw backpressure turbine for sugar plant

In addition, in the various fields of the chemical industry the process steam supply power plants have been popularly utilized. In the backpressure turbine and bleeder backpressure turbine there is a high efficiency of power generation. The efficiency in the rather small plants is more than 80% so that it becomes possible to generate electric power more

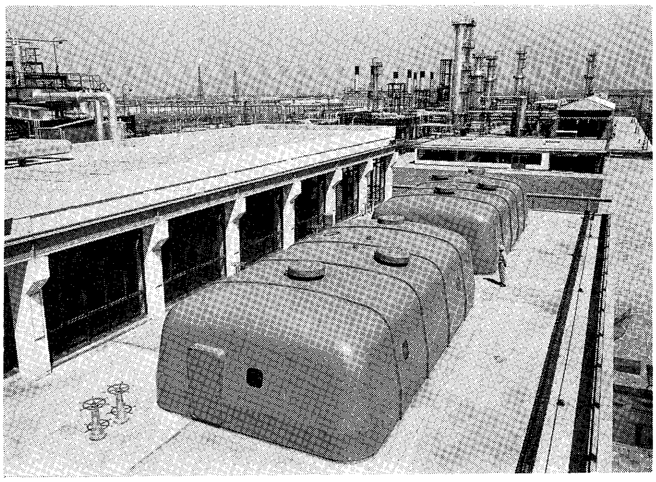


Fig. 5 Outdoor turbines in petroleum plant

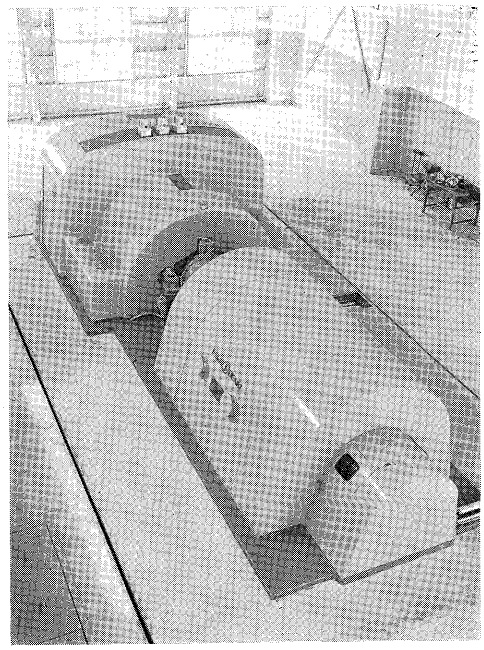


Fig. 7 10,800 kw backpressure turbine for petrochemical plant

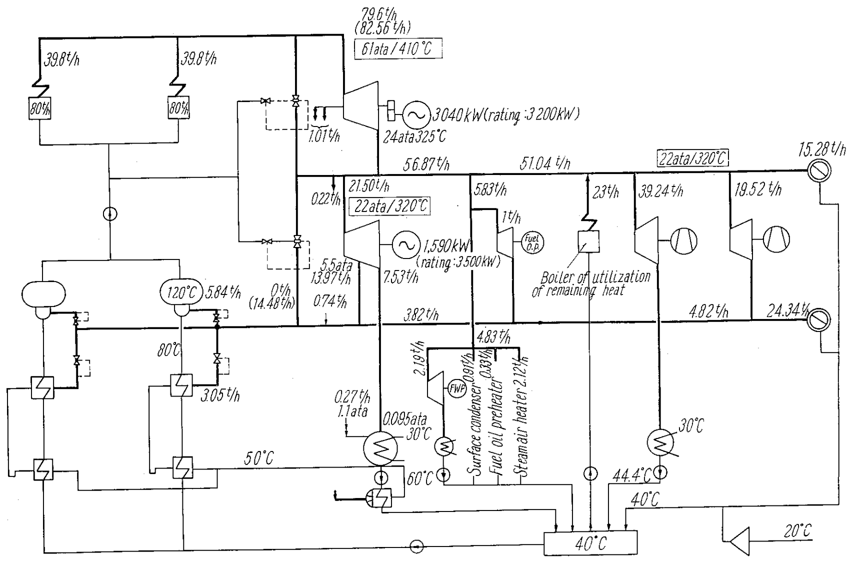


Fig. 6 Heat flow diagram of steam power plant in Fig. 5

than twice as efficient as the commercial steam power stations. If the steam conditions of the turbine inlet are increased and the capacity is also increased, the returns through the balance of buying electric power increase remarkably since the station costs are very cheap. Recently, in view of this, the steam conditions of the industrial turbines have increased gradually.

Fig. 7 illustrates the backpressure turbine for the Goi Factory, Chisso Petro-chemical Corp. Here the 135 kg/cm^2, 500°C turbine inlet conditions have been adopted in the combination of the Benson boiler and the pot type turbine. *Fig. 8* diagrams the heat flow of this plant.

V. STEAM POWER PLANTS UTILIZATION OF EXHAUST GAS

1. Energy Balance in Iron Works

The electric power generation of utilization of exhaust gas has been popularly carried out in iron works. In the process steam supply power plants the type is decided by the steam demand, while in iron works the type is decided by the relation of the energy supply and demand against it. This relation is very different compared to other industries.

It is the blast furnace and the coke oven which produce the greatest surplus energy in iron works. This energy comes from the blast furnace as blast furnace gas and from the coke oven as coke oven gas and the fact that these gases are used effectively greatly influences the reduction of pig iron making costs. The blast furnace gas has the 900～700 kcal/Nm^3 calorific value and the combustible ingredient is carbon monoxide (CO) chiefly. As the coke ratio has decreased with the improvement of the pig iron making methods, the calorific value in the blast furnace has gradually decreased. However, the possession energy in the blast furnace is very great, for example, in the daily output of a 2000 ton blast furnace the gas generated is 4,800,000 Nm^3 per day and it becomes 3,840,000 Mcal as the calorific value is 800 kcal/Nm^3 and this is proportioned to 186 Mw.

The coke oven gas has a calorific of 4800 kcal/Nm^3 and it is fairly high compared with the blast furnace gas. As in the coke oven for 2000 ton blast furnace the coke oven gas is 630,000 Nm^3 per day, the calorific value is 3,000,000 Mcal/day (145 Mw) and it yields surplus energy nearly equal to that of the blast furnace.

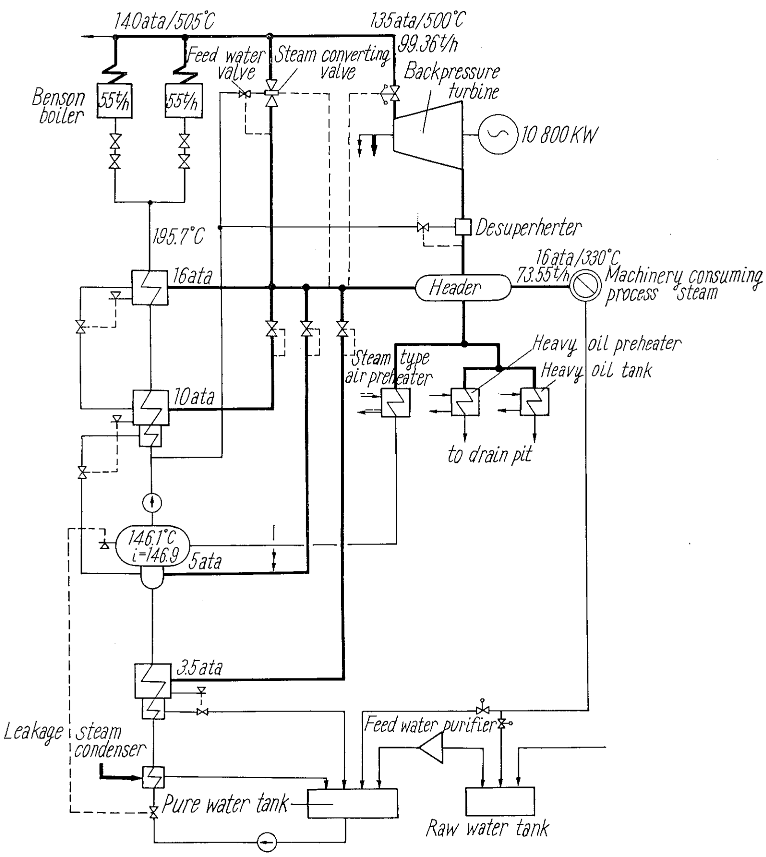


Fig. 8 Heat flow diagram of backpressure turbine in Fig. 7

The following are the energy demands which are the counterplans for recovering surplus energy as fuel as mentioned above:

As fuel
(1) Hot stove (heating the air to blast furnace) (blast furnace gas)
(2) Coke oven (blast furnace and coke oven gas)
(3) Sintering furnace (coke oven gas)
(4) The other heating furnaces

As power
(5) Power for rolling and the other processes
(6) Blast furnace blower as steam

As steam
(7) Steam for heating

Among these, (2) and (3) become the object of recovery by the steam turbine. It is profitable for (5) to be supplied as electric power. Since (6) has a fluctuating number of revolutions frequently, it is better to be driven by the steam turbine directly. Therefore, the industrial electric power installations in iron works become synthesis power plants which have three objects: electric power, power and steam.

Since 5% of the blast furnace gas is released into the air and 50% is consumed for heating, in a power plant it is possible to utilize 45%. So the calorific value is 1,730,000 Mcal/day and if this were changed in 30% efficiency about 25,000 kw would be utilized for electric power and power. About 70% of the cock oven gas is able to be utilized in the power plant and the capacity by this gas becomes 30,000 kw. Therefore, a total of approximately 55,000 kw is able to be utilized for electric power and power. Practically, the coke oven gas is able to be used effectively for materials in the chemical industry so that generally it is not all utilized in the power plant.

2. Constructon of Power Plant for Iron Works

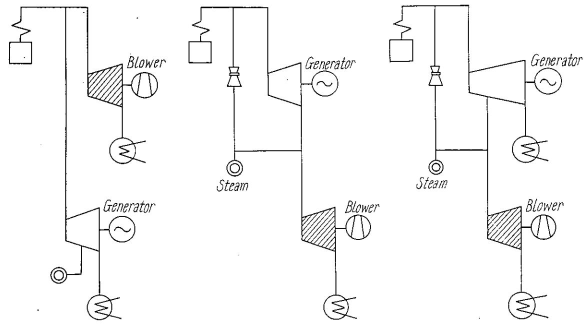
The blast furnace blower is most important among the power demands in iron works. It be driven at anytime and the highest level of reliability is required, therefore, it is desirable that it be driven by a different power source and, since it is necessary for its speed to be changed, the blower is generally driven by a steam turbine. A 2000 ton blast furnace usually has about a 8000 kw blower. Let us assume that 70% of the available power of 55,000 kw mentioned above is used for the power plant and the blower uses 8000 kw, and the remaining 30,000 kw is used as electric power. In the case of the practical construction of a power plant it is well to install two 15,000 kW generator turbines taking into consideration their periodic inspection, and also to install an additional blower turbine as a spare in view of its importance.

The primary condition required of a power plant is reliable operation especially of the blower turbine. Since the fluctuation of the speed and load with regard to a blower turbine is rather great and since it is quite dangerous to set up the steam conditions too high, technical problems are encountered if the inlet pressure is selected higher than 90 kg/cm². The lower the inlet pressure and temperature are, the more safely the operation can be carried out.

Secondly, high thermal efficiency is required. It is important for the cost price of the cast iron to estimate the unit price of gas as fuel. As present, it is generally considered that the unit price of gas per calorific value is equal to other fuels, for example, heavy oil. Therefore, the thermal efficiency must be high enough to be economical in case that only heavy oil is used.

To increase the thermal efficiency it is necessary to set up high steam conditions, however, it is immediately obvious that this is not in conformity with the primary condition mentioned above and thus a problem is created.

For the power plant that is composed of the blower turbine and the generator turbine, the systems listed in *Fig. 9* are intended. We have generally adopted the parallel system, two turbines being self-supported, and this system is easily operated. As the steam



(a) Parallel system (b) Topturbine system (c) Combined system

Fig. 9 Arrangement of multi-purpose power plant for blast furnace

condition is restricted from the turbine it cannot be so high and the thermal efficiency is low. Since the quantity of steam per one turbine is small, the in-stage leakage loss increases and the turbine efficiency decreases. In order to increase the turbine efficiency the top turbine system is intended. In this case, since the steam condition of a generator turbine is loosely restricted it can be set high. Yet this system has a weak point in that the output of a generator turbine is greatly varied by the output of a blower turbine and this is not general. To correct this weakness we make a generator turbine a condensation turbine with a bleeder which drives a blower turbine. This is called the combined system and in this system the output of a generator and a blower can be independent of each other.

3. Comparison of Each System

Since the top turbine system cannot be adopted generally, let us compare the parallel system with the combined system. Let us assume that each system has two 15,000 kw generator turbines, one 8000 kw blower turbine, and an additional 8000 kw one as a spare, and that the process steam is 30 kg/cm^2, 40 t/h.

The first plan is the combined system. In this case, the steam conditions can be chosen rather freely and in order to make the best one of such a strong point of this system it is desirable to select high steam conditions and we assume that it is 120 kg/cm^2, 535°C. The inlet pressure of the blower turbine is set at 30 kg/cm^2 considering the process steam.

The second plan is the parallel system in which the steam condition is 90 kg/cm^2, 510°C increasing the thermal efficiency although decreasing the safety slightly.

The third plan is the parallel system in which the steam condition is 60 kg/cm^2, 480°C increasing the safety. *Fig. 10* illustrates this plan.

Table 3 compares the three plans. In the second plan, it is remarkable that the blower turbine efficiency is very low, and that the efficiency of a condensation turbine which has comparatively little power is remarkably decreased by increasing the steam condition at turbine inlet. In the first plan, the steam condition is high and therefore the cycle efficiency is of course high and the rather high turbine efficiency is obtained too.

These are the strong points of the combined system.

Particularly a blower turbine gives high efficiency. Its profits depend on the low inlet pressure of the turbine.

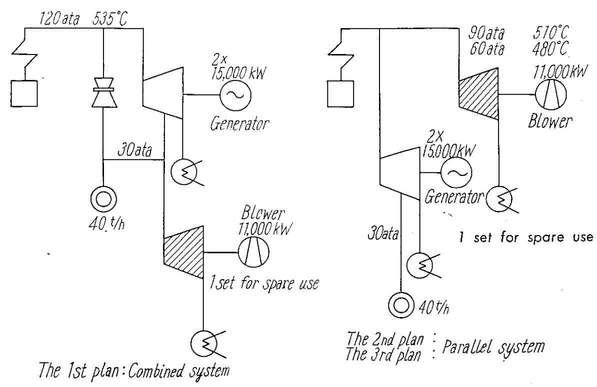


Fig. 10 Tentative plan of power plant for 2000 t blast furnace

Table 3 **Comparsion of three plans of power plants for 2000 t blast furnace**

Item	The 1st plan	The 2nd plan	The 3rd plan
	Combined system	Parallel system (High pressure)	Parallel system (Low pressure)
Inlet steam condition	120 ata 535°C	90 ata 510°C	60 ata 480°C
Inlet pressure of blower turbine (ata)	30	90	60
Generator turbine outlet (kw)	2×15,000	2×15,000	2×15,000
Blower turbine output (kw)	8000	8000	8000
Process steam quantity (t/h)	40	40	40
Generator turbine efficiency (%)	74	75	77
Blower turbine efficiency (%)	78	69	73
Thermal efficiency of plant (no process steam included) (%)	31.4	29.6	27.6
Station cost (yen/kwh)	2.995	3.145	3.260

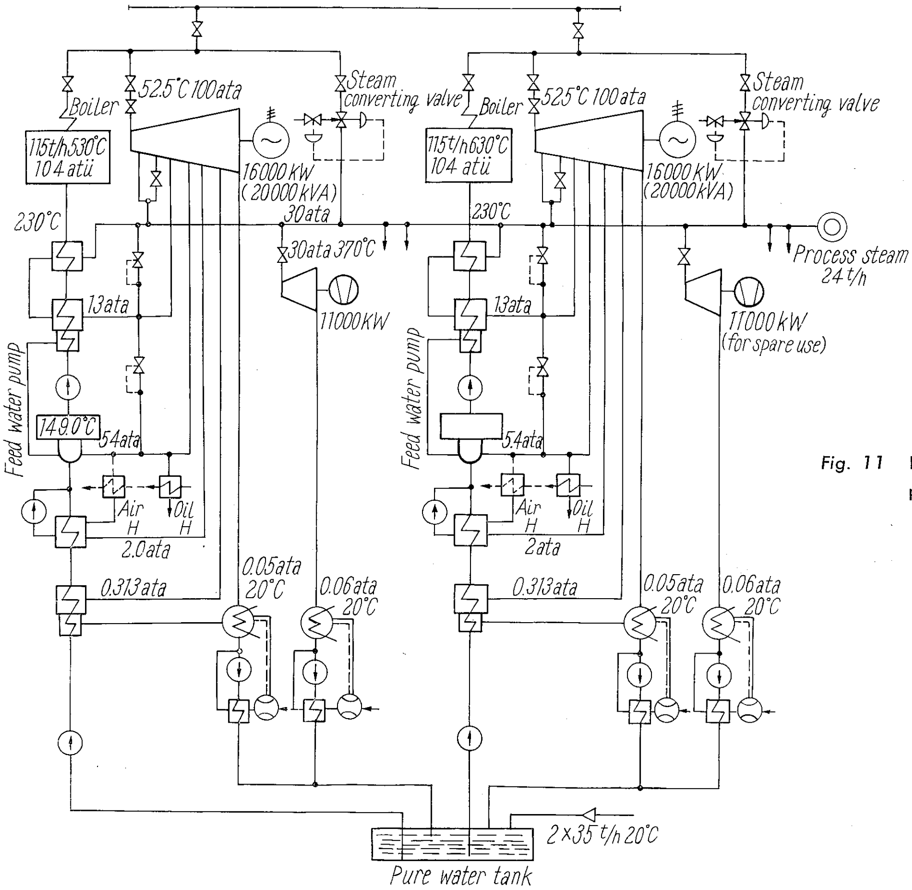


Fig. 11 Example of multi-purpose power plant for blast furnace

The first plan shows the highest efficiency if the process steam is not included.

We calculated the station cost on the basis of the following: assuming that the fixed price is the depreciation amount (4.5%), the rate of interest (8%), the tax (0.5%) and the mending price (1%) of the total construction expenses; and that a load factor of generating is 100%, a load factor of blowing is 67%, a load factor of steam is 50%, the rate of operation is 90%; and that a unit price of fuel is 0.75 yen/Mcal., a unit price of feed water is 20 yen/t, and a unit price of steam is 900 yen/t.

The first plan proved most profitable.

Fig. 11 gives an example of a power plant constructed according to the information mentioned above. *Fig. 12* shows the generator turbine for this plant. A pot type turbine is utilized in the high pressure part and it is connected with a low pressure turbine by a reduction gear.

4. Steam Converting Valve

A problem of the combined system is to get steam for a blower turbine in case of generator turbine emergency. To resolve this problem, the steam for a generator turbine must be by-pass by reducing equipment with a quick response. The higher the inlet steam condition of the turbine, the more important the reliability of this equipment becomes.

The steam converting valve is one of the ways to meet this requirement. This valve reduces the pressure and temperature simultaneously. Since the speed of steam at the spray point is high, the mixing condition of spray is good and also since the valve is small in size it is reliable enough against the sudden

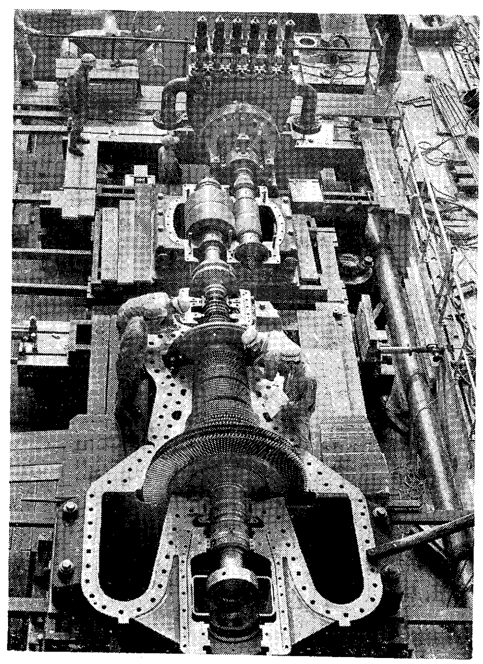


Fig. 12 Generator turbine

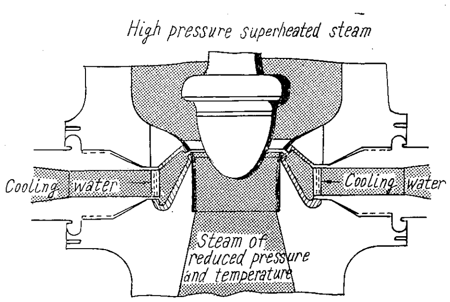


Fig. 13 Steam converting valve

variation in temperature. *Fig. 13* shows its construction. The combined system can be realized only by such a by-pass system.

VI. STEAM POWER PLANT FOR COALMINES

The effective utilization of poor quality coal is one of the important methods to the rationalization of coal mines. Since the combustion of poor quality coal is accompanied by various difficulties, the use of it is considerably limited. The load of the boiler for generation is stable, therefore, it is suitable for the utilization of such coal. If the cost of fuel, being generated at the coal mine, is very cheap so that the cost price of generation becomes cheaper even though using the turbine of a rather small output.

Table 4 **Items of some industrial steam power plants**

Customer	Boiler		Turbine						Generator		
	Type	Capacity (t/h)	Type	Output (kw)	Pressure (ata)	Temperature (°C)	Degree of vacuum (mmHg) Back-pressure (ata)	Speed (rpm)	Capacity (kva)	Voltage (kv)	Speed (rpm)
Nippon Light Metal Co., Ltd	Benson	50	*	5498	85	510	11.5	6000	6500	3.45	3600
〃			**	2697	10.5	268	704	3600	3000	3.45	3600
Furukawa Mining Co., Ltd	Benson	53	***	12,000	85	520	725	HT-LT 7000/3000	15,000	6.6	3000
Nippon Kokan K.K.	Benson	110	*	6690	100	525	30.5	3000	8400	6.6	3000
〃	Benson	110	****	5310	30	370	702.5	3000	6700	6.6	3000
〃			**	4000	30	370	707	Blower 4310~4800	—	—	—
〃			**	4000	30	370	707	Blower 4130~4800	—	—	—
Fujita Tourist Enterprises Co., Ltd	Subterranean heat	2.9	*	30	2.4	130	1.2	3000	40	0.22	3000
Yokohama Sugar Ref. Co., Ltd	Natural circulation	30	*	1500	30	390	4	7200	1875	3.3	1800
Idemitsu Kokan Co. ,Ltd	〃	100	*	3400	42	350	15.5	6000	4250	3.3	1800
〃	〃	80	*	3200	50	410	24	6000	4000	6.6	3600
〃			****	3500	22	320	690	3000	4375	6.6	3000
Nippon Kokan K.K.	Benson	115	*****	16,000	100	525	720	HT-LT 6000/3000	20,000	11.0	3000
〃	Benson	115	*****	1,6000	100	525	720	HT-LT 6000/3000	20,000	11.0	3000
〃			**	11,000	30	375	715	Blower 3900~2300	—	—	—
〃			**	11,000	30	375	715	3900~2300	—	—	—
Fuji Sugar Mfg. Co., Ltd	Natural circulation	56	*	2200	40	370	4	8000	2750	3.3	3000
Chisso Petro-chemical Corp.	Benson	55×2	*	10,800	135	500	16	3000	13,500	6.6	3000
Nippon Kokan K.K.	Natural circulation	—	**	5500	24	375	710	Blower 3000~4400	—	—	—
Tokai Seitetsu K.K.	Benson	150×2	*****	25,000	89	510	730	3600	31,250	11.0	3600
Daishowa Paper Mfg. Co., Ltd			*	6000	23	375	4.5	5000	7500	3.3	3000
Kyushyu Sekiyu K.K.	Natural circulation	45	*	2500	55	420	14	8000	2500	3.3	1800
〃	—	—	*	180	14	270	2	10,000	—	—	—
Kureha Chemical Industry Co., Ltd	Benson	70×2	*	14,400	120	535	20	3000	18,000	3.3	3000
〃			****	9600	19.5	310	720.5	3000	12,000	3.3	3000
Idemitsu Kosan K.K.	Natural circulation	100×2	****	5750	69.5	468	686	6000	7200	3.3	3600
Sanko Seishi K.K.	Benson	65	○○	9600	101	500	15/5	6000	11,000	3.3	3600
Nihon Zeon K.K.	Natural circulation	55	○	7140	81	465	12/5	8000	9000	3.3	3600
Asahi Chemical Industry Co., Ltd	Benson	100	*	15,000	120	495	5.5	3000	17,647	12.0	3000
Daishowa Paper Mfg. Co., Ltd	Natural circulation	100	*	15,000	107	505	5.5	3000	17,647	3.3	3000

Remark) *: Single cylinder backpressure turbine
**: Single cyinder condensation turbine
***: Two cylinder condensation turbine
****: Single cylinder bleeder condensation turbine
*****: Two cylinder bleeder condensation turbine
○: Two cylinder bleeder backpressure turbine
○○: Single cylinder bleeder backpressure turbine

Fig. 14 gives an example of such a steam power plant for a coal mine. This plant uses the high speed geared turbine at the high pressure part of the turbine thus an increase in turbine efficiency is obtained. The chief characteristics of this plant are that it stably burn poor quality coal and that it use various methods in order to facilitate the disposition of ashes.

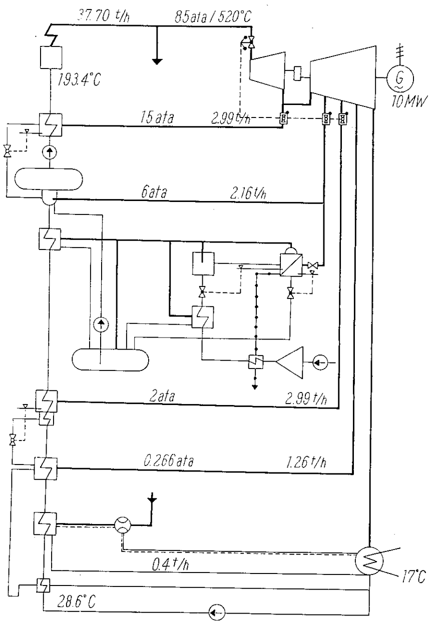


Fig. 14 Steam power plant for coal mine

The Ube-Roshe mill produces powdered coal and this mill requires little power and the construction costs are cheap and in addition, since it is a vertical type the area of installation is small. By adopting the slug tap system as the combustion system of the boiler, disposition of ashes becomes easy and the heating surface is tainted a small degree because of the quantity of dust in the flue. Presently at this boiler, poor quality of 3450 kcal/kg of lower calorific value is stably burned without auxiliary burning of heavy oil. As a result of this success a use of poor quality coal is obtained.

VII. CONCLUSION

We mentioned the characteristics of industrial electric power generation by steam turbines at each field of industry. The cost of electric power accounts for a large part of the cost price of products of most recent industries, therefore, it has become an important problem to reduce the cost of electric power by industrial electric power.

There are various types of industrial electric power plants according to the energy supply and demand of the particular enterprise and in all cases an effort is being made to obtain high efficiency and stable electric power.

Table 4 lists the various industrial electric power generating equipment mentioned in this text, existing installations and those under construction.