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FUJI STEAM TURBINE FOR INDUSTRIAL THERMAL POWER PLANTS

By Masao Osamura

Technical Dept.

I. FOREWORD

Based on a technical contract with the Siemens Co., F. R. Germany, we manufactured and delivered at first two steam turbines to the Shimizu plant of the Japan Light Metal Co. in 1957. Since then we have been manufacturing many steam tmrbines.

In Europe, most power plant steam turbines used are for base load at first and peak load operation afterward. Therefore, Siemens based the design standards for steam turbines on these two objectives. This type of turbine allows prolonged operation, high efficiency and longer life, as well as durability against rough handling. Siemens pioneered in the field of high-pressure high-temperature design of industrial type turbines, and, having acqured these technique of Siemens, we currently maintain high quality in our products related to industrial steam turbines of the 500°C class or above, despite our comparatively late start in the manufacture of these thermal plant facilities. *Fig. 1* shows the layout of the plant equipment delivered to an Tokai Iron and Steel Industry Co. *Fig. 2* is a diagram of the turbine chamber.

Our turbine manufacturing plant has a unique

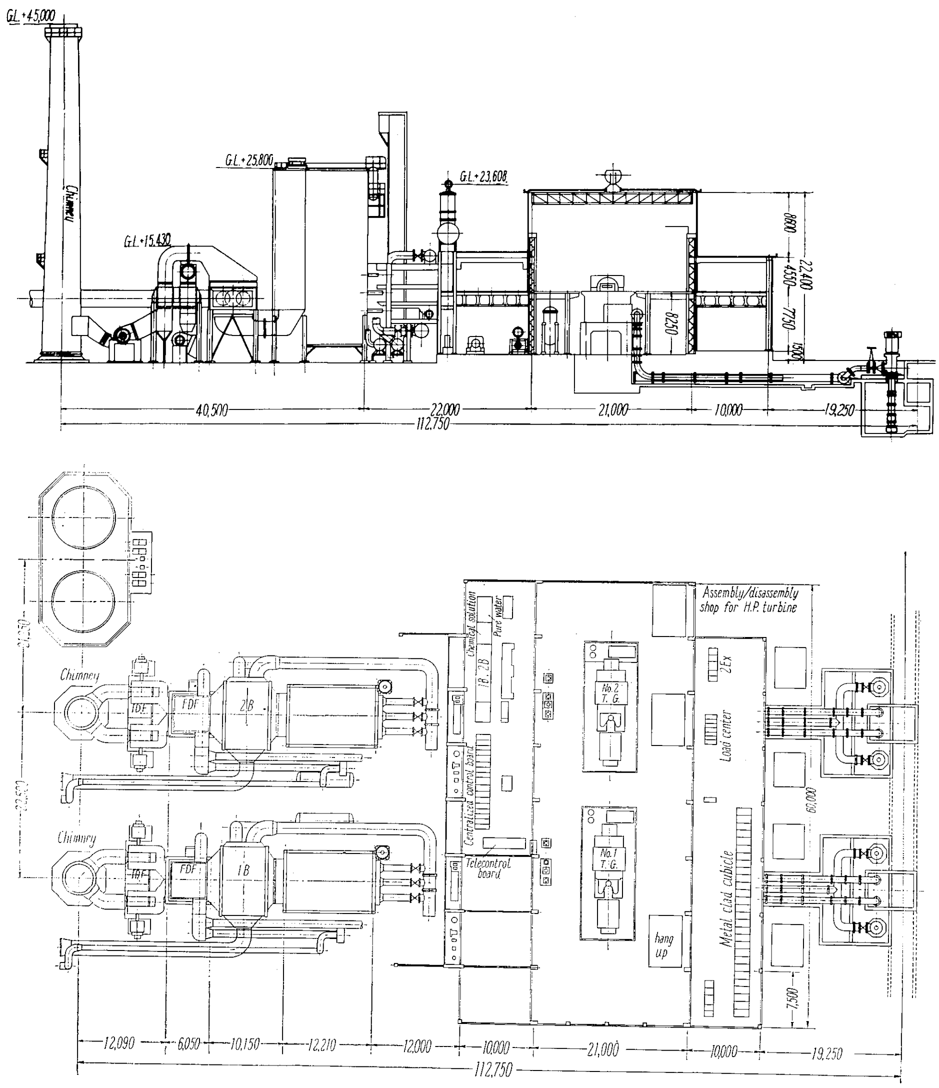


Fig. 1 Arrangment of machine (for iron and steel plant) 2×25,000 kw turbine and 2×150 t/hr Benson boiler

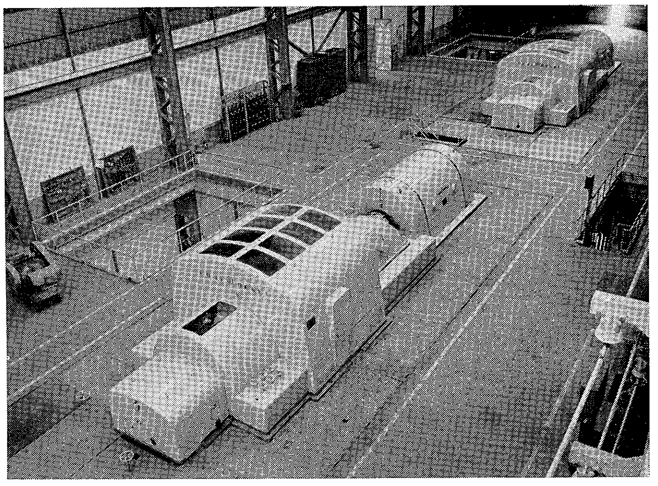


Fig. 2 External view of turbine
2×25,000 kw bleeder condensation turbine

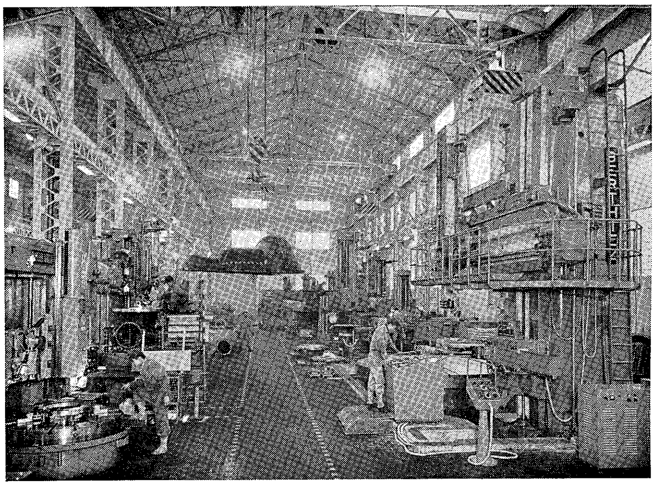


Fig. 3 Turbine shop

structure with completely airtight construction. It has the following characteristics:

a) Dustproof building

To keep out dust, the outer wall is made of steel concrete with no windows. The ceiling is of a special triple layer structure which is heat-proof and soundproof. Floors are plastered with wooden tile throughout to prevent penetration of dust into the building.

b) Air conditioning

Uniform air circulation is maintained throughout the building by an air conditioning system which warms and cools air according to temperature. To dispose of gas produced by welding and cutting operation, a powerful ventilation fan is installed. Air pressure inside the building is regulated to be slightly higher than that of the outside atmosphere to prevent dust from penetrating into the building.

c) Illumination

Large glass blocks installed on the wall provide comfortable natural illumination. The lace-pattern glass blocks giving uniform lighting also serve to prevent the undesirable heating efiect of strong sunlight which may warp delicate mechanisms of machines or products.

Fig. 3 shows a part of our turbine plant. All machine tools and equipment are up-to-date models.

The boiler (30 t/hr, 160 kg/cm^2 max. 176 kg/cm^{2}g, 540°C) shown in *Fig. 4* is one unit of our turbine plant test equipment. Also, we have a cooling system of 2000 m^3/hr capacity for test operation of condensation turbines of the 200 Mw class. *Fig. 5* shows a plant test being conducted on the 25 Mw condensation turbines for the Tokai Iron and Steel Co. We sent many design engineers and field technicians to the Siemens Co. to learn the techniques of turbine manufacture. They were chosen from the top members of our technical school graduates. They acquired first-hand knowledge and skill by working in coop-

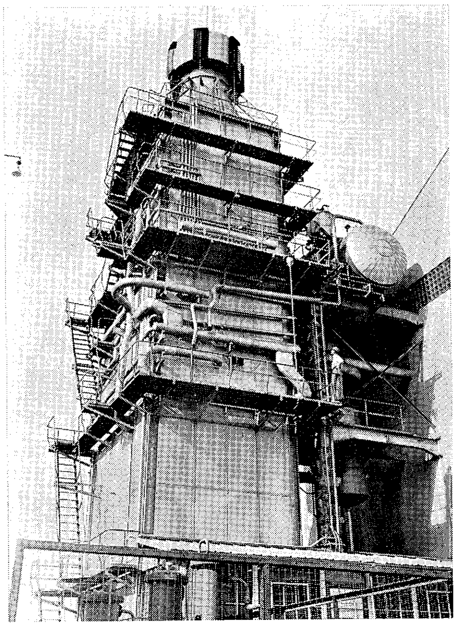


Fig. 4 Boiler for turbine test operation

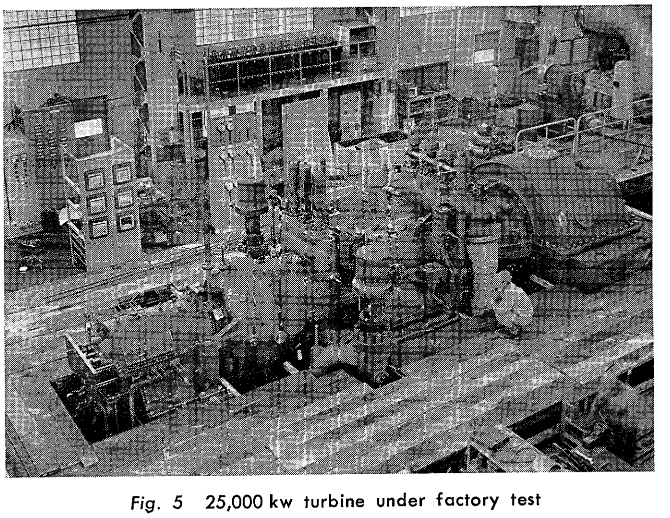


Fig. 5 25,000 kw turbine under factory test

eration with German turbine manufacture engineers at Siemens. Many of them have already returned and are currently assigned to the production line of our steam turbine plant, applying the techniques they learned. At present, many of our men are still being sent to Siemens.

II. CHARACTERISTICS OF FUJI STEAM TURBINE

There are two types of steam turbines, classified by operation mechanism : reaction type and impulse type. The Fuji steam turbine is a reaction type turbine. The characteristics of the reaction turbine are as follows :

1. Efficiency

One of the major characteristics of the reaction turbine is its high efficiency compared to the impulse turbine.

2. Stage Structure

The structure of the impulse turbine is complex, with each stage composed of dashboard of nozzles and a disk with moving blades. Because the axial length of each stage occupies a large space, increasing the number of stages is difficult and expensive.

On the other hand, the structure of the reaction turbine is comparatively simple. Each stage is composed of only stationary and moving blades of the same profile, which are implanted in slits of the casing and rotor ; the short axial length of the blades allows as many stages as are necessary.

3. Operation Safety and Flexibility

1) Radial clearance

In the case of the reaction turbine, expansion of steam is separated by stationary and moving blades. Its numerous stages minimize the pressure difference between the front and back sides of each blade, which in turn minimizes the pressure loss due to steam leakage through the radial clearance. This structure therefore allows ample radial clearance for operational safety.

On the other hand, fewer stages of impulse turbine and its steam expansion depending only on nozzles cause a larger pressure difference between the front and back sides of the nozzles. Also, it becomes necessary to prevent steam leakage by minimizing the diameter of the rotor and the radial labyrinth clearance between the rotor and the dashboard.

2) Axial clearance

In the case of the impulse turbine, since the exhaust velocity of the steam is greater than that in the nozzle and the exit angle is small, it becomes a prerequisite to minimize the axial clearance of the nozzle and the moving blades for maintenance of efficiency. However, in the case of the reaction turbine, the exit angle is sufficiently large. Also, it is rather desirable to enlarge the axial clearance between the moving and stationary blades for efficiency and safety of the turbine, especially when Fuji's thick, round-top blades are utilized.

3) Critical speed and vibration

For the foregoing reasons, the shaft of the impulse turbine is of small diameter, and its critical speed is usually below normal running speed. Upon starting and stopping, the machine invariably must pass this critical speed. Moreover, stationary warping of the shaft is considerably large, creating the possibility of vibration.

On the other hand, the reaction turbine has rotors of a massive, solid forged structure, with its critical speed above normal running speed, insuring higher operational stability and safety with less vibration.

Among industrial turbines, those of the compact type have room for high speed design ; their high rate of rotation provides the following advantages.

(1) The high peripheral speed of their blades makes the heat drop rate per stage larger and number of stages fewer. It is also possible to make the average diameter of the blades small and the blade length large with the heat drop kept constant, thereby decreasing the loss at the blade tips.

(2) The small average diameter of the blades narrows the blade tip clearance and hence permits total circumference of clearance. This decreases losses due to clearance leakage.

These advantages increase the inner efficiency of the turbine considerably, and permit light weight and compact design of the unit. High speed design requires reduction gears, yet efficiency increase compensates for this gear reduction loss with sufficient margin, and the unit can be made compact by 20% weight reduction even with the reduction gear weight included. Further, it allows free choice of rate of rotation of connected generator through gear reduction. Especially for minor power output, a 4-pole generator of low cost can be used by reducing rotation to 1500～1800 rpm. Not only weight can be reduced, but the entire unit can be made compact, thereby reducing the heat stress and deformation of the casing and rotor upon starting/stopping or sudden changes of operation condition. Through such advantages, operational safety and reliability is greatly increased. Thus requirements for compact, high speed turbines are steadily rising because of their high efficiency and economy. In Europe they are widely used because of their leading characteristics among all compact turbines.

There are two types of Fuji steam turbine, classified by structure. One is operated with inlet steam pressure below 80 kg/cm^2 and installed with ordinary split casing, the other with above 80 kg/cm^2 with pot type casing. These turbines are standardized in steps and are manufactured under a well-planned, efficient production system.

III. SPLIT CASING TURBINE

1. Standard Model Turbines

Chart 1 illustrates standard model compact turbines of high speed design, which are the most widely used off all industrial turbines. In particular, the G-type backpressure turbine is mostly used for plants combined with process steam supply, a utility of which is indicated in chart 2. *Fig. 6* shows the rotor and the lower part of the casing of a typical G-metal turbine.

2. Structure

The Fuji steam turbine is of the reaction type, but only the stage behind the control valve is an impulse stage employing a nozzle governing system to minimize throttle loss of steam. Other stages are of the reaction structure.

1) Turbine rotor

Rotors including the impulse stage wheels are solid-forged into one unit. This structure insures safety against heat and deformation stress, and vibrations

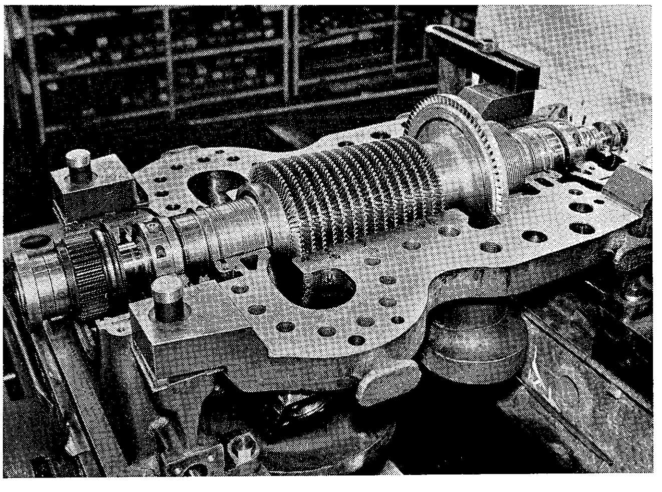


Fig. 6 Typical G type backpressure turbine under assembly (for a pulp & paper plant) 6000 kw backpressure turbine 22 kg/cm²g 375°C backpressure 3.5 kg/cm²g 5000 rpm

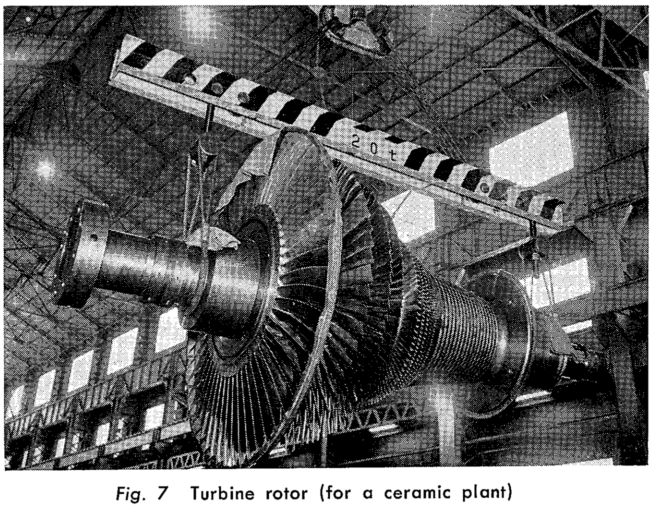


Fig. 7 Turbine rotor (for a ceramic plant) 30,000 kw condensation turbine 42 kg/cm²g 435°C 724 mmHg 3600 rpm

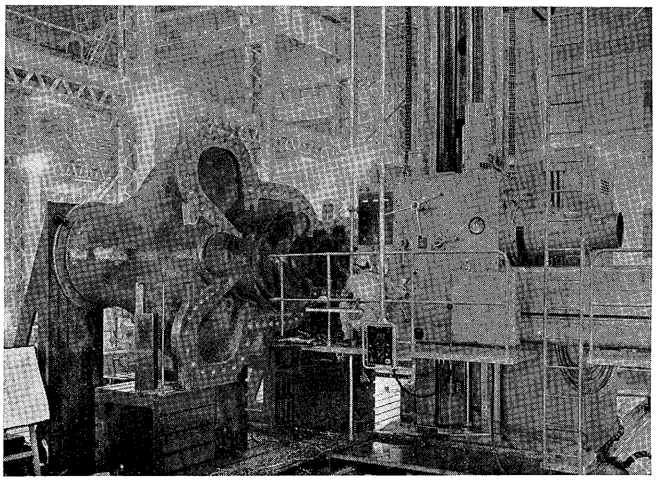


Fig. 8 Bottom half casing

upon starting/stopping. Also, critical speed of rotors is designed to be higher than the maximum running speed, which does not allow vibration under any condition whatever, and does it result in damage of rotor tip or labyrinth packing.

As to material testing of rotors, an ultrasonic wave detector test is conducted to reveal any defects inside the rotor material, as well as magnetic damage detector test for surface crack and thermal stability test for material stability. Further, overspeed test is made of rotors after dynamic balance has been made of the installed rotors. *Fig. 7* illustrates the 30 Mw condensation turbine's rotor, designed for the ceramic industry.

2) Casing

The casing structure is split into upper and lower parts, with the control valve and nozzle chamber forged to its upper part in one unit. *Fig. 8* shows the lower part of the casing during processing.

To correctly maintain the relative positions of rotor and casing, a Mitchell thrust bearing is installed inside the bearing stand on the high pressure side. Rotor extension is performed from this point toward the turbine exhaust side, While the turbine casing extends in opposite direction. Because of this, the turbine outlet is fixed on the stand, and its high pressure side slides on the guide stand installed under the bearing stand.

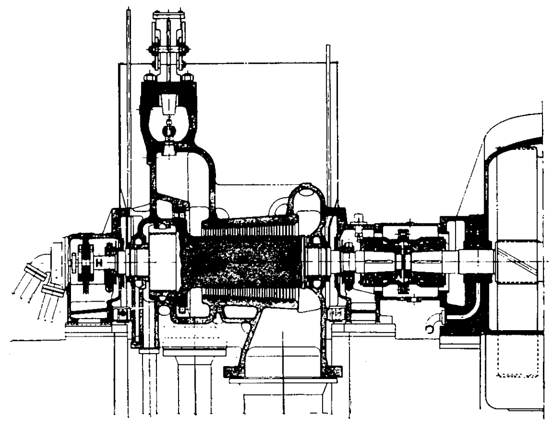
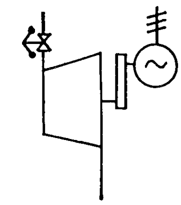
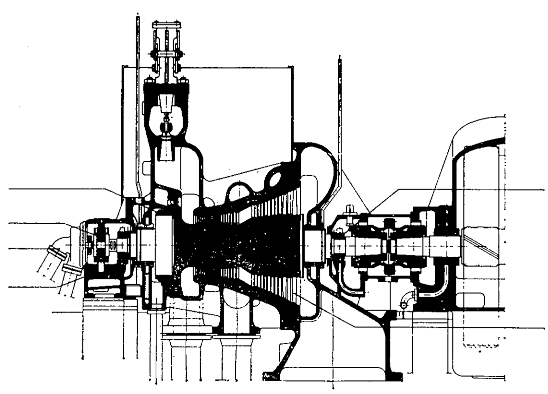
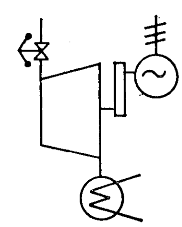
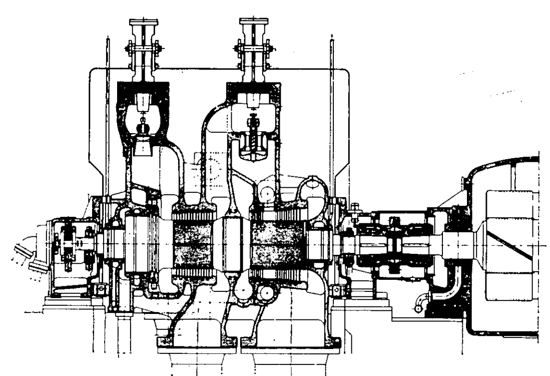
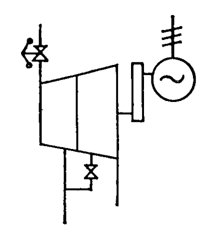
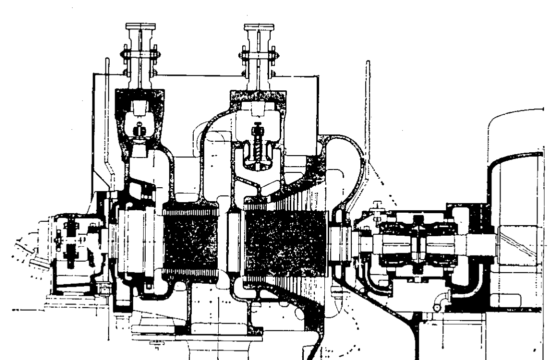
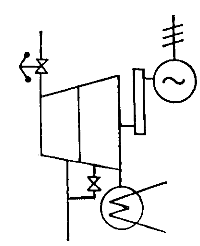
3) Blades

All blades are made of 13% Cr stainless steel. Reaction blades have round tips, and have the following characteristics:

(1) It maintains superior efficiency not only under normal load, but also under partial load, since it is relatively unaffected by the stream direction, as indicated in *Fig. 9*, when compared to the conventional thin blade mainly used in the past.
(2) It retains high durability against corrosion, cracks and vibration stress.

The shroud rings of the moving blade tips are cut out in one unit with blades, providing sufficient strength, particularly in withstanding the centrifugal

Table 1 **Standard Models of Fuji Small Power Industrial Steam Turbine**

	Model	Cross-section of turbine	Diagram
Backpressure system	G-200 G-300 G-400 G-500		
Condensing system	K-600 K-601 K-800 K-801 K-1100 K-1101		
Bleeder backpressure system	EG-200 EG-300		
Bleeder condensing system	EK-600 EK-800 EK-1000 EK-1100		

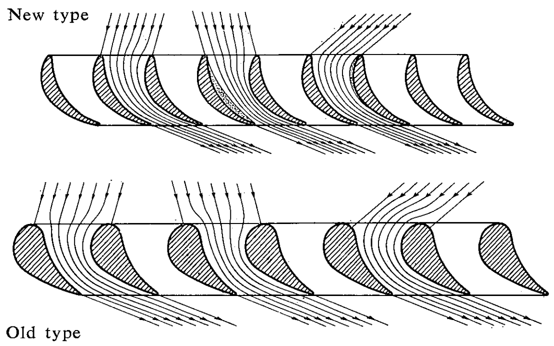


Fig. 9 Blade profile

force of high speed operation. Generally, cylindrical raval type legs are used for the moving blades of the velocity stage instead of the conventional T-shaped legs.

Blades of the last stage of the condensation turbine are standardized at 825 mm for the 50 cps machine and 690 mm for the 60 cps machine, respectively. The low pressure blades of Fuji turbines are implanted independently in stages without using intermediate lacing wires, with each blade tested for vibration. This structure eliminates the complex vibration problems accom panying machines with these wires. Each blade is polished to the exact measurement of a high precision gauge, and at each step of the manufacturing process, accurate measurement is insured by an automatic digital blade tester.

4) Labyrinth type ground packing

Labyrinth type ground packing is mainly used in our turbines. There are two types of packing, i.e., (a) and (b) of *Fig. 10*. There are selected for use according to size, rotor, etc. Fin tips are extremely thin and sharp, and are designed to prevent heating in the ground parts when they make contact.

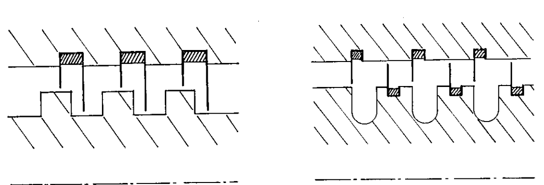


Fig. 10 Labyrinth system of axial direction

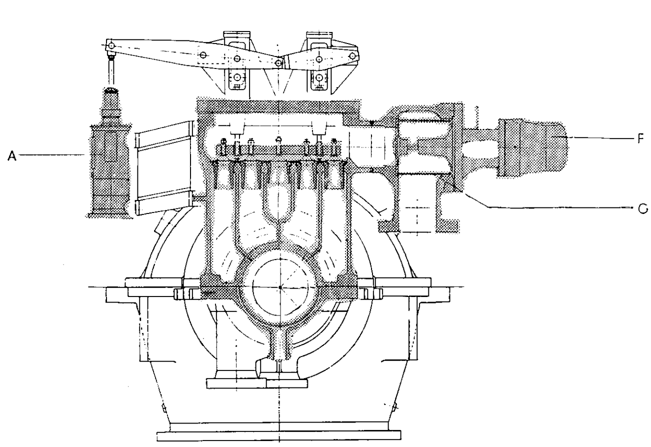


Fig. 11 Cross-section of turbine inlet room

5) Control valve and main stop valve

Normally, 3 to 5 control valves are installed to prevent a large drop in efficiency under partial load. Diffuser valves are employed to minimize pressure loss. (However, basket type valves are sometimes used for low steam pressure turbines.) They are of such simple structure that each valve opens/shuts one after another by up and down motion along a horizontal beam, permitting easy maintenance and inspection. (Refer to *Fig. 11*.)

The main valve also serves as an emergency stop valve, and in case of small capacity turbines, it is installed on the side of upper part of the casing as shown in *Fig. 11*. The steam filter, composed of a a wave-shaped metal strip wound around the frame, is installed inside the main stop valve, as shown in *Fig. 12*. The area of the steam inlet of the filter is wider than that of the conventional filter by 50% and is several times stronger.

6) Reduction gear

Reduction gears are composed of pinion and rack gears made of special steel and a gear box made of cast iron. Gears are cut with a Maag gear cutter,

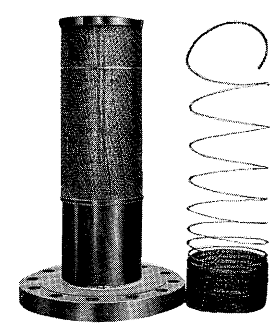


Fig. 12 Steam filter

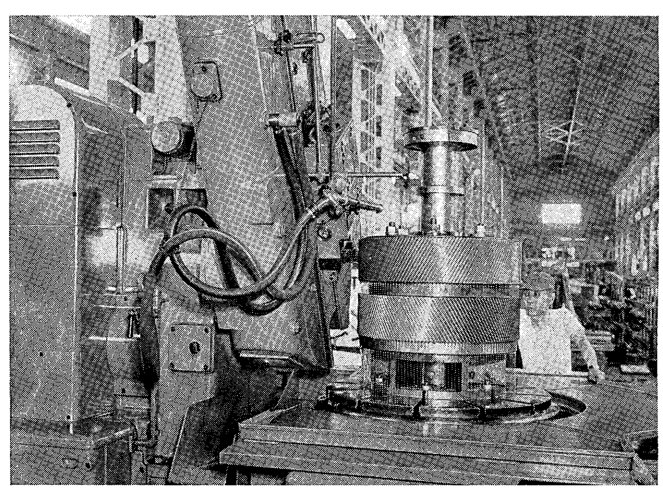


Fig. 13 Reduction gear in processing (for a food plant) 1500 kw backpressure turbine
29 kg/cm^{2}g 390°C backpressure 3 kg/cm^{2}g 7200/1800 rpm

which is capable of cutting gears of various sizes up to 3 m diameter and 900 mm tooth width. Double helical type gears of proper tooth patterns are used, providing smooth gear engagement. This coupled with the superior degree of precision reduces noise to a bare minimum during operation despite its high rate of rotation.

Moreover, a closed and forced lubrication system is employed to insure safety and ease of maintenance, which are liable to be affected by the use of reduction gears. *Fig. 13* shows the reduction gear assembly under construction.

7) Turning device

According to our standards, a turning device is installed on turbines of capacity above 8000 kw. (Refer to *Fig. 14*.) This device is of oil-hydraulic operation, i.e., it is rotated by pressurized oil from the auxiliary pump outlet which is sprayed over the turbine wheel of the first stage attached to the pinion of the reduction gear unit. (In case of turbines without reduction gears, it is attached to the end of the turbine shaft on the generator side.) In this event, the jack oil pump is actuated to float the rotor by spraying oil at 80 to 100 kg/cm^2 pressure over the lower part of the bearing. However, once the rotor starts turning, the bearing is covered with a film of oil and the jack oil pump may be stopped. (This turning device, however, does not affect operation of the turbine even if it is left running.)

This type of hydraulic system insures ease of operation and safety compared to the mechanical system using removable gears.

8) Condenser

The most important factor for the condenser is completely airtight separation of the cooling water chamber, steam chamber and the atmosphere. Specific attention is paid to this requirement in the manufacture of the condenser, its perfection being doubly assured by airtightness and hydraulic tests performed on the product both at the plant and at the destination. Normally, condensers used for home power plants of smaller capacity are manufactured in one unit for delivery. *Fig. 15* shows the condenser for the 25 Mw condensation turbine being manufactured. Pipes and pipe supporting plates are selected according to the type of cooling water. Additional operations may be added as required, such as prior processing of cooling water, installing of zinc plate for corrosion prevention, or electric anti-corrosion processing using external power supply.

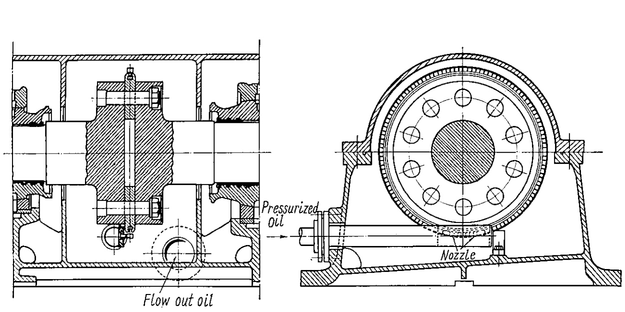


Fig. 14 **Oil-hydraulic turning device**

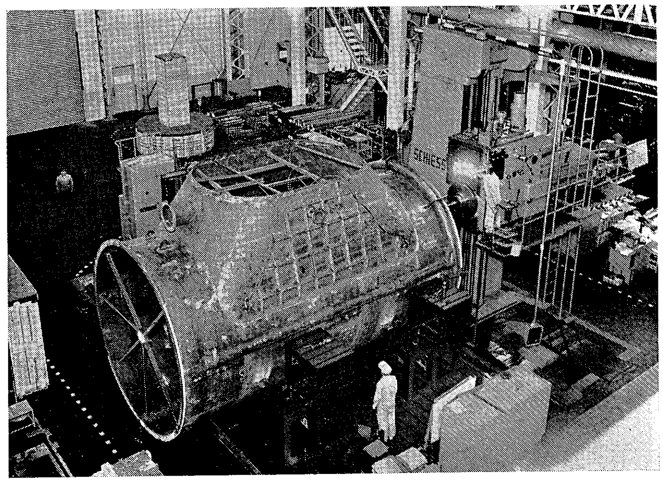


Fig. 15 **Condenser (25,000 kw condensation turbine)**

Cleaning of cooler pipes can be performed either by separating the condenser and washing one side of it while the other side is shut for water circulation, or running cooler water in reverse direction. However, the Taprogge system is the most effective cleaning method, especially for washing away water containing deposit and dirt. In this system, rubber balls are passed through the cooling pipe which rub the inside wall during their passage inside the pipes. Rubber balls emerging from the pipe are automatically recovered for continuous circulation. This system permits cleaning as necessary even while the machine is in operation. For the air ejector of the condenser, either an ordinary steam jet air ejector or Elmo-vacuum pump is used. The Elmo pump was developed by the Siemens Co. and has been used widely in the industry for more than 50 years because of its outstanding quality and structure, surpassing the conventional water sealing pump of similar principle. The efficiency of the condenser can be increased by combining the Elmo pump with a gas ejector. It is most suitable for a condenser of 0.02$\sim$0.07 ata inner pressure. Also, it consumes less internal energy than the steam ejector, and the time required for starting is considerably reduced.

IV. TURBINES WITH POT-TYPE CASING

1. Outline

Efforts are being made, in the area of business plant facilities, as well as industrial thermal power plants, to reduce the cost of power generation by increasing the thermal efficiency of the plant power generator. This tendency, coupled with marked technical development in the fields of boiler and turbine manufacture, is leading to further attempts to increase the capacity of the individual product and to raise the pressure and tempereture at the steam inlet of turbines. On the other hand, superior

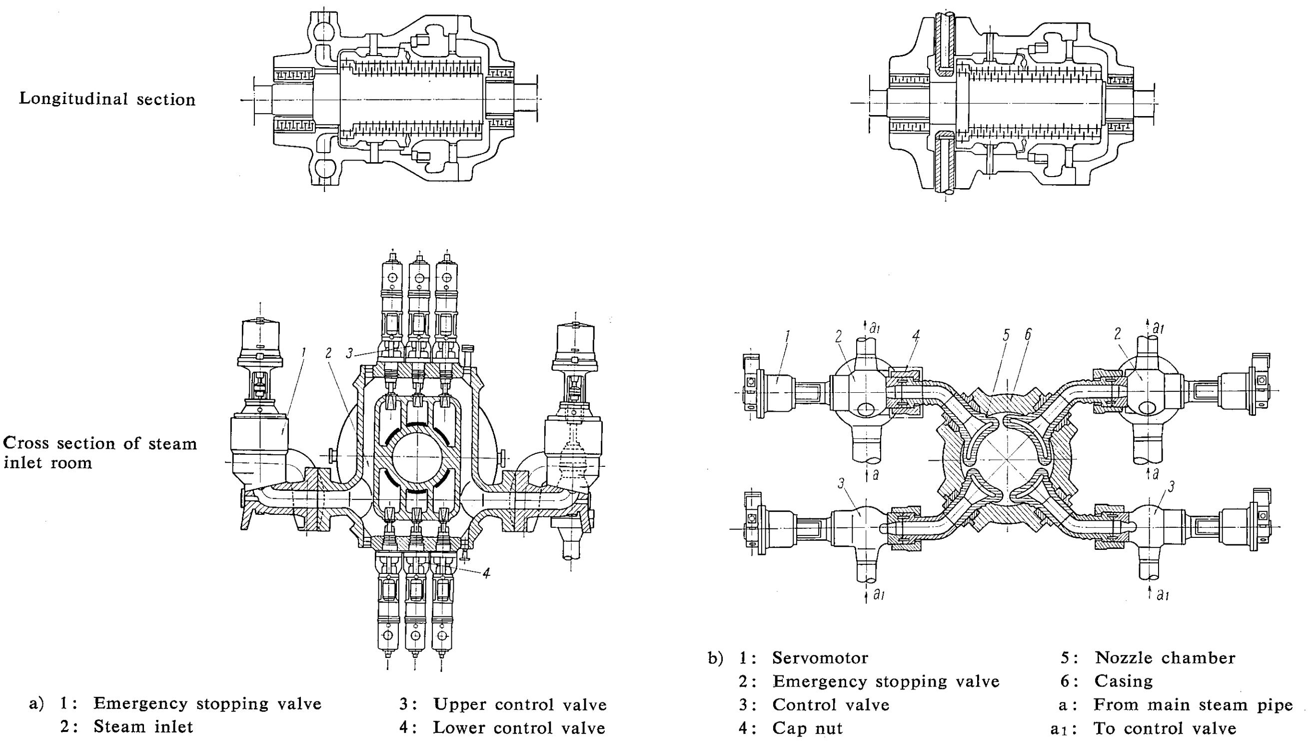


Fig. 16 Cross-sectional view of pot type turbine

heat elasticity is required of turbines to endure frequent starting and shutting down of the machine, such as peak load types. Our pot-type casing turbine, with its outstanding performance record in the past, best fulfills these requirements.

As shown in *Fig. 16*, there are the following two types of pot-type casing:

(a) Casing forged with steam chamber into one unit

(b) With insertion type nozzle chamber

(a) is applicable for high speed turbines, etc. of comparatively small power output. Because of the small casing and thin wall, it is possible to forge the steam chamber with casing into one unit. It is designed and manufactured with utmost accuracy with special attention paid to the uniformity of material to insure quality forging.

Further, the structure and layout of steam and nozzle chambers are arranged to insure uniform heating and cooling upon sudden stopping and starting.

(b) type casing is used mainly for turbines of larger power output with extremely high steam pressure and temperature. In this type, the steam chamber is not forged to the casing; the nozzle chamber, which has been independently forged and mechanically processed, is attached to the casing afterward. The main characteristics of this type of casing are as follows:

i Simple structure permitting easy forging

ii High reliability of forged material

iii Rich heat elasticity

2. Structure of Pot-casing Turbine

One of the noteworthy charateristics of Fuji's high pressure turbine is its structure composed of a pot-type casing and radial flange, assuring outstanding airtightness and durability. (Refer *Fig. 16.*) This type of casing has the following advantages.

(a) It has no axial flange, and is equipped with a contact surface perpendicular to the axial direction on the exhaust side with the circular flange. This assures uniform temperature distribution over the flange part, precluding the possibility of temperature being distributed irregularly which may result in irregularity of expansion of the material. Also, because the flange is furnished only on the exhaust side, airtightness against exhaust pressure and temperature only is maintained regardless of the amount of pressure in the high pressure part. With its circular flange allowing easy processing, this type of casing completely precludes the possibility of steam leakage.

(b) The casing is designed with rotational symmetry which eliminates stress non-uniformity; its axial length is shorter than the diameter. It also has high strength with respect to flexural moment.

(c) The inner casing for stationary blades is used for implanting stationary blades in the casing. This stationary blade holder is separated into two parts horizontally, with no flange protruding like that of the casing of a conventional turbine; it has a cross section free from irregular thickness of material. This is because steam pressure from the control stage is applied to the front part while the back pressure is applied to the rear part of the stationary blade holder. Therefore, the only care to be taken concerning the blade holder is

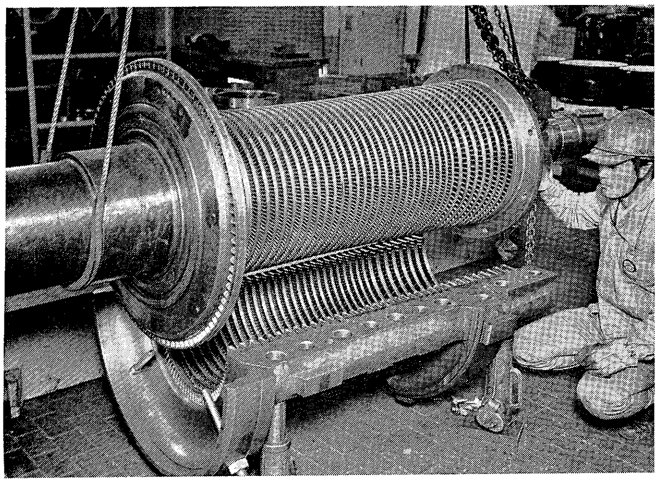


Fig. 17 Stationary blade holder and rotor of pot type turbine (for chemical fiber plant) 14,400 kw backpressure turbine 119 kg/cm^{2}g 535°C backpressure 18 kg/cm^{2}g 3000 rpm

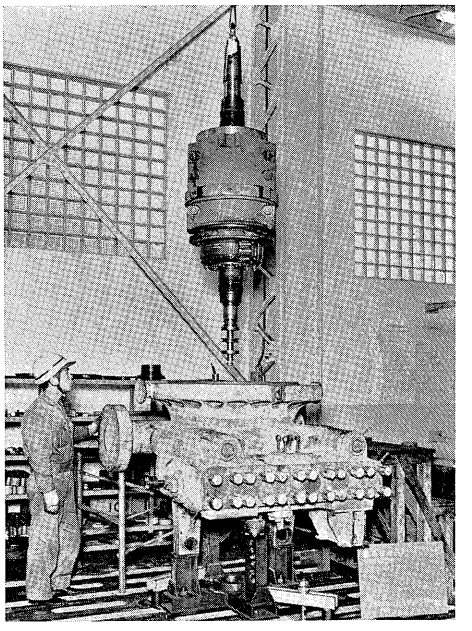
the pressure difference between the steam inside and both of the above parts. The stationary blade holder is installed so that it can be freely expanded or contracted in either the radial or axial direction with respect to the casing. Also, the mass of the stationary blade holder corresponds to that of the rotor, minimizing the expansion difference between the holder and the rotor. *Fig. 17* shows the rotor and stationary blade holder being constructed.

The high pressure casing as above is perfected, based on the rich experience of Siemens.

Consideration has been given to efficiency in assembly, disassembly of this type of turbine. For disassembly, the entire turbine casing unit can be removed from the bearing and lowered vertically on a disassembly jig. Then the packing gland is extracted and the inner mechanism of the turbine consisting of the stationary blade holder and rotor is taken out of the casing for further dismantling. Assembly is accomplished by reversing this process. Special tools are utilized for maintenance of the axial center position after extraction of the axial packing gland, and for that of the mutual relationships of rotor and blade holder upon removal of the inner mechanism to assure ease and accuracy of the assembly and disassembly operations.

Furthermore, completed products are delivered in the state that turbines are centered and perfectly constructed at the plant so that installation is easily accomplished at the receiving factory. *Fig. 18* shows the rotor-stationary blade holder assembly being installed on the casing at a regular inspection step. The radial packing gland shown in *Fig. 19* is used for high pressure turbines. Compared to the axial packing gland, this enables reduction of the axial length of a high pressure turbine which requires a greater number of labyrinths.

A thin strip of special steel is attached to the tip



Fig, 18 Assembling of casing and stationary blade holder of pot type turbine (chemical industry) 5300 kw backpressure turbine 84 kg/cm^{2}g 510°C backpressure 10 kg/cm^{2}g 6000 rpm

of labyrinth which does not induce malfunction of the turbine itself even when this part makes contact; thus the clearance between the rotating part and the stationary part can be made smaller.

3. Structure of Pot-casing Turbine with Nozzle Chamber Insertion System

1) Casing

The casing of this type of turbine is of perfect rotationally symmetric design, as shown in *Fig. 16* (b). In comparison with the casing with built-in nozzle chamber, it provides uniform thickness of material and simplicity of design. These advantages make it a turbine of high reliability capable of operating under conditions of very high pressure and temperature.

2) Installation of nozzle chamber block

The following process applies to the installation of

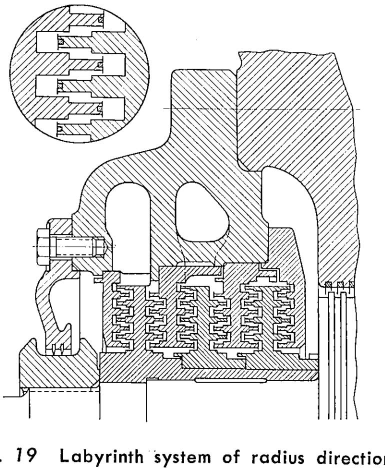
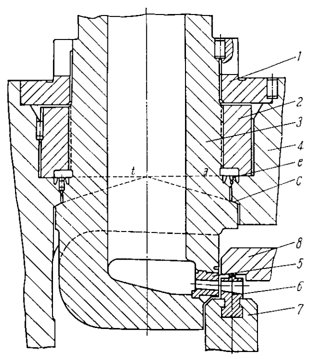


Fig. 19 Labyrinth system of radius direction



1. Centering ring
2. Threaded nut
3. Nozzle chamber
4. Casing
5. Nozzle
6. Impulsion blade
7. Wheel axis
8. Stationary blade holder

Fig. 20 **Construction of inserted nozzle block**

nozzle chamber block on the casing. (Refer to *Fig. 20.*)

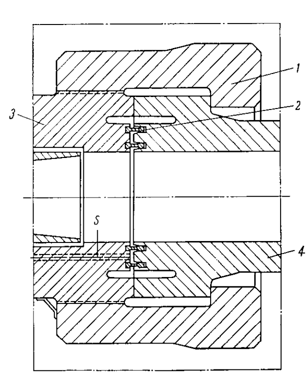
Each nozzle chamber is inserted one by one into holes previously drilled in the casing from the inside. The casing supports the nozzle chamber with the conical surface and threaded nuts tightly fixing the nozzle chamber in position. The conical surface is fitting-processed ; the nozzle chamber is pressed by high steam pressure against the casing from within, thereby maintaining sufficient airtightness. Also part (e) is welded to prevent steam leakage. By aligning the vertex of the conical surface *c* to the top of the screw nut and properly selecting its angle, the following advantage is obtained : in case the inserted block and the casing are of different material and heat expansion ratio, the resultant axial moment can be dissipated as they slide on the conical surface. This is especially important when austenite steel is used for material of the casing.

3) Installation of control valve casing

The connecting pipe from nozzle chamber can be combined with the control valve casing by screwing the cap nut. (Refer to *Fig. 21.*)

The contact points of the two parts are kept airtight by two sealing rings applied to them. Also leaking steam is led from the middle point of sealing rings to the leakage condenser, eliminating leakage of steam to the outside.

As mentioned above, the installations of the nozzle chamber to the casing and the control valve casing to the connecting pipe are not welded for the purpose of increasing strength, and no bolts are used



1. Cap nut
2. Airtight ring
3. Control valve casing
4. Connecting pipe

Fig. 21 **Construction of control valve and connecting pipe**

for construction. All fixing is accomplished with threaded nuts. These nuts are made with threaded parts of trapezoidal type and large pitch, freely movable in the radial direction. Assembly and disassembly can be performed easily by heating the nuts, without producing abnormal stress during operation. Further, because there is no welded part, no heating process after welding is necessary. *Fig. 22* shows the layout of this type of turbine.

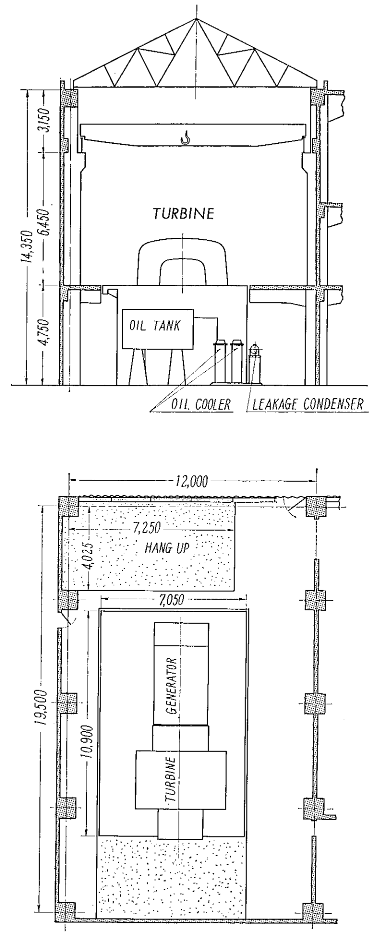


Fig 22. **Arrangement of machines in turbine room 15,000 kw backpressure turbine for a chemical fiber plant 119 kg/cm²g 500°C backpressure 4 kg/cm²g 3000 rpm**

V. GOVERNING AND PROTECTIVE DEVICES

1. Outline

The governing and protective devices of Fuji steam turbines are composed using hydraulic oil as a medium.

The governor is oil-hydraulically operated. This governor works in such a way that an oil pressure signal (initial pressure) which corresponds to a variation of the rate of turbine speed is transferred to a secondary pressure of variation in the reverse direction, thereby adjusting the opening of the control valve. It has superior efficiency, with simple structure, high sensitivity and quick response. No throttle mechanism is used in the initial hydraulic circuit to adjust the circuit diameter ; it depends only on the transfer of pressure. This is effective in eliminating such influences as temperature shift or change of oil viscosity.

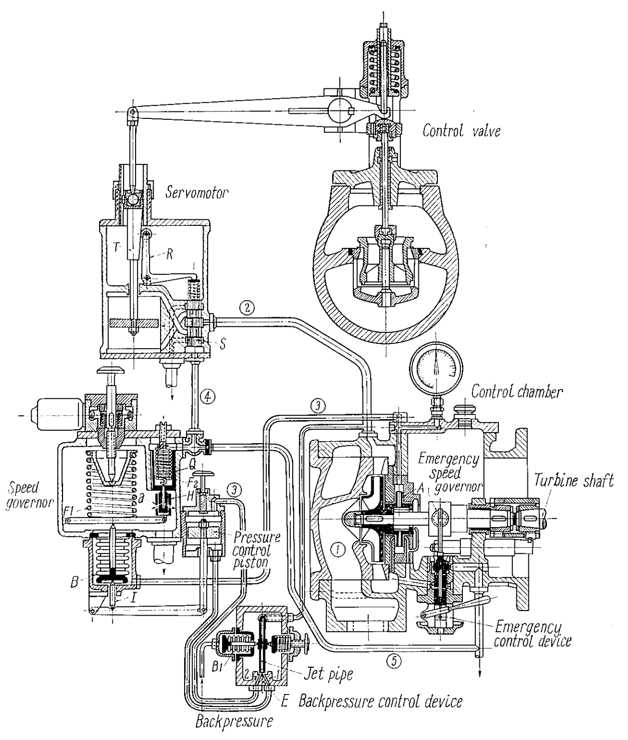
Such systems as the emergency speed governor, emergency stopping device, main stop valve (emergency stop valve) bled steam emergency stop valve and remote control stopping device are all operated in connection with a drop in pressure, increasing the safety factor of the turbines. Such devices as the starting device, oil-hydraulic governor, speed setting device and back pressure control device are made compact and are attached to the side of turbine for convenience in case of operation and maintenance inspection.

2. Governor

An oil hydraulic pressure type speed governing device connecting to the backpressure control device is illustrated in *Fig. 23.*

1) Speed governing

The operation system is now explained. The initial hydraulic pressure created at control impeller A produces pressure proportional to the square of the speed on the lower part of bellows B, maintaining balance with the force of the speed setting spring F_1. When this balance is upset by a change in speed and resulting change in hydraulic pressure or a change in force of spring F_1 with the speed setting device, control sleeve H is actuated. Control sleeve H and controlled piston Q each have their own slit a from which a part of the secondary oil flows out. Through action of sleeve H the area of throttle a is changed, causing the secondary oil pressure inside to change, upsetting the balance with spring F_2, and the controlled piston Q follows sleeve H to the new balance point. The secondary oil pressure works on the lower side of pilot valve S, whose movement actuates the pilot valve, thereby moving the servomotor of the control valve. Movement of servomotor is fed back to the top of pilot valve by the controlling lever R, causing the control valve to move back to its original position. By turning the swing back cone T, the governing rate can be freely altered during operation. This governor has no part with large mass or friction, and control is very stable and sensitive. *Fig. 24* shows an oscillograph of the governor test.



① Section of main pump
② Pressurized oil
③ Initial pressurized oil circuit
④ Secondary pressurized oil circuit
⑤ Pressurized oil circuit for emergency stopping valve

Fig. 23 **Oil-hydraulic speed control device incorporating backpressure control device**

2) Back pressure control device

Either oil hydraulic power or electric power is used for the back pressure control valve. As shown in *Fig. 22*, an Ascania type oil hydraulic system is employed. The jet pipe is attached to one end of the valve and is freely movable; it is operated by the balance kept between bellows B_1 and spring tension.

When the back pressure rises, hole ♯1 of oil inlet E receives a strong impact from the jet pipe, causing a pressure difference between hole ♯1 and ♯2, which in turn moves the pressure centrol piston upward, and at the same time pushes up bellows B of the speed governor against spring F. Upward movement of bellows B closes the control valve, thereby decreasing steam flow until back pressure reduces to the designed value. When the back pressure drops, the jet pipe moves toward hole ♯2, and through the reverse process of the above the control valve opens.

Upon starting of turbine, the back pressure control device is separated with the pressure control piston at its lowest position. When the turbine is loaded and the back pressure control device is connected to the turbine, the speed governing device is at its highest position. In this instance, the speed governor does not interfere with the movement of the pressure controller, but when load is cut off and the speed is increased, it is automatically actuated to return the rotation to its original status. In the event that parallel operation with an external electric system is cut off and the load balance is broken, it becomes necessary to switch the pressure-controlled turbine to speed governor control. *Fig. 25* shows this switching system. It indicates the status of turbine under back pressure control; switching is performed by an electromagnetic valve which is actuated by a relay system detecting whether connection with external power is parallel or not. In the event of switching to speed governor control, the oil pressure control circuit to the back pressure cylinder is opened to let out the oil inside, with piston at the fully open position. Also, bellows B of the speed governor is disconnected at the same time, allowing the turbine to continue controlled operation.

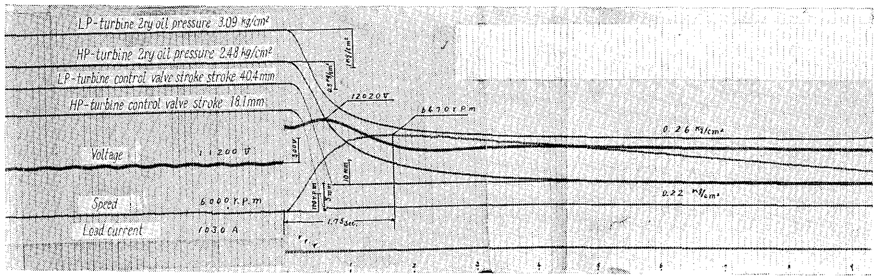


Fig. 24 Oscillogram of governor test 16,000 kw bleeder condensation turbine for iron and steel plant 99 kg/cm²g 525°C 720 mmHg 6000/3000 rpm

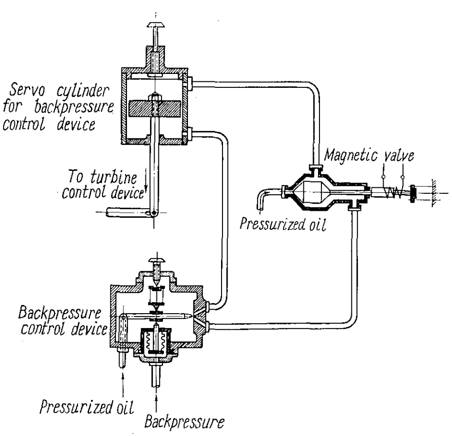


Fig. 25 Switching system (backpressure operation—power operation)

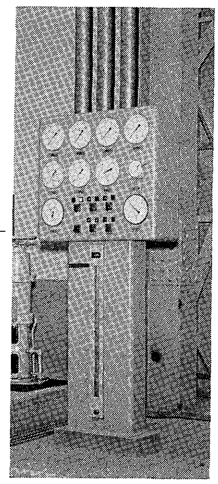


Fig. 26 Turbine starting panel

3. Protective Devices

Emergency stopping of the turbine is performed by cancelling the hydraulic pressure in the emergency stopper oil circuit. In this case it not only depends on emergency valve control but also on actuation of the control valve and bled steam emergency stop valves, thereby stopping down steam flow at two positions. This is an important factor to insure a high degree of safety of the machine during operation. Stopping of the turbine by the emergency system is accomplished by the following mechanisms:

(1) Emergency speed governor
Before the speed of turbine exceeds rated capacity by 11%, bolts attached to the end of the axis pop out by centrifugal force actuating the emergency stopping system of the turbine.

(2) Actuation of axial deviation control of the rotor
When the axial deviation of the rotor exceeds its tolerance, the protrusion on the axis pushes the lever of the emergency stopping system of the machine.

(3) Excessive oil hydraulic pressure drop
When the operating oil pressure drops, the auxiliary pump is automatically started, and even if pressure continues to drop further until it reaches below the designated value, the machine automatically stops operation.

(4) Vacuum drop protective device
When the vacuum drops below the designated degree, this system is actuated to stop turbine operation.

(5) Magnetic control valve
Either through manual control from the control center or through the trouble detecting relay of the electric circuit system, the magnetic control valve installed inside the emergency stop oil circuit is actuated to stop turbine operation.

4. Monitoring System

Normally, turbine operation is monitored by the instrument board in the control center. However, it can also be monitored by control switches at the side of the turbine. *Fig. 26* shows an example of this control switchboard. Besides this monitoring of pressure, temperature and steam flow conditions, the following special instruments are availabe to keep the machine in ideal operating condition. An oil hydraulic tachometer and rotor position indicator are installed on the main body of the turbine. Also in case of large capacity turbines, measurement is conducted of vibration, casing expansion, expansion difference of casing and rotor, and rotor deviation rate, as necessary.

VI. CONCLUSION

These small capacity-high speed turbines and high pressure-temperature turbines are already standardized products of our company, in answer to the ever-increasing demands in the industry for these types of turbines. They are manufactured and supplied at low cost through our efficient, well-planned production systems. Day-to-day development in industrial technology is leading to the production of turbines of higher pressure and temperature. In answer to these demands the Fuji pot-casing turbines are highly recommendable products, well capable of contributing to the technical and economic development of your country.

Due to the limited space for the introduction of our products, this report deals only with our turbine products. However, please feel free to consult with us at any time concerning problems involving industrial thermal power plants. Further, for examples of other plants which we could not discuss in this report, please refer to the chart illustrating their past achievements with photographs attached, which are available upon request.