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36,000 kW UNIT NO. 1 FOR THE CHATAN POWER STATION, RYUKYU ELECTRIC POWER CORPORATION

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I. INTRODUCTION

In April 1968 Fuji Electric received as a full turn-key job from the Ryukyu Electric Power Corporation an order of all equipment, as well as architectural and civil works for the Chatan power station with a max. output 36,000 kw. Recently the power station was completed ahead of schedule and put into operation. In Okinawa there is only one hilly area in the northern part of the island with 503 m Mt. Yonaha-dake as its highest point. Therefore, hydro-electric power generation is impossible and all electric power is supplied by thermal power stations.

The electric power demand of approximately 250,000 kw in Okinawa is met by the Kin power station (22,000 kw × 4 sets) and the Machinato power station (16,000 kw × 4 sets), the Impedance, Jacova and other power barges, as well as a recently completed gas turbine station and some diesel engine sets.

However, the thermal efficiency of the gas turbine is so low and the fuel is so expensive, and the other power stations are so old that they are not able to respond to the rapidly rising demands for electric power. Therefore the Chatan power station was planned and completed very quickly.

This power station was ordered from Fuji Electric as primary contractor of a full turn-key job, which included a detailed survey of the settled areas, dredging work of the sea-bottom for the circulating water ditch, grading work, shore protection work and all equipment including O.F. cable for connection to 69 kv lines.

The coordination and planning of construction and the control system for the whole plant were carried out by Fuji Electric. The turbine, generator, control equipment, instrumentation equipment, switch gears and other electrical equipment were also supplied by Fuji Electric.

Other main equipment and work were supplied as follows.

Steam generating equipment (Benson boiler)
......Kawasaki Heavy Industries Co., Ltd.

Planning and design for architectural and civil engineering work ......Fujita-gumi Co., Ltd.

Architectural and civil work
....................Ohshiro-gumi Co., Ltd.

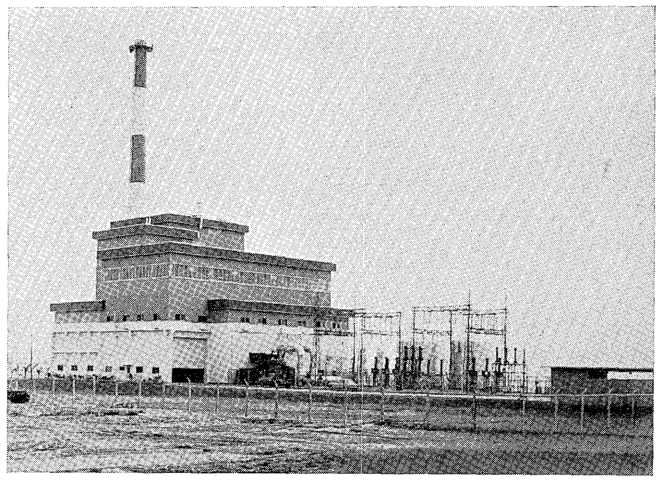


Fig. 1 External view of Chatan Power Station

The power station was put into operation one month earlier than expected and the progress of works from the time of order to completion was as follows.

11 May 1968:	Start of construction
10 December 1968:	Start of boiler installation
10 March 1969:	Start of turbine installation
20 May 1969:	Initial firing of boiler
15 June 1969:	Turbine first run
28 June 1969:	In operation
18 July 1969:	Opening ceremony

For completion of the plant in such a short time, not only scrupulous planning of the whole plant and careful equipment design but also coordination for delivery time of many types of equipment, machines, instruments and devices are very imprortant. Satisfactory progress of these activities made it possible to complete the power station and put it into operation in only 15 months.

Corodination between the work at the site and the delivery of machines is most important for rapid progress after starting installation of equipment and machinery. When customs formalities and shipment are required a key point for rapid completion is smooth finishing of these formalities and arranging a good shipping schedule.

The existing power stations in Okinawa generally contain equipment imported from the USA and the power barges are primarily for military use.

American standards and codes such as ASA, ASME, NEMA, etc. apply to the equipment in the existing plants and the units are in feet and pounds. For the Chaton Power Station, however, Japanese standards and codes, and metric units apply generally except in special cases for connection to existing equipment etc. For the convenience of operators almost all meters have two scales, one in the metric system and one in the feet-pound system. This article gives an outline of the Chatan power station.

II. CONDITIONS

In Okinawa, severe natural conditions arise when planning power stations.

The island is situated on the main route of typhoons and the maximum wind velocity reaches 80 m/sec (180 miles/hr), i.e. 2 times as large as the mechanical force at standard velocity of 60 m/sec (135 miles/hr) in Japan. All of the outdoor equipment, buildings and structures must be able to withstand winds of 80 m/sec. The seashore on Okinawa is studded with coral reefs and eroded by sea water, so that the surface is very uneven. The uneven surface causes much trouble for foundation work and it takes a lot of time to overcome it.

Another severe condition is water.

City water is used as replenishement water for the heat cycle of power stations, but it is very hard since in Okinawa the hilly region is very small and low and there are no large rivers, so that subterranean water is used for city water.

Owing to this very hard water, comparatively large water treating equipment is necessary to provide replenishment water for the heat cycle.

Naturally, sea water is used as circulating water. The sea near the power station has shoals on coral reef stretching for 300 m (900 feet) from the shoreline. This had to be dredged 300 m from the coastline in a 30 m width for the circulating water ditch to the intake pit, where circulating water pumps were installed.

As this power station is located on the seaside and on the main typhoon route, electrical equipment for outdoor use must be sufficiently resistant against salt contamination. However, because of the lack of water in Okinawa it is impossible to apply the hot-line washing method for the bushing or the water-curtain method which require a lot of water.

Therefore, only the bushings having a long creepage path must be protected against salt contamination with silicone grease. Moreover, metallic parts of the equipment must also be made to withstand erosion of salty sea breeze by means of sufficient painting and galvanization. Near the power station there is an airfield and the extension of its runway passes the side of the power station, so that the arrangement of the stack, 69 kv switch gear structure and building is very severely limited.

III. STEAM AND WATER LINES

The heat flow diagram of this power station is shown in *Fig. 2*. The operating steam conditions of the turbine are the highest level of steam temperature and pressure for this capacity, namely 535°C and 120 ata. Not only is the turbine heat rate very low, but the net heat rate including the boiler efficiency and power demands of the auxiliary equipment is also very low. The guaranteed net heat rate is 2588 kcal/kwhr but the test result is only 2446.3 kcal/kwhr.

When planning of the power station, economy concerning the heat rate and its initial cost in various cases was sufficiently investigated, and a boiler and a turbine of the following specifications were chosen.

(1) Boiler

Type :	Indoor use pressurized once-through Beson boiler
Fuel :	Bunker C heavy oil
Capacity :	ECR 120 t/hr MCR 134 t/hr
Outlet pressure :	124 kg/cm^2•g
Outlet temperature :	540°C
Feed water temperature :	201.1°C
Efficiency :	88.7% (based on high calorific value)

(2) Turbine

Type :	Reaction type 2 casing condensing turbine
Output :	ECR 33,000 kw MCR 36,000 kw
Speed :	3600 rpm

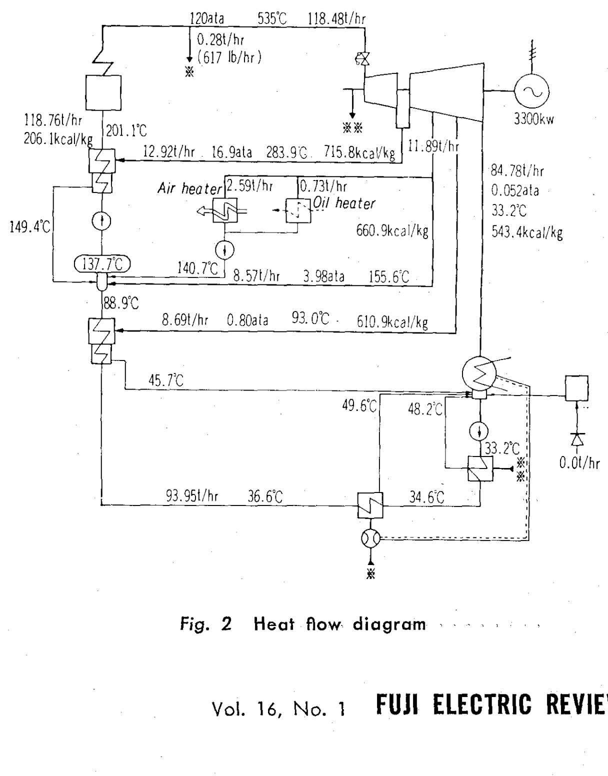
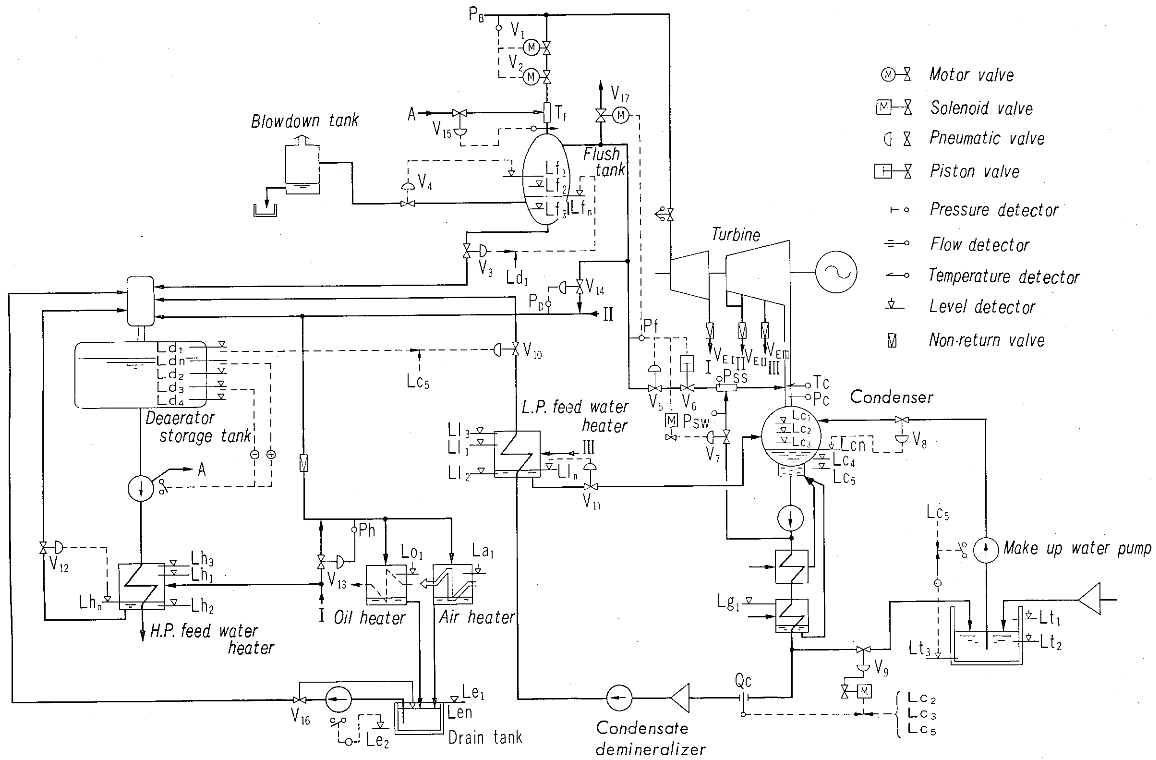


Fig. 2 Heat flow diagram



A. Water level

(1) Condenser

- Lc_1: Too high alarm level
- Lc_2: V_9 open at Level $>Lc_2$
- Lc_3: V_9 shut at Level $<Lc_3$
- Lcn: Level control by V_8 (to hold setting point)
- Lc_4: Tool low alarm level
- Lc_5: V_9 and V_{10} shut, make up water pump×2 sets start

(2) Leakage steam condenser

- Lgl: Too high alarm level

(3) L.P. heater

- Ll_1: Too high alarm level
- Lln: Level control by V_{11} (to hold setting point)
- Ll_2: Too low alarm level
- Ll_3: VEⅢ shut off

(4) Boiler feed water tank

- Ld_1: Too high alarm level and V_3 shut off
- Ldn: Level control by V_{10} (to hold setting point)
- Ld_2: Boiler feed water pumps can be started
- Ld_3: Too low alarm level
- Ld_4: Boiler feed water pumps emergency stop

(5) H.P. heater

- Lh_1: Too high alarm level
- Lhn: Level control by V_{12} (to hold setting point
- Lh_2: Too low alarm level
- Lh_3: VE I shut off

(6) Flash tank

- Lf_1: V_4 open at Level $>Lf_1$
- Lf_2: Too high alarm level
- Lfn: Level control by V_3 (to hold setting point)
- Lf_3: Too low alarm level

(7) Air heater

- La_1: Too hign alarm level

(8) Oil heater

- Lo_1: Too high alarm level

(9) Drain tank

- Le_1: Too high alarm level
- Len: Level control by V_{16}
- Le_2: Drain pump stop and alarm

(10) Treated water tank

- Lt_1: Too high alarm level
- Lt_2: Too low alarm level
- Lt_3: Make up water pump stop

B. Pressure, temperature and flow

- Pf: Pressure of Flash tank
- Pc: Condenser pressure (Condenser vacuum)
- Pss: Spill over steam pressure
- Psw: Spill over spray water pressure
- Pd: Deaerator steam pressure
- Ph: Air heater and oil heater steam pressure
- Tc: Exhaust steam temperature
- Tf: Steam temperature of flash tank
- Qc: Condensate flow
- PⅡ: Pressure of turbine extraction Ⅱ

C. Valve

(1) V_1 (Starting stop valve)
Auto. control: Open at Pb> 130 atg (=Ca. 1850 psig) and boiler emergency stop
Interlock: Manual operation
Don't shut at Pb> 130 ata and boiler emergency stop

(2) V_2 (Starting control valve)
Auto. control: Open at Pc> 130 atg and control to Pb≤130 atg (Shut off at Pb <130 atg)
Interlock: ——

(3) V_3 (Flash tank level control valve)
Aout. control: Control to hold water-level at setting point (Lfn)
Interlock:
Automatic and manual operation
Shut at B.F.W.T. water-level >Ld1

(4) V_4 (Blow down control valve)
Auto. control: Open at water-level>Lf1 and control to water-level <Lf1 (Shut off at water-level <Lf1)
Interlock: ——

(5) V_5 (Spill over control valve)
Auto. control: Control to hold Pf=20 ata (=Ca 283 psia) (Shut off at Pf <20 ata)
Interlock: In automatic control and manual operation
Shut off at the following condition (Emergecny shut)
Pc is too high (Vacuum too low)
Psw is too low
Pss is too high
Tc is too high

(6) V_6 (Spill over shut off valve)
Auto. control:
Open at Pf> 20 ata (=Ca 283 psia)
Shut at Pf<15 ata (=Ca 213 psia)
Interlock: Automatic control and manual operating
Shut off at the following condition (Emergency shut)
Pc is too high (Vacuum too low)
Psw is too high
Pss is too high
Tc is too high

(7) V_7 (Spill over water spray valve)
Auto. control: Open at Pf> 20 ata (=Ca 283 psia)
Shut at Pf< 15 ata (=Ca 213 psia)
Interlock: Manual operation
Don't shut at Pf> 20 ata and V_6 open

(8) V_8 (Condenser level control valve)
Auto. control: Control to hold water-level at setting point (Lcn)
Interlock: ——

(9) V_9 (Condensate return valve)
Auto. control: Open at water-level> Lc_2 or Qc <35 t/hr (=Ca 79,200 lb/hr)
Shut at water-level <Lc3 or Qc> 40 t/hr (=Ca 88,000 lb/hr)
(At water-level <Lc_3 and Qc< 35 t/hr : Open
At water-level> Lc_2 and Qc> 40 t/hr : Open)
Shut at water-level <Lc_5 though Qc< 35 t/hr
Interlock: Manual operation
Don't open at water-level <Lc_5

(10) V_{10} (Boiler feed water tank level control valve)
Auto. control: Control to hold watet-level at setting point (Ldn)
Interlock: Automatic operation
Shut at condenser water-level <Lc_5

(11) V_{11} (L.P. heater level control valve)
Auto. control: Control to hold water-level at setting point (Ln_1)
Interlock: ——

(12) V_{12} (H.P. heater level control valve)
Auto. control: Control to hold water-level at setting point (Lhn)
Interlock: ——

(13) V_{13} (Air heater and oil heater steam pressure control valve)
Auto. control: Control to hold Ph. higher than 3.5 ata (=Ca 50 psia)
(Shut off when PⅡ is higher than 3.5 ata)
Interlock: ——

(14) V_{14} (Deaerator steam pressure control valve)
Auto. control: Control to hold Pd> higher than 2.0 ata (=Ca 28 psia)
(Shut off when PⅡ is higher than 2.0 ata)
Interlock: ——

(15) V_{15} (Water spray control valve for flash tank steam temperature control)
Auto. control: Control to hold Tf at 350°C or lower
Interlock: ——

(16) V_{16} (Drain tank level control valve)
Auto. control: Control to hold water-level at setting range
Interlock: ——

(17) V_{17} (Steam blow off valve)
Control: Controlled by manual and automatic (T_2) at boiler starting.
At boiler starting V_{17} holds the pressure Ff at ca 12 atg. till V_5 and V_6 can spill over the steam from flash tank to condenser.
(Condenser vacuum is OK.)
Interlock: ——

(18) VE I, VE Ⅱ, VE Ⅱ: Turbine extraction stop valve

Fig. 3 **Spillover live and aux. steam line control diagram**

Inlet steam pressure:	120 $kg/cm^2 \cdot abs$
Inlet steam temperature:	535°C
Extraction pressure:	
No. 1 extraction	16.9 $kg/cm^2 \cdot abs$ (at rated point)
No. 2 extraction	3.98 $kg/cm^2 \cdot abs$ (at rated point)
No. 3 extraction	0.80 $kg/cm^2 \cdot abs$ (at rated point)
Feed water temperrture:	201.1°C (at outlet of high pressure feed water heater)
Condenser vacuum:	0.052 $kg/cm^2 \cdot abs$ (at design point)
Cooling water quantity:	7500 m^3/hr (for condenser)
Cooling water temperature:	27°C (max. 30°C)

A once-through pressurized Benson boiler and a 2 casing turbine with barrel-type casing are employed for operational economy, safety and facility. The main line of steam and water is shown in the heat flow diagram in *Fig. 2* and the spill over line and the auxiliary steam lines indicated in *Fig. 3* are provided for starting, stopping and light load operation of the power station.

(3) Spill over line and auxiliary steam line

Generally, it is impossible to operate a once-through boiler continuously at less than 1/3 load, and at starting, stopping and light load operation, the excess steam must be blown off and dumped out. This is the only demerit of the once-through boiler. In Okinawa water consumption must be kept as low as possible, and therefore the spill over line is provided for the first time in non-reheated cycle to compensate for this demerit.

The performance and safety of the spill over line have been confirmed by tests. Usually, steam and water blown off from boiler at starting and stopping of the once-through boiler are flashed into the blowdown tank through the reducing valve. The steam is blown off to the vent and the drain is dumped out into the drain pit.

In the spill over system, steam or water from boiler is flashed into the flash tank, which has a pressure of 12～20 $kg/cm^2 \cdot g$. The steam in the flash tank is spilled over into the condenser, cooled and recovered as condensate. The drain in the flash tank is recovered in the deaerator.

To shorten the power station starting time the steam in the flash tank is used for the fuel oil heater and the steam air heater at a pressure higher than 1 $kg/cm^2 \cdot g$ and for the steam ejector of the condenser at a pressure higher than 12 $kg/cm^2 \cdot g$. The condensate is injected into the spill over steam and the spill over steam temperature is reduced.

The condenser vacuum, condenser temperature, injection condensate pressure and spill over steam pressure are confirmed and interlocked under spill over conditions.

If, the pressure in the 120 ata lines exceeds 130 ata for some reason other than starting, stopping and light load operation, the boiler starting stop valve and the boiler starting control valve are automatically opened and the steam is flashed into the flash tank. If this happens, the water extracted from the boiler feed water pump is injected into the steam and the steam temperature of flash tank is controlled at lower than 350°C.

The quantity of steam flashed into the flash tank fluctuates according to the starting condition of the boiler or others. The pressure of the flash tank is held at 20 ata by controlling the steam spilled over into the condenser with the spill over control valve. Therefore the steam flashed into the flash tank through the boiler starting control valve is recovered in the condenser while holding the flash tank pressure at 20 ata, and the drain formed owing to low temperature of the steam is recovered in the deaerator.

If the steam in the flash tank can not be spilled over into the condenser for some reason, the steam is exhausted into the air by the steam blow off valve and if the drain in the flash tank can not be recovered in the deaerator and the water level in the flash tank reaches the limit, it will be exhausted into the blow down tank and dumped out into the drain pit.

By means of spill over system, the once-through boiler plant can be operated continuously at less than 1/3 load without water consumption.

When turbine load is suddenly shut off and the 120 ata line pressure rises, the boiler starting/stop valve is automatically opened and the 120 ata line pressure is held below 130 ata by regulation of the boiler starting control valve. The spill over stop valve is automatically opened and the flash tank pressure is held at 20 ata by regulation of the spill over control valve.

By this control of the spill over system, the operation of the safety valves at the boiler outlet is kept as low as possible and the water consumption is also saved.

The reducing by-pass valve provided from the flash tank to the No. 2 extraction line makes deaeration of the feed water possible soon after starting. This by-pass also prevents the deaerator pressure from dropping quickly at shut-off of turbine load and stable operation of the boiler feed water pump is ensured.

If the turbine load drops and No. 2 extraction pressure falls below 3.5 ata, the reducing by-pass valve from No. 1 extraction line to No. 2 extraction line is opened and holds the steam pressure for the fuel oil heater and the steam air heater at 3.5 ata.

To save water, the drain of the fuel oil heater and the steam air heater is recovered through the heater drain pump and pressure atomizing burners are provided in the boiler, but no steam converter is used in the fuel heating line. Therefore a double con-

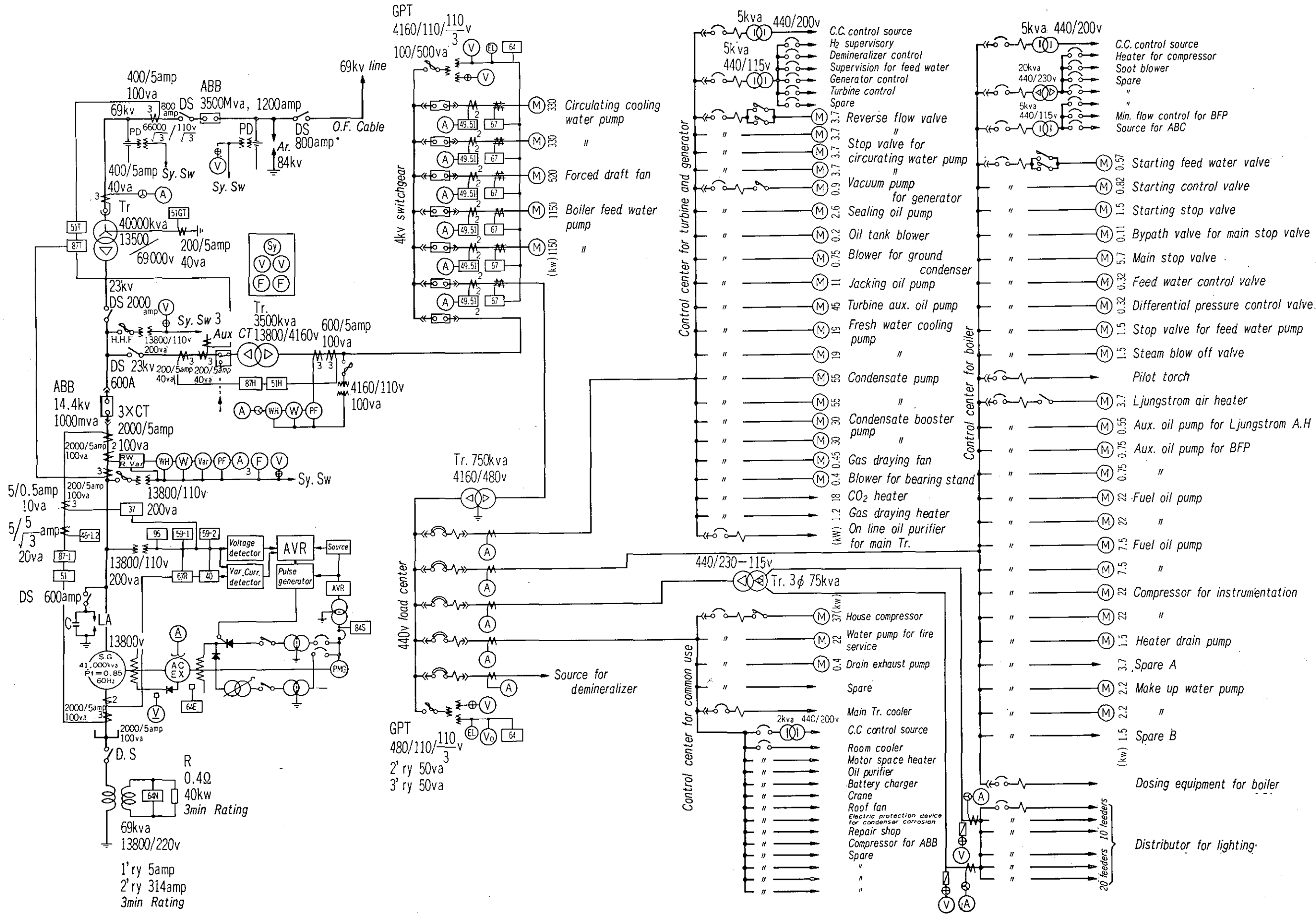


Fig. 4 Electrical skeleton diagram

struction tube is adopted for the fuel oil heater to prevent any fuel leakage. Even if fuel leakage should occur the fuel oil can not leak into the steam or drain and leaks only to the air.

IV. ELECTRICAL SYSTEM

As is shown in *Fig. 4*, electrical skeleton diagram, the 13,800 v generated by the 41,000 kva generator is stepped up to 69,000 v by the main transformer and connected to the 69 kv line.

The station power is supplied by a 3500 kva house transformer which steps down 13,800 v to 4000 v. Votlages of 4000 v, 440 v, 220 v, 110 v and 125 v dc are used for station power. 4000 v is applied to the motors of 150 kw and over, 440 v to those of lower than 150 kw, and 220 v, 110 v and 125 v dc to special motors and the control source. 220 v and 110 v are employed for illumination and other general uses.

In normal operation the house transformer is supplied from the 13,800 v generator output while at standstill of the turbo-set it is supplied by the 69 kv line and can also be supplied from the power barge Jacova as a standby source in an emergency.

The 440 v line is supplied from the 4000 v line by a 750 kva step-down transformer, and the 220/110 v lines are supplied from the 440 v line.

The main electrical equipment is as follows.

(1) Generator

Type:	Horizontal shaft cylindrical rotary field-type synchronous generator
Output:	41,000 kva
Voltage:	13,800 v
Power factor:	0.85
Phase:	3ϕ
Frequency:	60 Hz
Speed:	3600 rpm
Short-circuit ratio:	0.64
Cooling system:	Hydrogen cooled (Pressure: max. 2 kg/cm$^2\cdot$g)
Connection:	Star
Insulation:	B class
Exciting system:	Brushless
Neutral grounding:	5 amp transformer grounding

(2) Main transformer

Type:	Outdoor type forced-oil circulation, forced-air cooling, diaphragm conservator, on-load tap-changing transformer
Capacity:	40,000 kva

Voltage:	1ry 13,800 v
	2ry 60,000～69,000～72,000 v 17 step on-load tap-changing, tap-voltage: 750 v
Frequency:	60 Hz
Connection:	1ry delta
	2ry star
Neutral grounding:	Direct grounding

(3) House transformer

Type:	Outdoor use self-cooling nitrogen sealed type
Capacity:	3500 kva
Voltage:	1ry 13,800–13,500–13,200 v
	2ry 4160 v
Frequency:	60 Hz
Connection:	1ry delta
	2ry delta

(4) 69 kv line circuit breaker

Type:	Outdoor use constantly-pressurized air blast circuit breaker
Rated voltage:	72,000 v
Rated current:	1200 amp
Rupturing capacity:	3500 Mva
Frequency:	60 Hz
Air pressure:	15 $kg/cm^2 \cdot g$

(5) 13.8 kv line circuit breaker

Type:	Indoor use constantly-pressurized air-blast circuit breaker (included in cubicle)
Rated voltage:	14,400 v
Rated current:	2000 amp
Rupturing capacity:	1000 Mva
Frequency:	60 Hz
Air pressure:	15 $kg/cm^2 \cdot g$

(6) 4.16 kv line circuit breaker

Type:	Indoor use minimum-oil circuit breaker (included in cubicle)
Rated voltage:	7200 v
Rated current:	600 amp
Rupturing capacity:	150 Mva at 4160 v (250 Mva at 7.2 kv)
Frequency:	60 Hz

The 69,000 v stepped up from the 13,800 v of the generator can not be directly connected to the overhead wire of the existing 69 kv line, since the power station is located near an airfield. Therefore, it is connected in the 69 kv switch yard of the power station to O.F. cable, which is laid underground for approximately 300 m, and then connected to the 69 kv overhead wire.

The power station is started by the 4000 v stepped down from 13.8 kv in turn stepped down from 69 kv. For outdoor use 69 kv equipment measures must be taken against salt contamination, but the hot-line washing method can not be applied and the only means is to coat bushings having a long creepage path with silicon grease. For example, the 69 kv bushing of the main transformer has a 3060 mm creepage path. At the 13.8 kv line the connection from the generator to the main transformer through a 13.8 kv circuit breaker is performed by means of bus-ducts and the connection to the house transformer is by a cable connection, namely elephant type transformer. None of the 13.8 kv parts are exposed to salt contamination. The 2ry side of the house transformer is also of the elephant type and connected to the 4000 v metal-clad cubicle. All switch gears for the motors and power station equipment are included in the electrical power room and all electrified parts are covered by cubicles or bus-ducts. Thus this electrical equipment is able to withstand salt contamination and maintenance is safe.

V. COOLING WATER SYSTEM

The cooling water system for the condenser and miscellaneous equipment is shown in *Fig. 5.* The circulating water is pumped up by the circulating water pump at the intake pit through a bar-screen and a rotary screen (which will be installed in the future) and sent to the condenser.

The cooling water boxes of the condenser are divided into 2 parts and the circulating water line is also divided into 2 lines. At each inlet of the cooling water boxes a reverse flow valve is provided and the condenser can be cleaned and washed half at a time during operation of the turbine. From the condenser, the circulating water passes again through the reverse flow valve and is led to the syphon pit which has been installed to provide syphon action in the circulating water line. From the syphon pit the circulating water is discharged to the drainage apron through a concrete pipe 150 m in length.

The condenser is directly cooled with circulating water, but all other machines and equipment are cooled with fresh water which is cooled in the fresh water cooler with circulating water from the main circulating water line.

The fresh water is the same water as the boiler feed water, treated with chemical water treating equipment and replenished by level control of the fresh water tank simultaneously with the make up water pump for the boiler feed water. A deoxidizer is periodically put into the fresh water. In Okinawa it is difficut as a rule to use the city water for cooling since it is very hard type water.

As a rule all the fresh water used for cooling is recovered and returned to the fresh water tank to keep water consumption low.

Ductile cast iron and stainless steel pipe are used for the circulating water line, steel pipe for the fresh water line, 10% cupronickel tube for the cooling tube of the condenser and alminum brass tube for the cooling tube of the fresh water cooler.

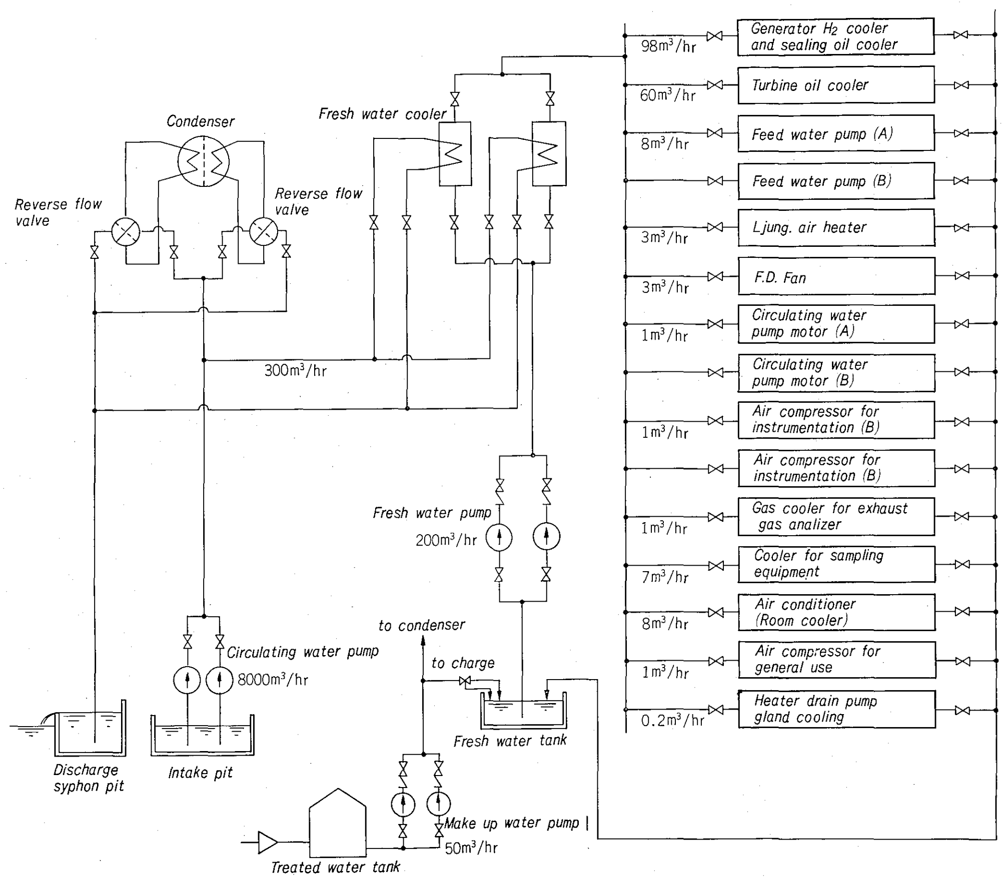


Fig. 5 Cooling water system

The main equipment in the circulating water system is as follows.

(1) Circulating water pump

Number of sets:	2 (1 standby)
Type:	Vertical diagonal flow type
Capacity:	8000 m^3/hr
Head:	11 m Aq.
Speed:	500 rpm
Req. motor:	330 kw

(2) Fresh water cooler

Number of sets:	2 (1 standby)
Circulating water flow:	300 m^3/hr
Fresh water flow:	200 m^3/hr
Circulating water temperature:	Max. 30°C
Fresh water temperature:	Inlet 41.5°C
	Outlet 35°C

(3) Fresh water pump

Number of sets:	2 (1 standby)
Type:	Horizontal double suction centrifugal type
Capacity:	200 m^3/hr
Head:	20 m Aq.

VI. REPLENISHMENT WATER AND WATER TREATMENT

The standard quality of city water for replenishment is shown in *Table 1* and the specifications of the chemical water treating equipment for the boiler feed water are as follows.

The water quality, however, fluctuates according to seasons. During periods of water shortage, the quality is very low and in summer so much chloride is added for sanitary reasons that the free chloride increases. Therefore more sodium sulfate must be injected into crude water and as a result the total capacity of the water treating equipment goes down.

(1) Chemical water treating equipment

Type: 2-bed 3-tower with mixed bed polisher type demineralizer

***Table 1* Standard Quality of City Water**

Total Cation	316 ppm	as $CaCo_3$
Total Anion	331 ppm	〃
Free CO_2	10 ppm	〃
Ca^{++}	260 ppm	〃
Mg^{++}	22 ppm	〃
$Na^{+}+Ka^{+}$	34 ppm	〃
HCO_3^-	205 ppm	〃
SO_4^{--}	25 ppm	〃
Cl^-	86 ppm	〃
SiO_2	5 ppm	〃

Capacity :	152 tons/day × 2 lines (8 tons/hour × 2 lines) (operation : 19 hours, regeneration : 5 hours)
Regeneration chemicals :	Caustic soda, sulfuric acid
Treated water quality :	Conductivity : 0.2 μ℧/cm Residual silicon acid : 0.02 ppm
Crude water tank :	120 m^3
Treated water tank :	200 m^3

Water which is replenished to the heat cycle is supplied from the treated water tank to the condenser with the make up water pump. Part of the water is branched off and led to the fresh water tank for replenishment of the fresh water cooling line.

In addition to the chemical water treating equipment for boiler feed water, a condensate dimineralizer is provided at the outlet of the condenser so that the turbine can be operated continuously even if sea water (circulating water) leaks into the condenser. The 36,000 kw turbine capacity is comparatively small, but 36,000 kw corresponds to 15% of the total capacity of the line and is the largest capacity unit in Okinawa. The operation of this unit has a great influence on the lines, and therefore safer operation is expected by installation of the condensate demineralizing equipment. The specifications of the condensate demineralizing equipment are as follows. The equipment consists of 2 sets, each half of the capacity of the maximum amount of condensate.

Both sets are always operated and regenerated periodically one by one and when there is no sea water leakage by bypassing one half. Therefore the equipment is always prepared for leakage.

When the condensate is contaminated owing to a leakage of sea water and the conductivity rises to 10 μ℧/cm, the 10,000-ton condensate can be treated with the condensate demineralizer and the turbine can be operated for 100 hours at full load.

In the case of 100 μ℧, the 1000-ton condensate can be treated and the turbine can be operated for 10 hours. Therefore if the conductivity rises, the two cooling water boxes are opened one by one at a half load of the turbine and the condenser can be inspected and required half at a time. The tubine need not be stopped and can be operated continuouly when repairing condenser leakages.

(2) Condensate demineralizing equipment

Standard water quality at inlet :

pH :	8.3～9.5
Coductivity :	0.3 μ℧/cm
P-alkalinity :	0.05 ppm
M-alkalinity :	0.01 ppm
O_2 :	0.03 ppm
Fe :	0.03 ppm
Cu :	0.005 ppm
SiO_2 :	0.2 ppm

Treated water quality (standard)

Conductivity :	0.2 μ℧/cm
Fe :	0.01 ppm
SiO_2 :	0.01 ppm

Treated water quality at 100 μ℧/cm

Conductivity :	0.2 μ℧/cm
SiO_2 :	0.02 ppm

Operation and regeneration time

Standard :	2 weeks
Conductvity 10 μ℧/cm :	100 hours
Conductvity 100 μ℧/cm :	10 hours
Regeneration :	4 hours
Regeneration chemicals :	Caustic soda, sulfuric acid

VII. ARRANGEMENT, STRUCTURE AND FOUNDATION

The overall plan view of the power station is shown in *Fig. 6*. The plan view of the first and second floors are shown in *Figs. 7* and *8* respectively. The Chatan

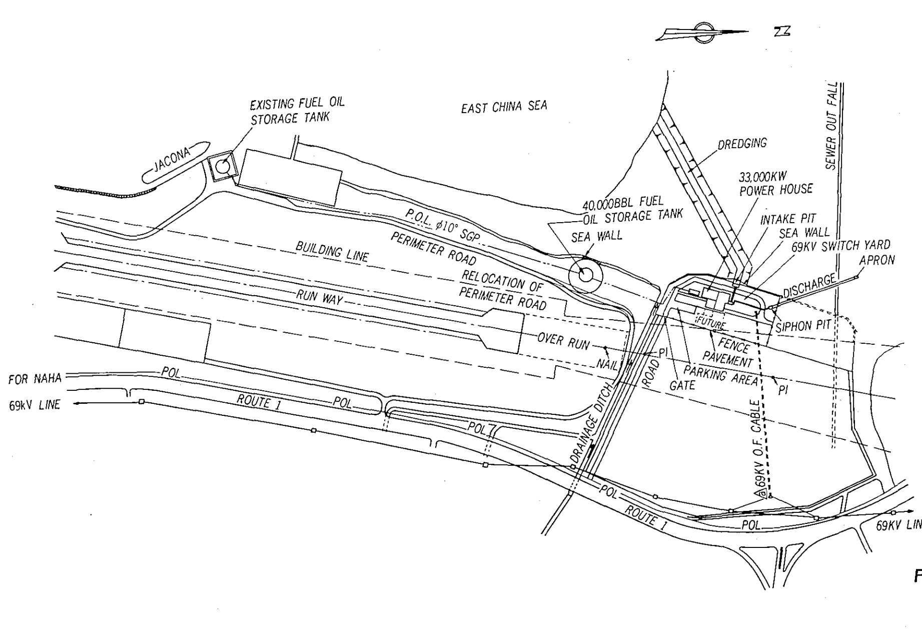


Fig. 6 Plan view of Chatan Power Station

Frequency :	240 Hz
Speed :	3600 rpm
Power factor :	0.9 (lag)
Number of poles :	8

(2) Rotary rectifier

Type :	3-phase Graetz-connection silicon rectifier
Output :	130 kw
Voltage :	250 v
Current :	520 amp

(3) Permanent magnet generator

Type :	Horizontal-shaft rotating permanent-magnet field type generator
Output :	3.5 kva
Voltage :	110 v
Frequency :	60 Hz

(4) Automatic voltage regulator Thyristor TRANSIDYN type AVR

The brushless excitation system of this generator has been used in more than 15 generators and is highly praised for its excellent controlability and reliability.

Equipment for field circuit ground detection, field current measurement, field voltage measurement, stator coil temperature measurement and the field coil tem- perature measurement are provided for supervising the generator. In spite of the brushless exciting system, the field current and the field coil temperature are still measured.

X. CONCLUSION

The Chatan power station presented in this article has been planned and constructed by the primary contractor, Fuji Electric, as a full turn-key job. Because of the stringent conditions of electric power supply in Okinawa, installation work, trial operation and test work also had to be finished in a very short time and all work made very rapid progress.

From the beginning of planning, the delivery time and the transportation of all machines and equipment were carefully and scrupulously kept to schedule. For example, terminals of both 440 v and 220 v were provided for the low tension motors so as to be operated with the electric source for the installation work in case of emergency. Thus the power station could be completed one month earlier than expected.

This means that the manufacturing not only made rapid progress according to schedule, but each piece machinery and equipment could perform satisfactorily. This is also evident from the fact that the guaranteed net heat rate of this not-reheated power station was a very low value of 2588 kcal/kwhr and the test result was 2446.3 kcal/kwhr lower than guaranteed.

Fuji Electric was able to finish the Chatan power station in a very short time with a very fine performance through the cooperation of the Ryukyu Electric Power Corporation and the subcontractors. We would like to express sincere thanks for the cooperation of all persons concerned.

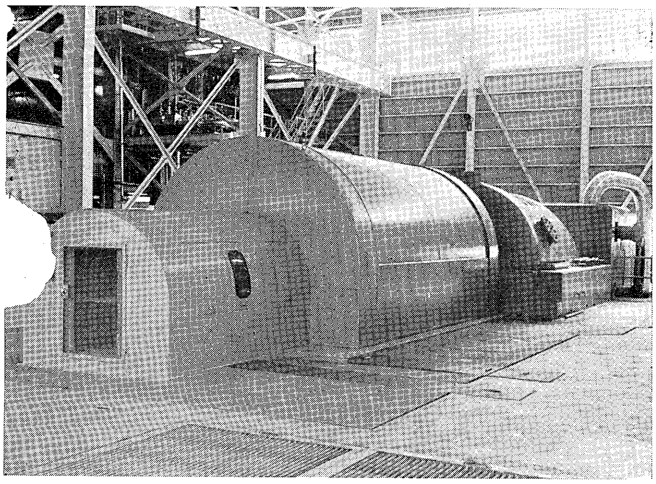


Fig. 11 Turbine room

sing, and No. 2 and No. 3 extraction steams are extracted from the low pressure casing. The high ssure casing and the low pressure casing are arnged in opposite directions so as to balance thrust e axial direction.

e blades employ a round reaction profile, the efficiency of which has been confirmed in cascade e tests and the actual test results with many exist- turbines. The profile makes possible the extremew value of the turbine heat rate.

ne blades of high and medium pressure parts are ed together with the shroud to the round reac- profile. The profile has a very high value of section modulus so that it is able to lower the stress level of the blades, while the friction damping effect of the shroud lowers vibration stress remarkably. Blades 465 mm in length were employed in the last tage of the low pressure turbine which has the greatest influence on turbine efficiency. The blades which are of the independent self-supporting propeller type, have neither wire lacings nor shroud rings, and have very high vibration stability and strength. Both rotors of the high and low pressure turbines have a critical speed as high as 130% of the normal operating turbine speed, i.e. the rotor is a rigid rotor. urbines' with rigid rotors have very high stability and reliability at installation, starting and operation, and the maintenance of the turbine is very easy.

The speed governor and load control is the Fuji draulic governer which has a very high stability and makes stable operation possible in spite of the small inertia of the 6.6 sec machine inertia constant.

Considering the small machine inertia constant and energy of the steam included in the turbine casing nd the nozzle box, a load shedding relay is provided and the turbine is prevented from tripping due to overspeeds at turbine load interruption.

(2) Condenser

Cupronickel tubes are used for the cooling water of the condenser and in the condenser, the steam the spill over system explained in Item III–(3) must be also cooled and recovered at starting, stopping and light load operation. The spill over steam can be spilled over into the condenser only under the following conditions.

Condensate pressure: Lower than 0.5 kg/cm²·abs

Condenser temperature: Lower than 120°C

Spill over steam pressure: Higher than 12 kg/cm²·g

Injection condensate pressure: Higher than 1 kg/cm²·g

Even if only one of these conditions is not satisfied, the spill over control valve and the spill over stop valve are automatically closed.

The replenishment water to the heat cycle of the boiler and the turbine is supplied to the condenser so that control of water quantity in the heat cycle, i.e. water level control in the cycle, is finally regulated at the water level in the condenser so as to open the the make up water control valve V_8 in *Fig.* 3 on the low water level, and to open condensate return valve V_9 in *Fig. 3* and return the condensate to the treated water tank at the high water level.

A steam ejector is applied to the vacuum pump of the condenser and the steam used in the ejector is cooled with condensate. At light load operation of the turbine, the cooling water for the ejector is ensured by opening condensate return valve V_9 in *Fig. 3* and circulating the condensate between the condenser and the treated water tank. The condensate pump is divided into a condensate booster pump and a condensate main pump. The condensate booster pump which can fully appropriate the water level of the condenser for the suction head of the pump, has a sufficient margin for the required NPSH of the pump. The condensate is sent by the condensate booster pump from the condenser to the outlet of the condensate demineralizer, and by the condensate main pump from the outlet of the condensate demineralizer to the deaerator through the low pressure feed water heater. Owing to the division of the condensate pump, the withstand pressures of the steam ejector, the gland steam, condenser and the condensate demineralizer can be lowered.

IX. GENERATOR

The generator is of the hydrogen cooled type and has a brushless exciting system as explained in Item IV. The specification of the brushless exciting system is as follows.

(1) Ac exciter

Type:	Horizontal-shaft rotating-armature type synchronous exciter
Output:	140 kva
Voltage:	195 v
Curreut:	415 amp

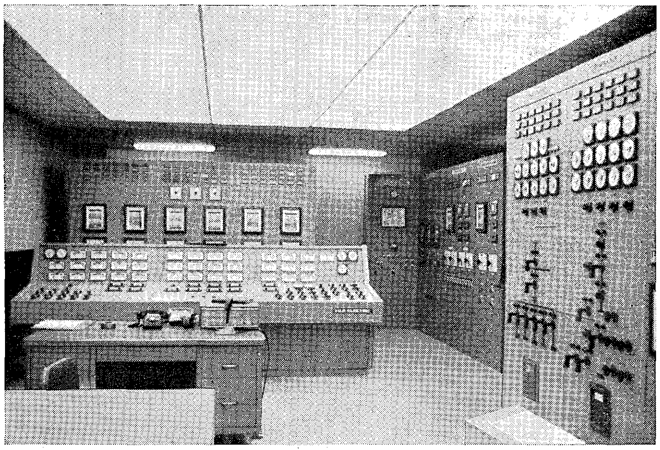


Fig. 9 Central control room

into consideration for the arrangement of the machines and equipment. The turbine room is located in the center of the station and the chemical water treating equipment and the condensate demineralizer are installed on the opposite side of the boiler where the circulating water pipe comes into the turbine room, to prevent the piping and cable from becoming congested.

The central control room and the electrical power room are located in the same position on the first floor and the second floor, and the cable room is located between the central control room and the electrical power room. All of the control cables for the electrical system and the instrumentation system which are the nerves of the power station are concentrated in the cable room. Here they are rearranged and connected to the central control room and the electrical power room.

The control and supervising panel for the whole station, boiler, turbine, electrical systems, chemical water treating equipment, condensate demineralizer, feed water quality and others are centralized in the central control room and all electrical switch gears for 4000 v and less are installed in the electrical power room.

During typhoons all opening parts of the station house such as windows, doors, etc. must be tightly closed to withstand winds of a maximum speed of 80 m/sec. The boiler is for indoor use and the forced draft fan is also installed indoors so that an inlet with a suitable area corresponding to the amoun of boiler combustion air and ventilation air must be provided.

At the air inlet, open areas of 8 m^2 and 1.2 m^2 are provided on the wall near the forced draft fan and around the exhaust gas duct of the boiler.

A protection screen and louvers are installed again wind and rain and saran wool filter are provided side the louver to prevent rain from entering house due to the wind.

The difficulty with the foundations of the structures and the turboset was the great unevenness of the site base foundation. When piles for the turboset foundation were driven in one meter apart, one of the piles was inserted 10 m deep and reached the base foundation but another was inserted only 1 m deep. In this case it had to be confirmed by boring that the pile reached the base foundation and could support the load.

The turbine base is of elastic construction with a natural vertical resonant frequency lower than t normal turboset speed (3600 rpm).

This has meant that the columns and beams be very small so that little concrete was req but the design had to be most carefully investi with regard to base vibration for the various len of the piles.

After completion, the base was tested with a of 500 tons before installation of the turboset safety was confirmed.

VIII. TURBINE

(1) Turbine

As is shown in *Fig. 10*, this turbine is constructed in two cylinders : a high pressure casing and a lo pressure casing. The high pressure casing employs an inserted nozzle box type pot casing (barrel type casing). The pot casing is a unique Fuji Electric design with the most appropriate elastic construction In this case, the turbine capacity corresponds to 15% of the line capacity so that the barrel-type casing is very effective for stable operation of the line.

The low pressure casing has a horizontal flang and is composed of upper and lower parts. No. 1 extraction steam is extracted from the inlet of the low pressure casing, i.e. the outlet of the high pressu

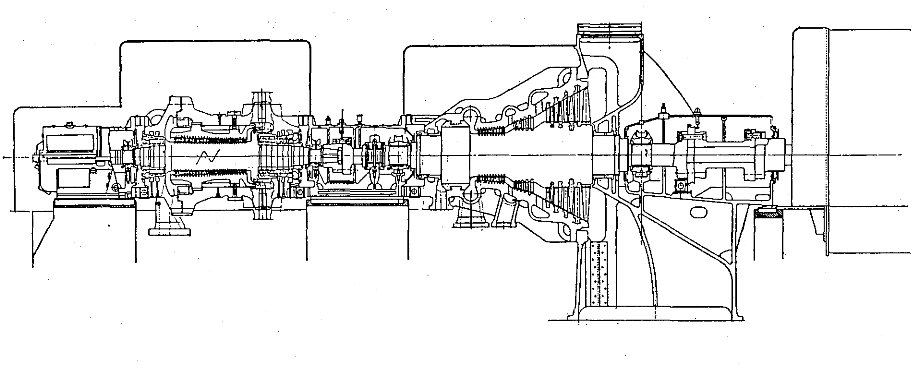


Fig. 10 Turbine sectional view

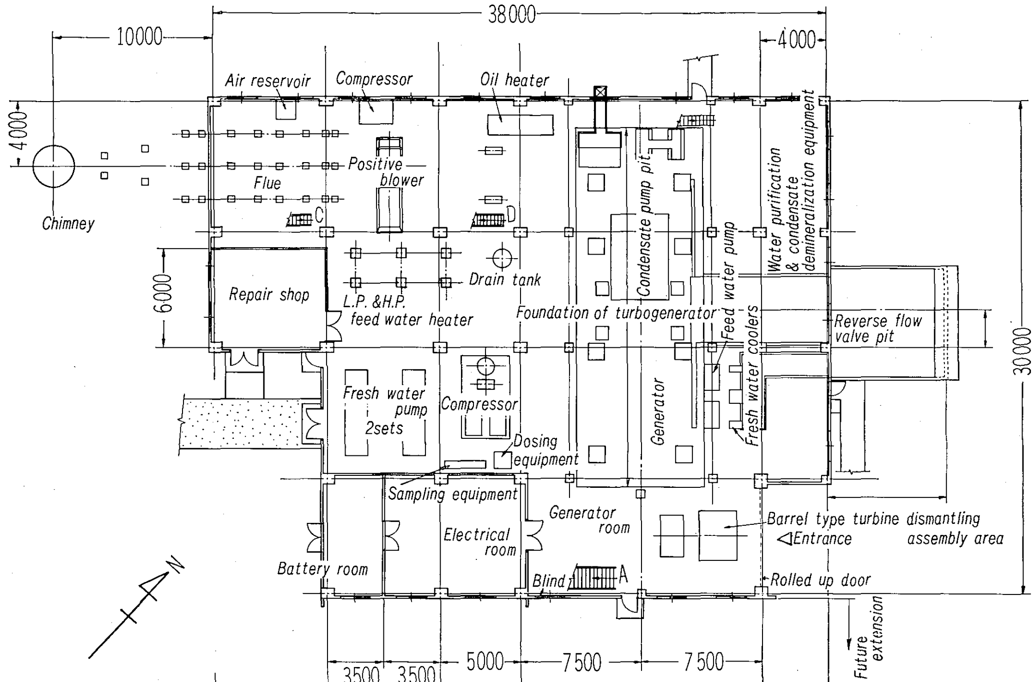


Fig. 7 Plan view of the power station 1st floor

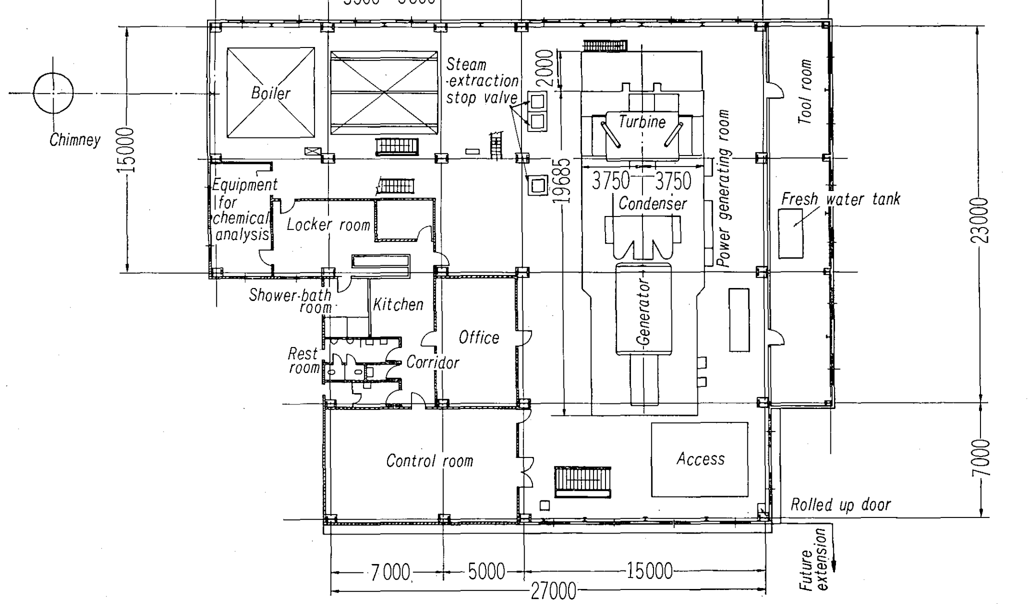


Fig. 8 Plan view of the power station 2nd floor

power station is located on the west coast of Okinawa some 15 km north of Naha City on the left side of Route No. 1.

As can be seen from *Fig. 6*, the Jacova power barge is moored 1000 m south of the power station, where the fuel oil is pumped up and sent from tankers to the existing fuel storage tank and a new 40,000-barrel fuel storage tank, from which the fuel oil is transferred to the service tank in the power station by means of the fuel oil transfer pump.

It is clear from *Fig. 6* that the runway extension of the airfield passes near the power station so that the arrangement of the power station, especially the arrangement of the stack, the building and the 69 kv switch yard structure, is restricted and connection to the existing 69 kv line must be made with O.F. cable, laid for about 300 m underground.

The shore protection works were excecuted from the fuel storage tank to the station building across a creek and further to the discharge piping. The intake pit for circulating water is located at the side of the station building. The circulating water is pumped up and led from the pit to the condenser through underground ductile cast iron pipes, and then sent from the condenser to the syphon pit. From the syphon pit it is discharged to the drainage apron through concrete pipes across the sewer line.

The beach near the power station consists of coral reef and shoals stretching for about 300 m out from the coastline. This beach was dredged for the circulating water ditch and the dredged sand was used for grading the site. Shorter connections and clear separatotn of the steam system, feed water system, circulating water system and electrical system were taken