FIRST NUCLEAR POWER STATION IN JAPAN

By

Hirosaburō Yamamoto

(Atomic Power Dept.)

I. INTRODUCTION

A nuclear power station of 150 MW output is now under construction at Tōkaimura, seventy miles north-east of Tokyo, by the Japan Atomic Power Co. (JAPCo.) It is the first nuclear power station in Japan, and is expected to be completed in 1963.

The formal order to manufacture the main reactor including reactor building and turbo-generator sets for the above power station has been given to the General Electric Co. (G.E.C.) of England at the end of last year, and the Fuji Denki Seizo K.K. (Fuji Electric Mfg. Co., Ltd.) as the leading company of the First Atomic Power Industry Group (FAPIG) in this country is now co-operating with G.E.C. by supplying some essential parts of the reactor such as pressure vessels, steam raising units and a reactor building. The JAPCo. was established in 1957 having nine representative electric power companies and five atomic power industry groups in this country as its chief shareholders aiming to construct nuclear power stations necessary at present for our country.

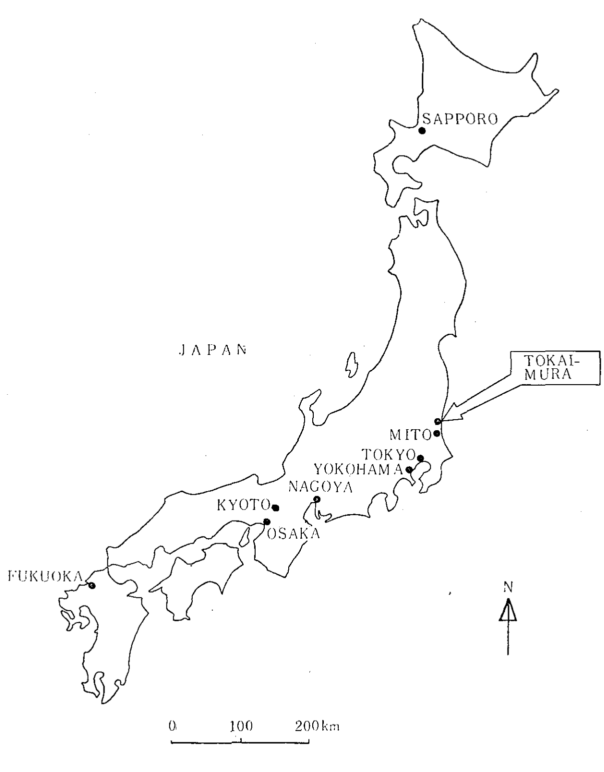

Fig. 1. Location of Tōkaimura

The value of the present order amounts to £ 20 million. The natural uranium fuel elements are to be supplied by British A.E.A, the amount of which is approximately £ 4 million. The total cost of construction including the above two, station site and others, will become approximately £ 35 million.

II. GENERAL FEATURES

It is a single-reactor power station and the reactor proper is similar to those already being built for the British nuclear power programme. It is a carbon dioxide gas cooled graphite moderated natural uranium reactor and belongs to the so-called advanced Calder Hall type.

The reactor core is piled with interlocked graphite units which in total weigh approximately 1,500 tons. It is surrounded with a cylindrical core restraint made of steel. The outer diameter is approximately 13 m and height is approximately 8 m. Inside the graphite core are approximately 2,000 vertical channels which receive the uranium fuel elements.

The core with the restraint is contained in a spherical steel pressure vessel having a diameter of approximately 19 m. The thickness of a concrete wall surrounding this sphere and acting as biological shields is 3 m.

Four steam raising units are provided and CO_2 cooling gas is circulated by four steam-driven centrifugal fans of each 8,000 HP as indicated by arrows in Fig. 2. The gas pressure is 14 kg/cm^2 and the diameter of pipings is 1.8 m.

III. SPECIAL FEATURES

The reactor is provided with a total of about 120 control rods made of neutron absorbing boron material and a fuel element charging and discharging machine which can operate while the reactor is even on full load. The control rods and the charging and discharging machine are located above the reactor pressure vessel making the centre of gravity of the reactor itself as near as possible to the

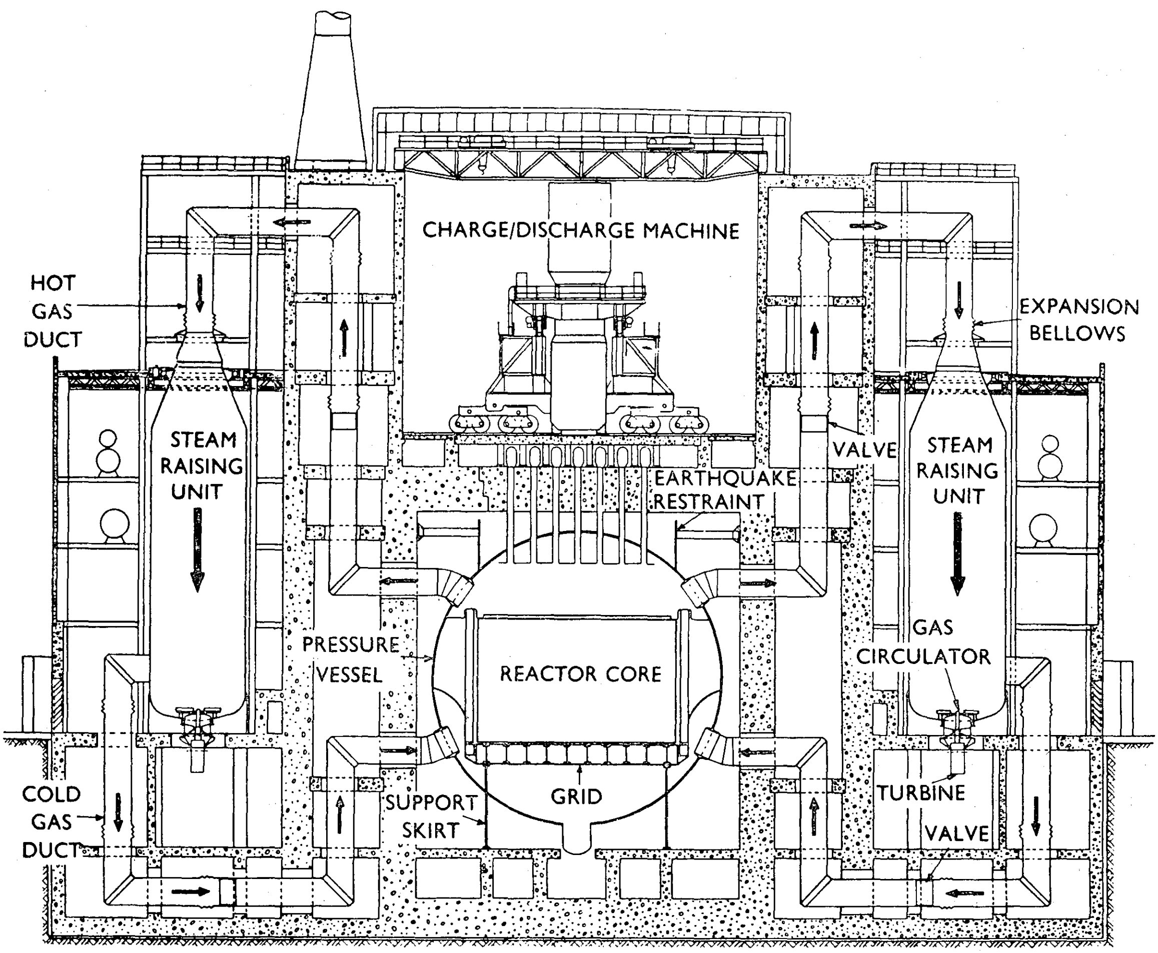

Fig. 2. Section of reactor building

ground floor and thus increasing the stability of the vessel against earthquakes.

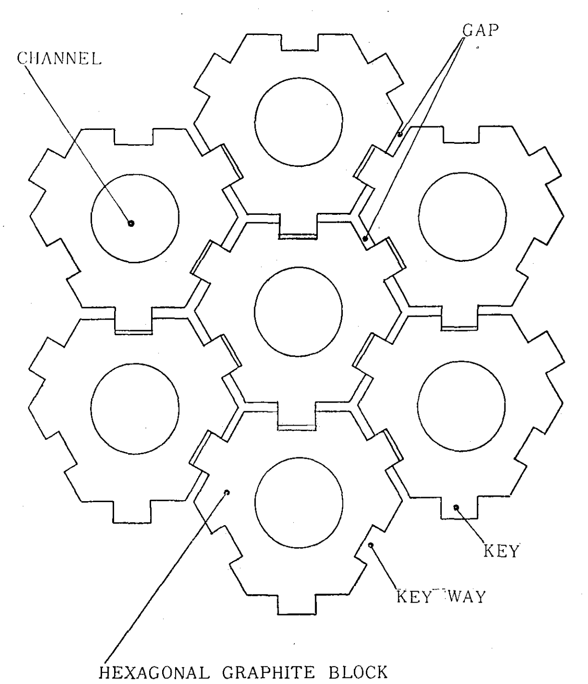

Fig. 3. Graphite block

The most important special problem for nuclear reactors to be installed in this country is to make them earthquake-proof and a special consideration must be given to the structural construction. The reactor vessel and the steam raising units are mounted on one concrete foundation raft so that the uniformity of their movement during earthquake including gas circuit is assured. All the structural components are designed considering the earthquake shock of 0.6 g in the horizontal direction and 0.3 g in the vertical direction.

The elements of the graphite core are hexagonal blocks as shown in Fig. 3 and by gearing their keys and keyways each other the whole piling can be kept flexible and rigid, flexible for thermal expansions and rigid for earthquakes.

IV. IMPROVED DESIGN

If we compare some design data of the present reactor with those of Hunterston power station which is now under construction by G.E.C., we can understand that the present design is by far improved and it holds the top of technics at present.

Hollow cylindrical fuel elements are first to be used in this reactor instead of solid bar type elements which were common with the previous reactors. This fact of avoiding the excessive rise in temperature at the central part of the bar, and many other secondary improvements reduced the design weight in total of uranium fuel for 150 MW output to 185 tons as compared with the case of Hunterston power station which requires the fuel of 250 tons. Following the same line the total weight of the graphite pile becomes 1,500 tons instead of 2,150 tons.

The outlet temperature of CO_2 cooling gas is raised to 400°C, 10°C higher as compared with the case of Hunterston and its pressure to 13.8 kg/cm^2 from 10.5 kg/cm^2. In addition to the change of core dimensions, this reduced the diameter of pressure vessel to 18 metres from 21 metres.

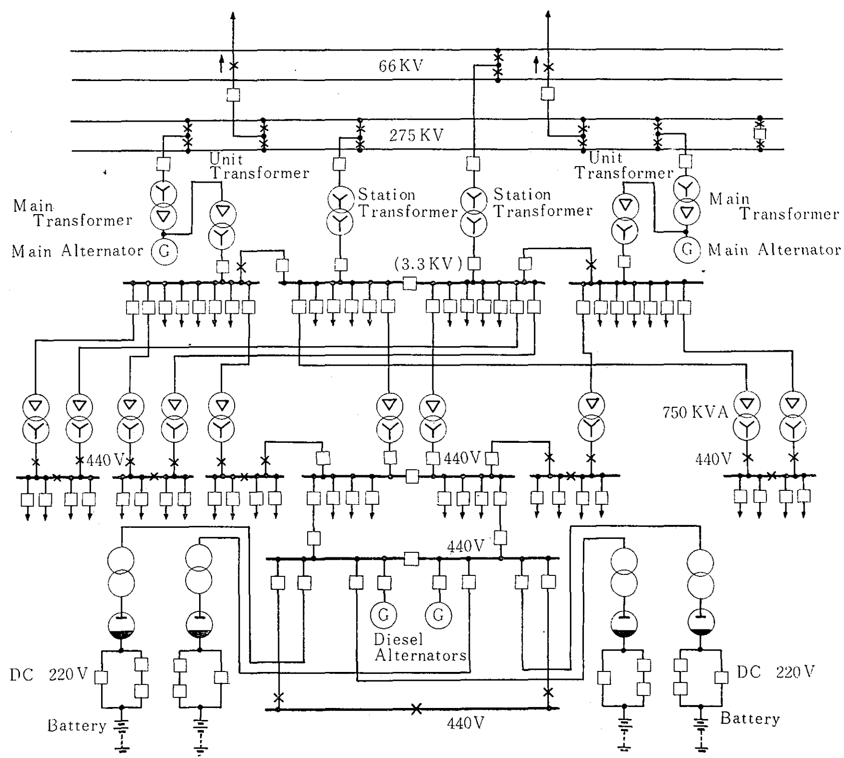

Fig. 4. Connection diagram of electric equipment

The temperature of steam and its pressure are also increased ; temperature being 376°C and pressure 65 kg/cm^2, while the number of steam raising units and of the turbo-generator sets are halved, number of steam raising units being 4 and number of turbo-generator sets 2. This means that the size of units is much increased.

V. GENERATING EQUIPMENT

Two steam turbines have each 85 MW output at 3,000 rpm. They belong to dual-pressure steam turbines with condensing plants and driven by high pressure steam of 63 kg/cm^2·G. and low pressure steam of 21 kg/cm^2·G. from the steam raising units. Besides these two main turbines, there are four other 8,000 HP back pressure steam turbines for driving the centrifugal blowers in the plant and 90% of high pressure steam from the steam raising units first passes through these four turbines before they enter the main turbines.

The steam condensers for the steam turbines consist of two main condensers and two dump condensers. The main condensers have each a cooling surface of 100,000 m^2 which is large enough for a 150 MW class modern thermal plant with steam of higher temperature and higher pressure. The dump condensers are designed for capacities of each 10% of the main condenser. These receive the exhaust heat from blower turbines at the starting of the reactor and absorb the decay heat from uranium fuel at the shutting down of the same. The cooling water for the steam condensers amounts to 6 m^3/sec. and after comparing the economy between river water and sea water, it was decided to take the water from the sea (Fig. 5).

The capacities of two generators are each 100,000 kVA at 11.8 kV 0.85 pf, 3,000 rpm and 50 c/s They are hydrogen cooled rotating field type synchronous machines, directly coupled to the main steam turbines, using hydrogen gas of 3.1 kg/cm^2·G. and directly cooled hollow conductors for the rotor windings.

The generated electricity is stepped up to 275 kV by the main transformers (Fig. 4), and sent out to the network of the Tokyo Electric Power Co., Inc. The station switch yard will be located at the east side of the plant as shown in Fig. 5.

To get the necessary driving powers for the power station control, four step down transformers are provided.

They are 2–Unit transformers
5,000 kVA 11.8/3.3 kV
1–Station transformer
100,000 kVA 275/3.3 kV
1–Station transformer
5,000 kVA 66/3.3 kV

These powers are once more stepped down to 440 V to feed the power station auxiliaries which in case of emergency can also be fed by two Diesel engine driven generators of each 1,300 kW. Further

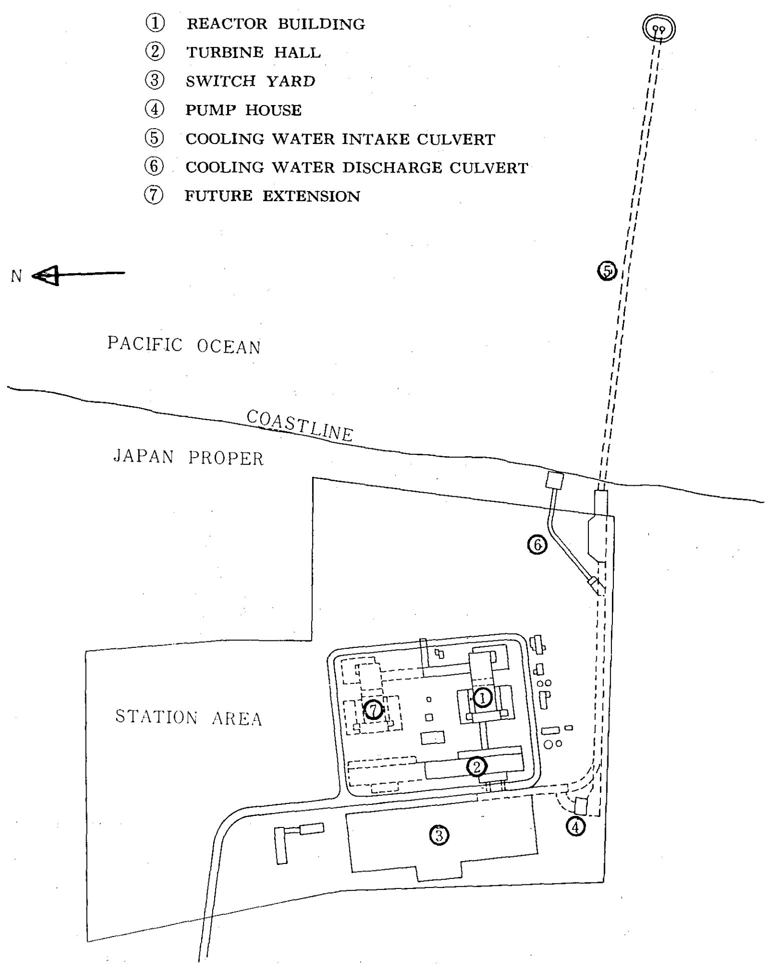

Fig. 5. Arrangement of power station

2 sets of DC 220 V battery sources supply necessary DC power for both ordinary and emergency control.

VI. METHOD OF CONTROL

When the output of the AC generator changes, the pressure of steam, the temperature of the CO_2 gas and consequently the temperature of the reactor core change. The principle of operation of this power station is to control to keep the CO_2 gas temperature at its reactor outlet constant at a fixed value by adjusting the gas flow with a variable speed gas blower and by changing the position of the control rods in the reactor core.

Each of the four single stage centrifugal blowers is mounted at the base of the pressure shell of each of the four steam raising units and is driven by a variable speed steam turbine having an output of 8,000 HP at its maximum speed. This direct steam drive is the first trial in this field and prevents the loss accompanied by converting the heat in the steam once into electricity, as in the case of electric motor drive.

The constant outlet gas temperature and direct-steam variable-speed-driven blowers keep the obtainable maximum efficiency of the power station throughout its working range.

VII. SAFETY DEVICES

In addition to the normal control rod system including emergency trips, a special shut-down device is provided for the reactor. The device comprises a large number of boron-steel balls which can be released into special channels through the core. These balls are dropped into the core in sufficient quantity to shut down the reactor even in the event of severe earthquake which might seriously disrupt the graphite structure. The diameter of these balls is about 20 mm.

Although the ducts and their supports connecting the reactor pressure vessel to the steam raising units have been designed so that no breach could occur in the gas circuits even under the conditions of severe earthquake, a spare carbon dioxide reservoir is provided to keep minimum cooling gas supply and to avoid the fusion of uranium fuel elements even if the ducts break in their junctions with the pressure vessel.

VIII. CONSTRUCTION PROGRAMME

The area of the site for the power station is 241,300 square metres. The same for the reactor building is 3,220 square metres and the building is of reinforced concrete, which is 43 metres high above ground and 15 metres deep under ground. The turbo-generator hall is separate from the reactor building.

The power station is expected to come in full operation in 1964 and to accomplish this aim the chief constructional parts will be finished in 1963 to receive the fuel elements.

The construction of access road to the area and the levelling of the ground began in January 1960. The site workshops and the temporary lodges will be completed by August 1960. The excavation for the reactor building foundation will begin in March 1960 and foundation work will be completed by November 1960.

The concrete work for biological shielding will be finished by September 1961. Following this the assembling on site of the pressure vessels and the

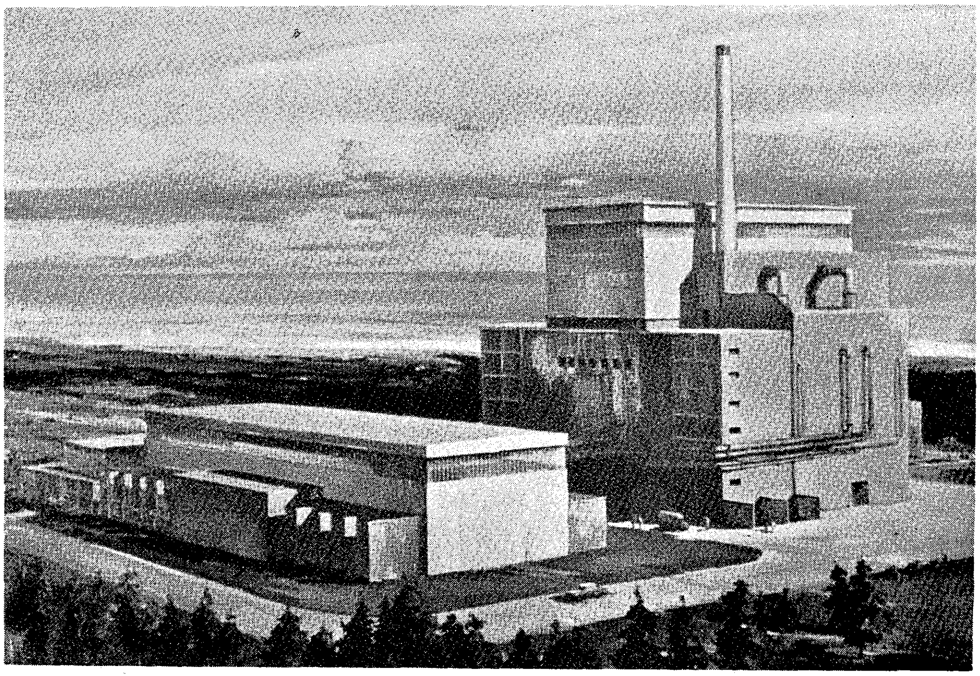

Fig. 6. Outer view of power station

steam raising units will start and parallel to the construction of the reactors proper, those of a waste fuel cooling pond, the turbine-generator hall, etc. will be carried on.

IX. MANUFACTURES OF FAPIG

Our company, the Fuji Denki Seizo K.K. (Fuji electric Mfg. Co., Ltd.) is cooperating with G. E. C. for the construction of the power station under a technical agreement between the two. The Fuji Denki Seizo K.K. as the leading company of the First Atomic Power Industrial Group (FAPIG), which was founded in 1956 and consists of 19 industrial companies, 2 trading companies and a bank, is managing the manufacturing of main parts within FAPIG, under the following scheme.

1) Fuji Electric Mfg. Co., Ltd. is to manufacture the pressure vessels, cylindrical restraints, a biological shield cooling system and burst cartridge detection pipe works.
2) Kawasaki Dockyard Co., Ltd. is to manufacture the steam raising units, main gas ducts, feed water heating facilities and main and dump condencers.
3) Kobe Steel Works, Ltd. is to manufacture carbon dioxide gas storages and gas purification system.
4) Shimizu Construction Co., Ltd. is to construct the reactor building and other concrete works.
5) Ebara Mfg. Co., Ltd. is to construct a waste disposal plant and decontamination facilities.

X. COST OF CONSTRUCTION

The cost of construction for this power station as disclosed by JAPCo. amounts in total to £ 35.3 million which consist of £ 30.8 million for construction expences, £ 4.2 million for the first inventory of uranium fuel and £ 0.3 million for others, so that the construction expenses per kW output will be £ 185.5.

The generating cost for the first one year calculated is ¥ 4.99 per kW made up of ¥ 3.30 for capital expenditure, ¥ 1.27 for fuel cost and ¥ 0.42 for direct and indirect expenses. This calculation is based on a load factor of 80%, that means generation of 11,116, 374 MWH in one year. The cost per kWH goes down year by year as the capital expenditures decrease as the refundments proceed and will be ¥ 3.52 after the period of 20 years. Accordingly, the average cost for 20 years will be ¥ 4.04 per kWH.