PRESENT STATE OF OUR NUCLEAR STUDY

By

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I. INTRODUCTION—BRIEF HISTORY

The history of our nuclear study dates back to the year of 1953 when we began the design of 1,500 kV Cockcroft-Walton high-voltage generator and 30 MeV electron synchrotron. These were handled by the members of the transformer section of the design department. From this time, some advanced members in that department began to study and discuss the possibilities of some types of research and power reactors.

In the summer of 1956, the year of the first Geneva conference for the peaceful uses of atomic energy, our Company took initiative and organized the first atomic power industry group (FAPIG) which includes in total 15 industrial companies, a trading one, the Nissho Co., and a bank, the Daiichi Ginko.

At about the same time, the atomic section was established in our research department as the center of our nuclear studies. The immediate tasks of this section at that time were to design a 1 BeV electron synchrotron for the Institute of Nuclear Study of Tokyo University and to design an 1,000 kW swimming pool type reactor for our FAPIG facility.

Our initial and final aim has been and will be to achieve high temperature gas cooled reactor combined with our closed-cycle gas turbine. Our Company, as an only supplier of the gas turbine in the orient, is developing it, because it will be an ideal power source with the aid of the nuclear reactor in the near future.

In the meanwhile in Oct. 1956, the world first commercial atomic power plant, Calder Hall, came into operation in England. And a little after this, the Japan Atomic Power Co. (J. A. P. C.) decided to adopt this type of the atomic power generating station for the first one and we are now following along this line and cooperating with J.A.P.C. But in the future we will complete a high temperature gas cooled breeder reactor by ourselves.

II. PARTICLE ACCELERATORS

The particle accelerators are important for our nuclear study as most practical and adjustable radiation sources. For the first experience, we built a 1,500 kV Cockcroft-Walton high voltage generator (Fig. 1) for Furukawa Electric Co. in 1954. This was applied for the testing of the break-down voltage of high tension d-c cables. Later in 1956, we completed another 400 kV one (Fig. 2) for Tokyo

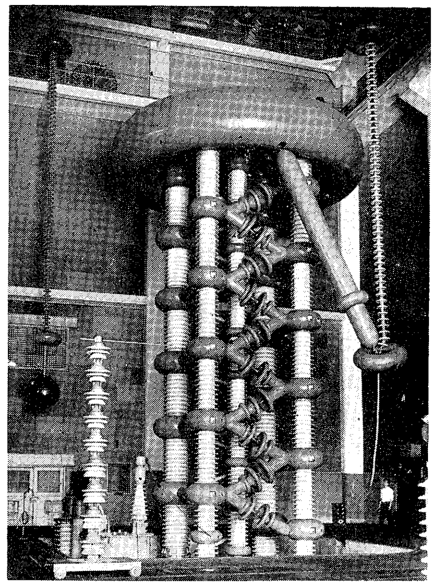

Fig. 1. 1,500 kV Cockcroft-Walton

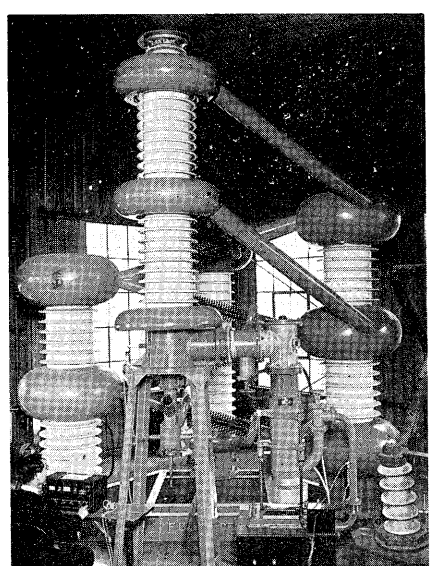

Fig. 2. 400 kV Cockcroft-Walton

Institute of Technology for the purpose of nuclear study. As the rectifying elements for the 1,500 kV set, we used Kenotrons but for the 400 kV set, we adopted selenium rectifiers of our own products in the place of Kenotrons. The fact that filament heating is not necessary for selenium rectifier makes the set much simpler and cheaper. The third set which is almost the same as the latter but for 200 kV output voltage is now under manufacturing for the physical laboratory of Ritsumeikan University.

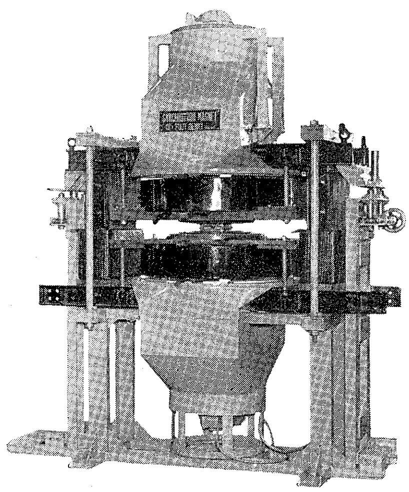

Fig. 3. 30 MeV Electron synchrotron

In 1954, we designed an electron synchrotron of 30 MeV (Fig. 3). This was completed in 1955 and supplied to Tokyo Institute of Technology again for nuclear study. In 1956, the Institute of Nuclear Study of Tokyo University gave us an order of the model magnet as well as the main magnets of 1 BeV electron sychrotron. The former was completed in 1957 and the latter which consists of 8 huge unit magnets is now under erection on site (Fig. 4).

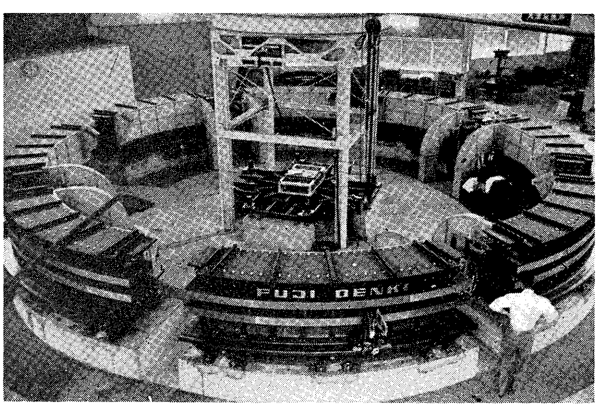

Fig. 4. 1 BeV Electron synchrotron

After completion this will be the biggest one in the world as a strong-focusing electron synchrotron. The diameter of the doughnut tube through which electrons pass is ca. 8 m. and the length of this tube inside each unit magnet is ca. 3 m. The weight of silicon steel plate used for the magnet cores amounts to ca. 110 tons and that of copper for magnet exciting coils to ca. 20 tons. To laminate the core in a form of sector, an epoxy resin named araldite was used as an adhesive paste between every plates. For the conductor of the coil, a copper conductor with a hollow hole through which cooling water passed was used. The accuracy of dimensions required at installation of these unit magnets is within ±0.1 min. for 4,000 mm (doughnuts pipe radius) and the stability of the electric supply (both voltage and frequency) is within ±0.01%.

The linear accelerator seems to be the most hopeful accelerator in the near future for the purpose of chemical and medical applications. We began to study it as an injection apparatus of the above-mentioned 1 BeV electron synchrotron in 1957. After many months of research and trial manufacturing of test cavities, we are just now completing to build a 12 MeV electron linear accelerator (Fig. 5) with a financial assistance from the Scientific and Technical Agency of our government.

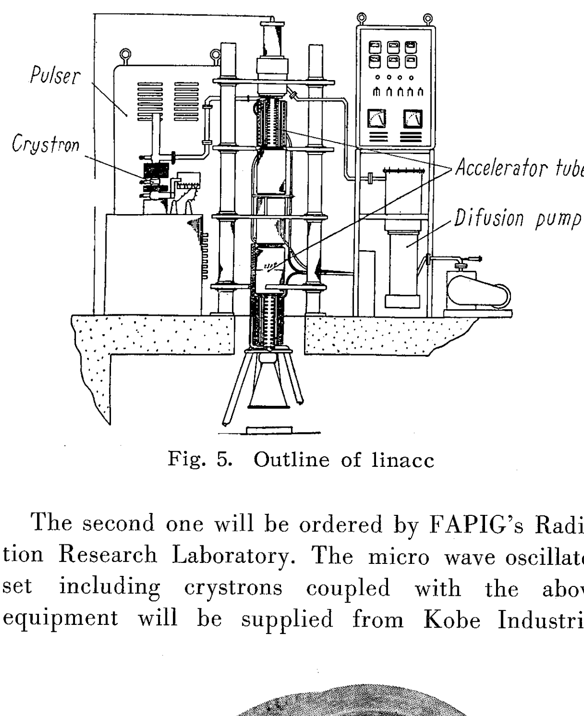

Fig. 5. Outline of linacc

The second one will be ordered by FAPIG's Radiation Research Laboratory. The micro wave oscillator set including crystrons coupled with the above equipment will be supplied from Kobe Industrial

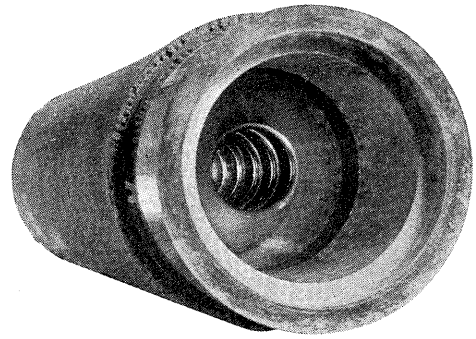

Fig. 6. Part of linacc

Co., who is one of leading members of FAPIG and manufacturing the electronic valves and transistors.

In the beginning stage, we tried to finish the cavity assemble of the accelerator only by machining but now we are manufacturing it through the procedure of electro-forming (Fig. 6).

III. RESEARCH REACTORS

Our first trial design of the nuclear reactor was a 1,000 kW swimming pool type research reactor. This lasted from 1956 to 1957 and in 1958, we had many meetings for discussion on erection of this type of reactor as a common experimental facility for both FAPIG and Saint Pole University. But after repeated examination of the cost of erection, we had to give up our initial plan due to the shortage of the fund. The above-mentioned reactor was designed for a thermal output of 100 kW with natural cooling and 1,000 kW with forced cooling. Using the MTR type fuel with 20% enriched uranium, we obtain the maximum thermal neutron flux of ca. 10^{13}n/cm^{2}sec. One water filled pool of 2 m inside diameter and 10 m height contains the reactor core, and another adjoining pool of 4 m × 3 m × 10 m (inside dimensions) is offered for the reactor design experiments examining effects of shielding.

We are now pushing foreward to erect a 100 kW TRIGA type reactor of General Dynamic Co. of U.S.A. as a common experimental facility of both Saint Pole University and FAPIG instead of 1,000 kW swimming pool type reactor. This is a tank type reactor and will be completed with a 3 m × 4 m water pool and some monitoring devices by the end of this year (Fig. 7). The site of the reactor is Takeyama near to Yokosuka (Fig. 8). In the adjoining area to the reactor we will build our Radiation Laboratory, having a 12 MeV linear accelerator and a 3,000 curie Co_{60} hot cave.

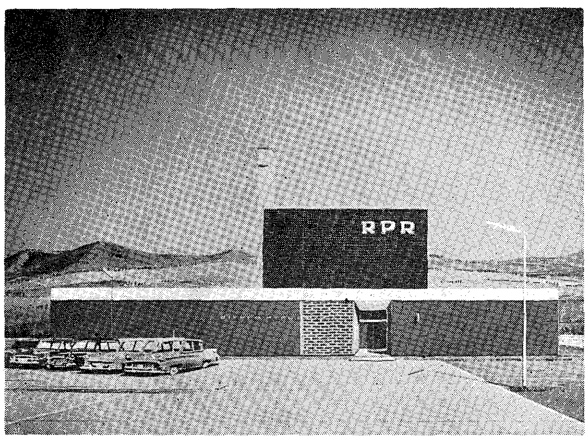

Fig. 7. Rikkyo reactor building

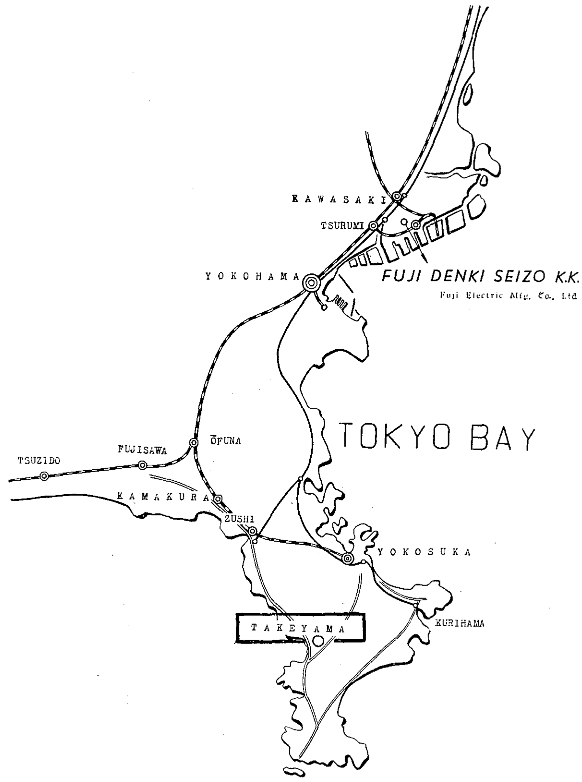

Fig. 8. Map of location of Takeyama

IV. POWER REACTORS

Our final aim on power reactors is to manufacture gas cooled high temperature breeder reactors directly combined with closed-cycle gas turbines which can produce electric power through a-c generators or can drive ships directly. For these purposes the temperature of gas must be more than 700°C in the pressure of more than 20 atms. This requirement is not easy to satisfy in the present state of techniques but we believe it will be overcome in the near future.

Before we can build a gas turbine reactor, we will be able to supply CO_2 gas cooled graphite modulated natural uranium reactors combined with steam turbine driven alternators for use in electric power stations. But before doing this way, some technical agreements between AEA in England and us will be necessary. UKAEA have already achieved a glorious success at Calder Hall where 2 × 60 MVA plant of this type have already been in practical operations.

Two kinds of fundamental studies on gas cooled reactors are now carrying on in our research department. One is the studies from mechanical side. It consists of a) Test of CO_2 blowers with model runners, b) Test of mechanical seales of blower shaft. The other is the studies on heat transfer. c) Heat transfer from uranium fuel to CO_2 cooling gas, and d) Heat transfer from hot CO_2 gas to raw water in heat exchanger.

a) Test of CO_2 blowers

The problem of blower design is serious because the driving power of CO_2 blower in the Calder Hall power station reached 5.45 MW per reactor and thus the blowers spend ca. 1/7 of the total generator electricity.

The aim of this test is to obtain the fundamental data for the blower design using model runners of centrifugal type or propeller type. The testing equipment, as shown in Fig. 9 and 10, is a closed circuit wind tunnel with a 600 HP d-c dynamometer type driving motor controlled by Ward-Leonard method.

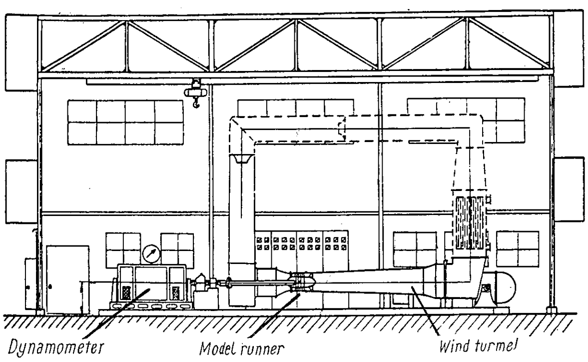

Fig. 9. Wind tunnel for CO_2 blower

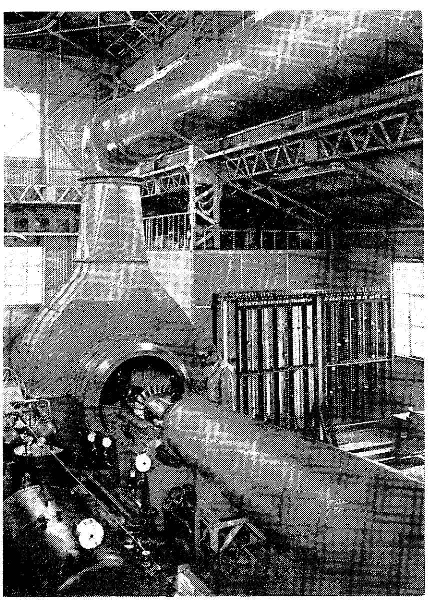
Fig. 10. Wind tunnel for CO_2 blower

The tunnel is designed for ca. 2 atms. and is coupled with a water cooler arranged in the tunnel. The set was completed at the end of 1958 and two model runners, one centrifugal type the other propeller type, have already been tested.

b) Test of mechanical seal for CO_2 blower

The blower is driven by an prime mover, it may be a steam turbine or an electric motor, with a shaft which penetrates through the wall of CO_2 ducting and there causes a leakage of CO_2 gas which is radioactive. To prevent this leakage, a mechanical seal as shown in Fig. 11 can be used. In this case the

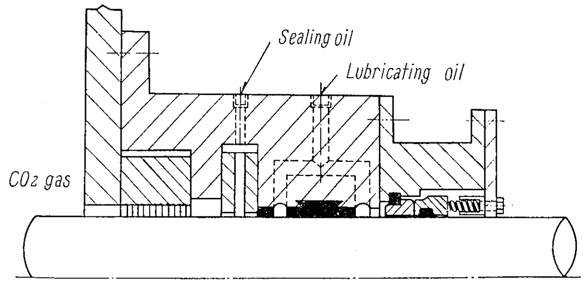

Fig. 11. Principle of mechanical seal

sealing oil prevents the leakage of CO_2 into the atomosphere. The testing equipment is shown in Fig. 12. A rotating shaft of 100 mm diameter and 300~1,500 rpm is driven by an electric motor through a variable speed gear unit. The pressure of CO_2 gas fed from gas tank is kept at 15 atms as the maximum value.

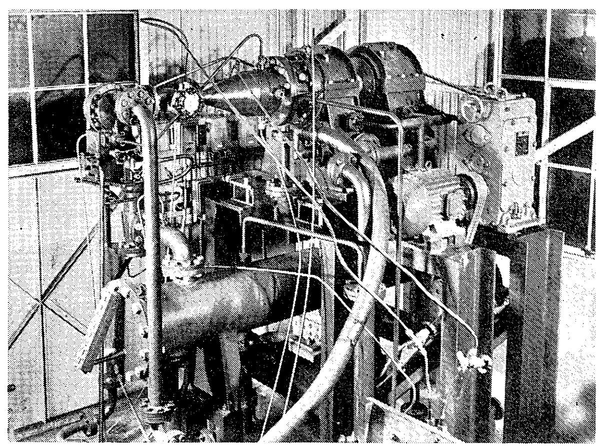
Fig. 12. Test equip. of mechanical seal

c) Heat transfer from fuel to gas

In Calder Hall type reactor, heat generated in uranium fuel is transfered to CO_2 gas through heat conducting fins of magnesium alloy. Fig. 13 shows

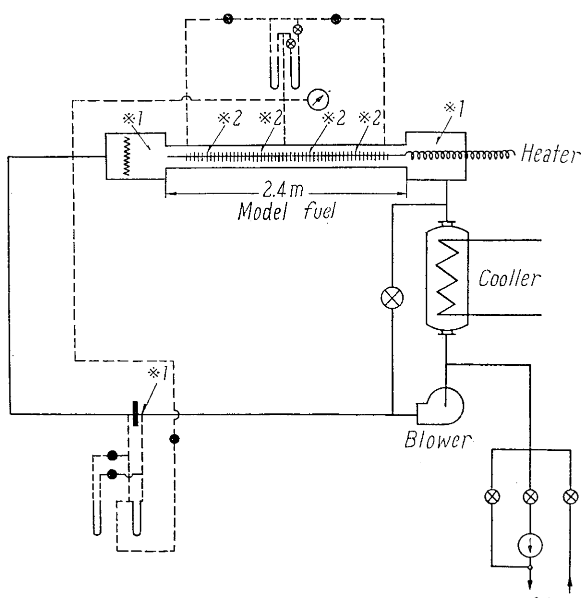

Fig. 13. Heat transfer from fuel to gas

the principle of this test procedure and Fig. 14 the testing equipment. Fig. 15 shows our model fuel. Instead of heat generation in uranium fuel a stainless steel rod inside the finned tube of duralumin is heated up by feeding electric alternating current of ca. 20 kV in our experiment. The pressure of CO_2 gas can be raised to 15 atms as the maximum value and the temperature of the heated gas reaches ca. 200°C.

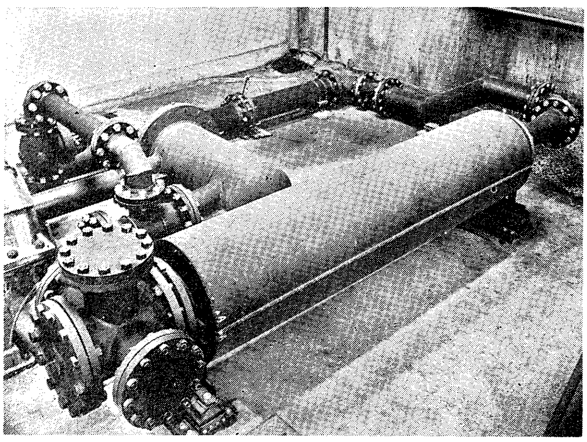

Fig. 14. Heat transfer from fuel to gas

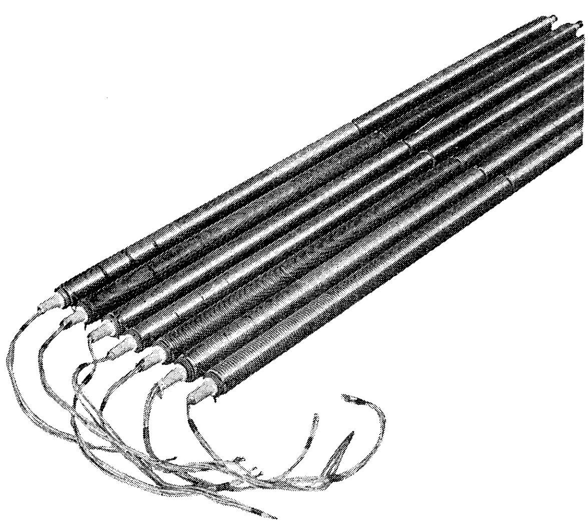

Fig. 15. Model fuel

d) Heat transfer from hot gas to raw water

This test corresponds to the heat transfer in a heat exchanger feeding steam to turbine. Fig. 16 shows the principle diagram and Fig. 17 the photograph of the testing rig. The temperature of gas

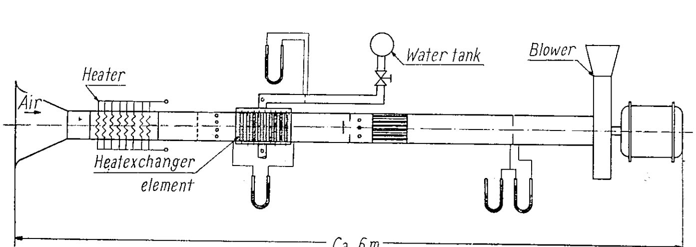

Fig. 16. Heat transfer from gas to water

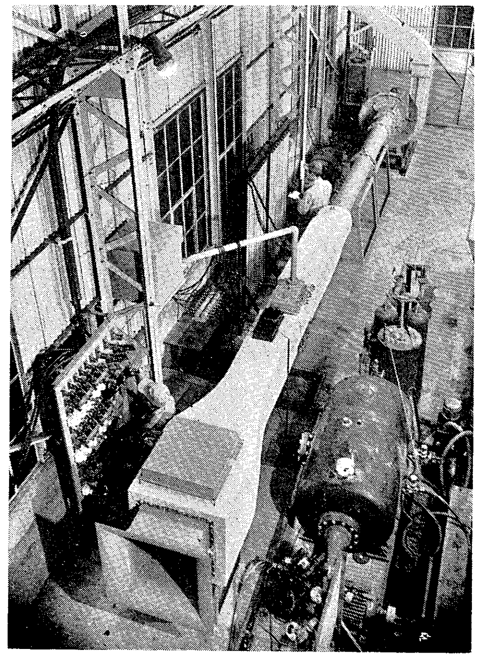

Fig. 17. Heat transfer from gas to water

heated up by electric heater is 90°C and it will be cooled down to 60°C after transfering the heat to water through the heat exchanger elements. The temperature rise of raw water across the heat exchanger elements is ca. 5°C.

V. CONTROL OF REACTORS

In this field, we have two kinds of control equipments under construction. One is a) the safety rod driving device for gas cooled power reactor and the other is b) measuring and controlling equipment for water and gas systems of a heavy water cooled and modulated natural uranium research reactor for Japan Atomic Energy Research Institute.

a) Safety rod control device

Our electrical engineers are devoting themselves to the study of control problems of the reactor. And one of them has completed a driving device of control rod shown in Fig. 18.

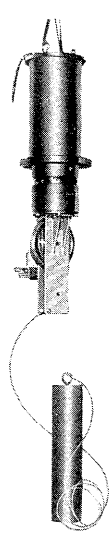

Fig. 18. Safety rod control device

This is for the power reactor of Calder Hall type. The driving device drives a control rod of ca. 50 kg and consists of a reaction motor, a magnetic clutch, an eddy current brake, a set of reduction gear, a rope wheel for winding up a suspending wire of the control rod. These 5 mechanisms are arranged one by one in order from top to the bottom in a cylindrical frame. The reaction motor is fed by a commutator type frequency changer of 0 to 1.3 cycles/sec. (Fig. 19). When the rod drops, in the case of emergency, the clutch cuts off the motor from the control rod and the brake limits the speed of following rod.

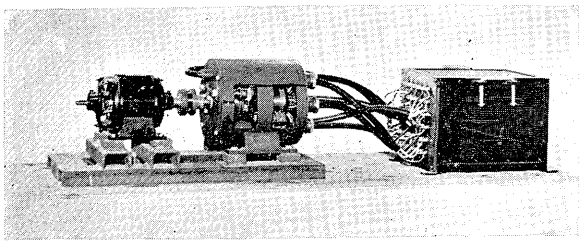

Fig. 19. Commutator type frequency changer

b) Instrumentation of water and gas system of experimental reactor JRR-3

The first home made reactor in our country is now under manufacturing. It is a heavy water cooled and modulated natural uranium experimental reactor with a thermal output of 10,000 kW. The design and manufacturing have been conducting in cooperation with 4 atomic industrial groups in Japan under the supervision of Japan Atomic Energy Research Institute. Our Company, having the largest manufacturing capacity for electric and industrial measuring instruments among the 4 groups, is now making the equipments for the instrumentation of water and gas systems of this reactor.

The system consists of, i) Heavy water as both modulator and cooler, ii) Helium gas system for separating the surface of D_2O modulator from air contact, iii) CO_2 gas system for cooling of graphite, iv) Light water system for recuperator. The devices of instrumentations in our region include not only all necessary temperature indicator, pressure gauge and flow meter, but also the following special measuring and regulating instruments. i) Temperature indicators of fuel rods, ii) Caloremeter of D_2O (Flow $\times$ Temperature), iii) Leakage detectors of D_2O, iv) Ohmmeters of D_2O and H_2O.

VI. UTILIZATION OF RADIOISOTOPES

The utilization of radioisotopes is also a category of peaceful uses of atomic energy. The utilization of radioactive γ rays for industrial photography is most familiar. We have two Co_{60} radiation units for this purpose in our Kawasaki works and have been using it for inspection of thick iron or steel blocks. One having the radiation source strength of 0.3 curie is good enough for thickness more than 50 mm, and the other of 3 curies for over 150 mm.

Another way of utilization of radioisotopes is an application for measuring instruments. Applying γ rays of Co_{60}, we have completed and supplied an effective liquid level measuring device for a closed iron tank containing chemical liquids and so whose level is not able to be observed from outside the tank. The right hand side of Fig. 20 is a tank with transmitter of this device and the left hand side shows the receiver i.e. indicator for the liquid level.

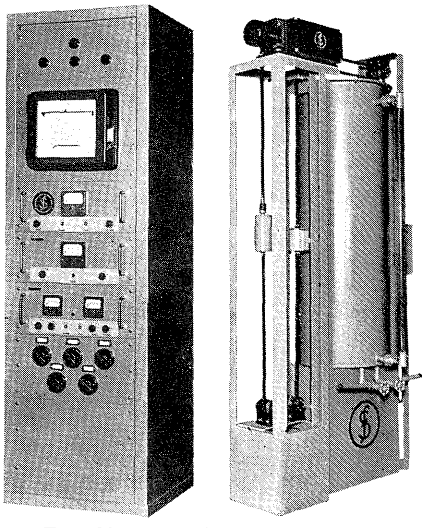

Fig. 20. Liquid level indicator

The flying distance of β rays is shorter than that of γ rays in nature but the former may well be applied to measure the thickness of the thin or low densi-

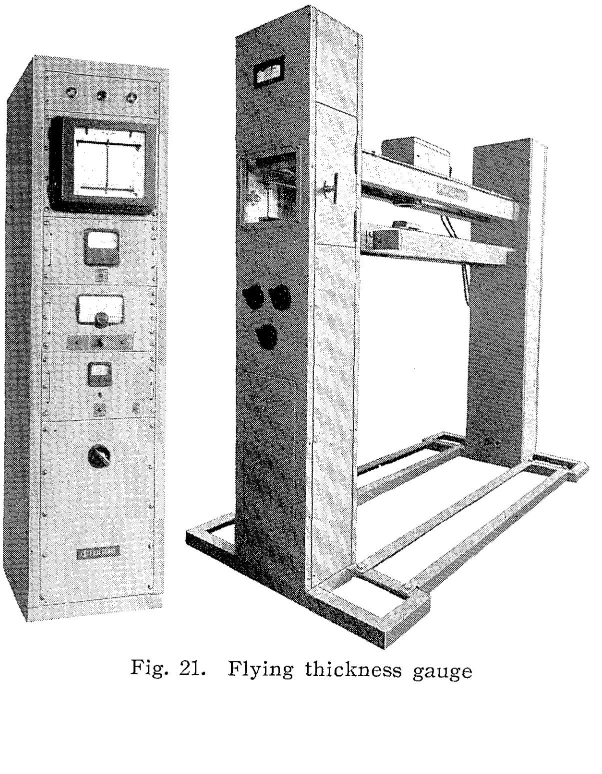

Fig. 21. Flying thickness gauge

ty materials. Using β ray of Sr_{90}, we manufactured a flying thickness gauge for thin metallic sheets. The right hand side of Fig. 21 is the measuring device and the left hand side is its indicator.

VII. CONCLUSION

Starting from a few years before the first Geneva conference for the peaceful uses of atomic energy, we have studied to a great extent in the field of nuclear science or technology so that we have supplied some particle accelerator sets and new measuring devices utilizing radioisotopes. Also, we have already manufactured some parts and instruments for reactor control.

Our laboratory accomodated with 100 kW research reactor and 12 MeV linear accelerator is now under construction. After this is completed, we hope we will make one step further and take up the manufacturing of home made power reactors.

We have now a number of engineers studying earnestly the nuclear science in our two atomic sections. One is in our technical department and the other in our research department. The former party is conducting projections for nuclear power plants and nuclear ships and the latter is devoting himself to research and design of power reactors and particle accelerators.