This equipment has 6 sections, including 3×180 HP, 1×150 HP and 2×60 HP d.c. motors, and the d.c. power is supplied from a 984 kW mercury arc rectifier. To synchronize the speed of each section motors, the excitation of section motors is regulated by amplitrans, which amplifies the proportional and integral values of speed difference between section motors and master shaft. To detect this speed difference, we use differential gears, which are driven by master shaft and synchronous motors, fed from the sliprings of the section motor's armature.

VI·4. MARINE SERVICE

Among the many sorts of d.c. machines for marine service, we must take up firstly cargo winch. The standard types of d.c. cargo winch in our factory are two, 3 tons 36 m/min and 5 tons 40 m/min. The characteristics of our these winches are the best in the world.

For the ships of a.c. system, we have offered a.c. Leonard winch. The Leonardgenerator was formerly installed in the beds of each cargo winches, but recently the motor-generator sets are separately installed, and one induction motor drives two d.c. generators, and further, these two generators together feed the power to a motor of mooring winch or a motor of anchor windlass. Since 1955 we raised the speed of driving motor of winch, and separated the exciter from each M-G set, and installed a common exciter in each M-G room of each hatch. Then, the construction of M-G set, for example, couplings, arrangements and ventilating systems etc., were originally improved, and the total weight of equipment in one ship was reduced indeed by 20 tons.

On the other hand, in 1956, more than the standard types of d.c. winches else, we completed the spur-geared new type d.c. winches, having a rating of 5/2 tons 30/75 m/min., and of 3/1.5 tons 30/75 m/min. These winches are lighter in weight and cheeper in price than the standard types.

V·5. D. C. DYNAMOMETERS

Many d.c. dynamometers of high speed and large capacity were manufactured by us before and after the II World War. In 1956 we completed a dynamometer for testing gas turbines, installed at Tamano-dockyard of Mitsui Zosen K.K., and this has the ratings of 450 kW 6,500 r.p.m., and has the double armature construction as shown in the photograph. The constant speed was regulated by amplitrans, which controlled the voltage of Leonard generator.

VII. TRANSFORMERS, INDUCTION VOLTAGE REGULATORS AND HIGH VOLTAGE TESTING EQUIPMENTS

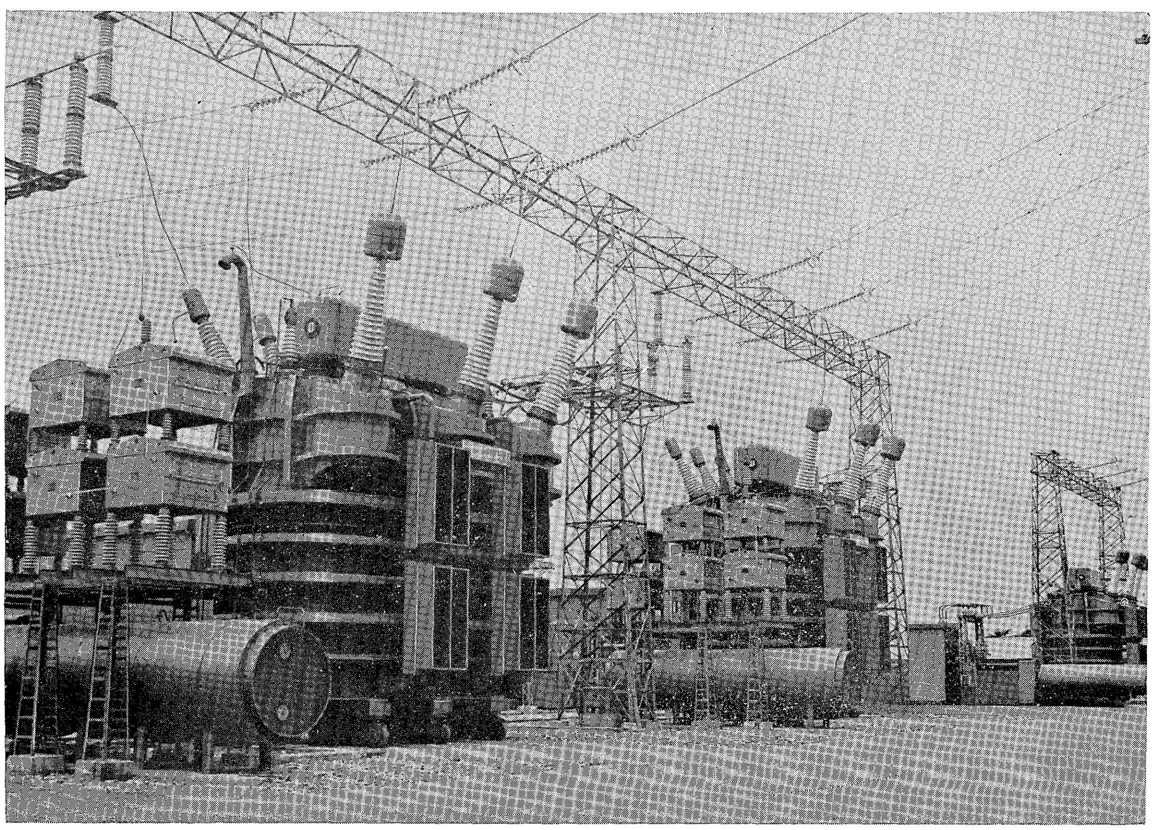

Fig. VII·1. 3×117 MVA 275 kV Transformers

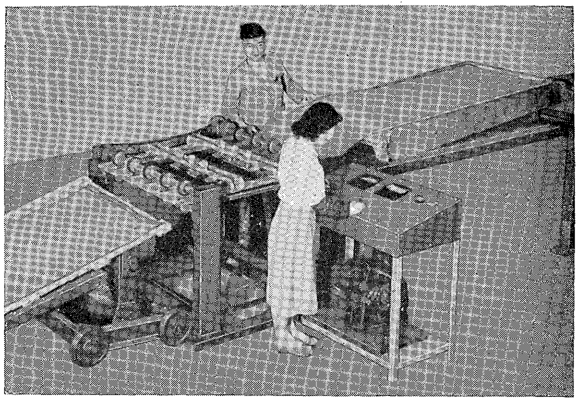

Fig. VII-2. Testing of Silicon Steel Plates

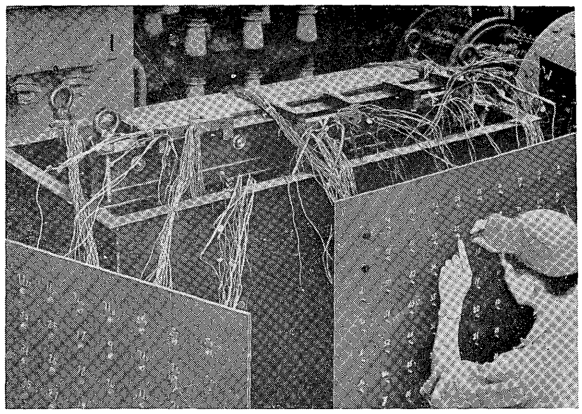

Fig. VII-3. Magnetic Model

VII·1. GENERAL VIEW

As one of the large transformer makers in Japan, we are now busily manufacturing many large power transformers. Two long transmission lines have recently been completed i.e. the 275 kV Sakuma, east and west line and the 187 kV Nukabira line. The former connects Tokyo and Nagoya and reaches ca 260 kM in length locating the 360 MVA Sakuma hydraulic power plant at about two-third way from Tokyo and the latter, having a length of about 210 kM, transmits the hydraulic power in central mountain districts of Hokkaido to the city of Sapporo. We supplied 3 × 117 MVA main receiving transformers (Fig. VII·1) for Nagoya Substation and 2 × 78 MVA main receiving transformers for Sapporo Substation.

For the newly completed thermal power plant Tsurumi No. II in Kawasaki, we supplied 4 × 81 MVA step-up transformers (Fig. VII·6) and for hydraulic power station Akiba under construction, we are now manufacturing one 41 MVA step-up transformer.

The testing of silicon steel core plates piece by piece (Fig. VII·2), which we have taken up in the year 1951 for the sake of quality control of the postwar core plates, and the improvements of core plates themselves and since then have succeeded in decreasing the losses per kg in the iron cores. For example, the iron loss measured in the above-mentioned 117 MVA transformer was ca 1.78 watt/kg. The use of cold-reduced directional sheet has also come into practice. A 16,000 kVA transformer with this core is now completed and an 1,000 kVA and an 1,500 kVA transformer are already in operation on site.

For the development of cylindrical-layer-windings to be described afterwards, the magnetic models (Fig. VII·3) and electrolytic tanks (Fig. VII·4) were very often applied. Our first magnetic model was manufactured in 1950, as a model for 4 × 9,000 kVA 154/11 kV perfectly oscillation-free transformers which, we think, are the first transformers of this kind supplied for practical service. The electrolytic tank is very convenient for studying the initial internal voltage distribution for incoming wave. Many investigations with electrolytic tanks were made also for our standard disc coil type winding with single coil connection. (Standard windings for 110 kV class.)

To measure the velocities of the oil in the cooling oil ducts between the coils and windings, we developed a test with a wooden model of section of transformer winding. (Fig. VII·5) The model has full size dimensions and oil velocities are measured by electric resistance thermometer. By this test, the most proper and economical cooling oil flow is guarranteed and for example, we got 15 kW for auxiliary powers, oil pumps and ventilating fans together, for the above 117 MVA transformer which is about half the value of those for existing transformers with the same ratings previously manufactured in this country.

VII·2. TRANSFORMERS WITH CYLINDRICAL-LAYER-WINDINGS

The cylindrical-layer-winding is adaptable for both H. T. high voltage and L. T. large ampere coils. Over 20 units and in total about 1,000 MVA H. T. transformers (>154 kV) including 3 × 117 MVA 275 kV sets (Fig. VII·1) were manufactured by us in these several years. This winding is also suitable as tap winding for on-load voltage regulatiog transformers with disc coil main winding.

Its merits as transformer winding may be stated as follows. 1) Any point on the transformer winding being free from any internal oscillations, the reliability of insulation belongs to the highest class. 2) The construction seen from insulation is especially suitable for transformers with neutral point of direct earthing or of reduced insulation. 3) The main insulation without oil ducts brings minimum leakage impedance and may contribute to the stability of transmission line. 4) The axial mechanical force during the short-circuit will be minimum by the parallel wound layer type tap winding. 5) The paths of cooling oil between the coils are uni-

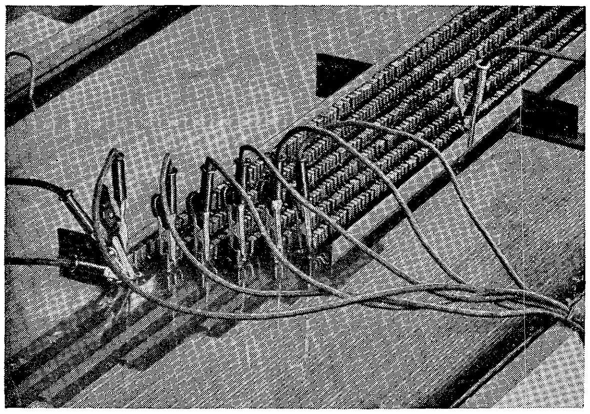

Fig. VII-4. Electrolytic Tank

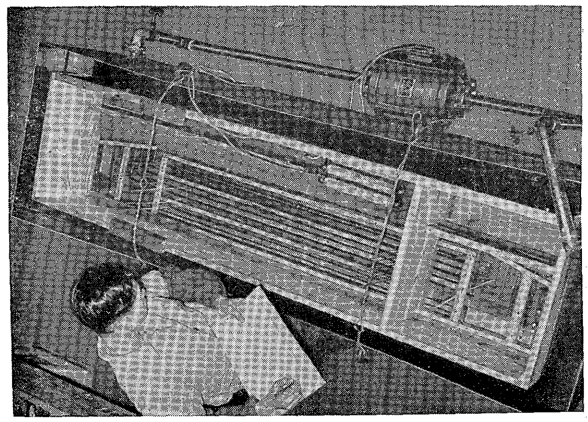

Fig. VII-5. Section Model

directional, promising the best cooling with the minimum loss of head. 6) The large inlet static capacity against earth moderates the steepness of the wave front of incoming surge. This also reduces the value of the switching surge.

VII·3. „FAHRBAR" (MOVABLE) TYPE TRANSFORMERS

To transport large power transformers on narrow gauge railways was a problem. Direct after the war, we took up the matter and solved it by applying a special transport wagon shown in Fig. VII·6. This is our „Fahrbar" type transformer. Transformers larger than 30 MVA and up to 150 MVA can now properly be transported as a one piece tank ones. Assembling and drying out on site will thus become no longer necessary and a long precious time can be spared. More than a dozen „Fahrbar" transformers have already been shipped including among them 4 × 81 MVA, 2 for 154/11 kV and 2 for 66/11 kV, transformers.

VII·4. TRANSFORMERS WITH LOAD-RATIO CONTROL

A new type of our standard on-load tap changers has been developed. The Jansen principle applied with success remains so far but the main contact is divided into 100 A unit parallel contacts and each contact is provided with an auxiliary circuit breaking contact. The auxiliary contacts are connected in parallel through balancing reactors to get balanced 100 A per contact breaking current. The damage of contacts and oil is proportional to the square of ampere and by this improvement the life of contacts is expected to endure over 1,000,000 switchings.

A 30 MVA 154/77 kV load-ratio transformer using this new tap-change switch is already on site. The switch is provided on the 154 kV side (star connection) and located at its neutral point. Useing the same switches Many 66—77 kV. 6,000, 7,500 and 10,000 kVA load ratio transformers, which are the standard transformers for feeding the city, are already supplied or under manufacturing.

VII·5. FURNACE TRANSFORMERS

A 3 ϕ 28,000 kVA 100,000 A furnace transformer manufactured in 1942 and three 1 ϕ 10,000 kVA 48,000 A ones manufactured in 1953 are representatives of our furnace transformers and remain as 3 ϕ and 1 ϕ record units in this country. Both are applied for carbide furnaces and are manufactured by Fuji Denki. Following furnece transformers are now under manufacturing. The Jansen type on-load tap changers, water-cooled L.T. high ampere terminals and large one turn L. T. coils are their special features.

1 × 3 ϕ	27,000 kVA	63 kV/224—134 V
1 × 3 ϕ	15,000 kVA	11 kV/180—120 V
1 × 3 ϕ	10,000 kVA	10.5 kV/160—90 V
1 × 3 ϕ	42,000 kVA	66 kV/308—176 V
3 × 1 ϕ	9,000 kVA	66 kV/224—134 V

Since 1953, the impulse test is applied to all furnace transformers of our supply. The withstand impulse level for 66 kV is 350 kV. Here also the cylindrical-layer tap windings are successfully applied.

VII·6. TRANSFORMERS WITH SYNTHETIC OIL AND DRY TYPE TRANSFORMERS

These two kinds of power transformers and instrument transformers were developed for the purpose to use them where there is danger of fire and explosion. A good synthetic oil is now available after a long year investigation together with Kanegafuchi Chemical Co. and our Company. Silicon insulating varnishes are supplied by Shinetsu Chemical Engineering Co. and others. The dry type transformers were originally developed for explosion proof mine use but now are also used for underground rooms of buildings in the similar way as those with synthetic oil. For example, a 1,000 kVA and a 1,500 kVA 20 kV class silicon insnlated dry type transformers have now been delivered to a underground substation of a department store.

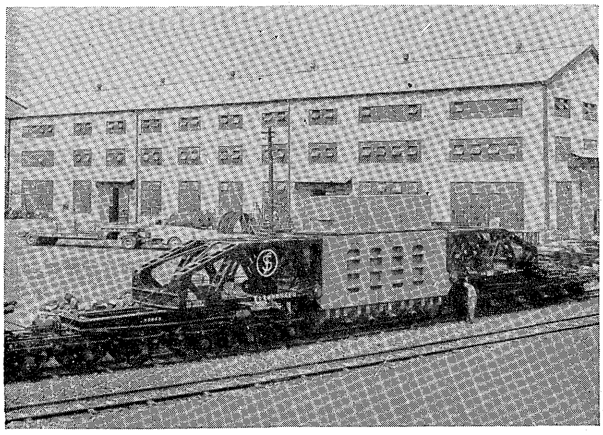

Fig. VII·6. 81 MVA Fahrbar Transformer

VII·7. INDUCTION VOLTAGE REGULATORS

Investigations on impulse voltage chatacteristics were made and, if specified, induction voltage regulators for power services are manufactured as surge proof ones. The impulse withstand level for 66 kV class is 45 kV. The rise of potentical of the neutral point of star-connected regulating rotor winding is limitted by a protecting condenser.

For power service, regulating transformers with multi-stage on-load tap changers, i.e., so-called step voltage regulators are gradually taking the place of induction voltage regulators but still we are suppling many of the latter regulators for testing and industrial services.

VII·8. HIGH VOLTAGE TESTING EQUIPMENT

A 1,050 kV a.c. high voltage testing set and a 1,500 kV d.c. high voltage testing set were newly delivered to Furukawa Electrical Engineering Co. for the purpose of testing of cables. The former consists of three 347 kV transformers connected in cascade the rated output ampere being 1.5 A. The three transformers may also be connected in star so as to obtain 3-phase 347 kV for testing of overhead lines of 330 kV class. The d.c. 1,500 kV testing set (Fig. VII·7) uses 10 stage kenetron rectifiers according to the Cockcraft-Walton's principle. The output ampere is 150 mA. a.c. 150 kV 600—1,200 c/s 160/80 kVA can also be superposed to the d.c. ampere to imitate the pulsation of current in case of high voltage d.c. power transmission through mercury rectifier and inverter.

2 sets of impulse generators were manufactured last year for our Kawasaki works. One is rated for 3,000 kV and applied to the testing transformers. This new one is almost same as the old existing one but this time the set was completed as a movable one. The other new set (Fig. VII·8) cousists of 3 × 1,200 kV units and by connecting the unit condenser in parallel, we can obtain impulse currents up to 150,000 A for the purpose of testing arresters.

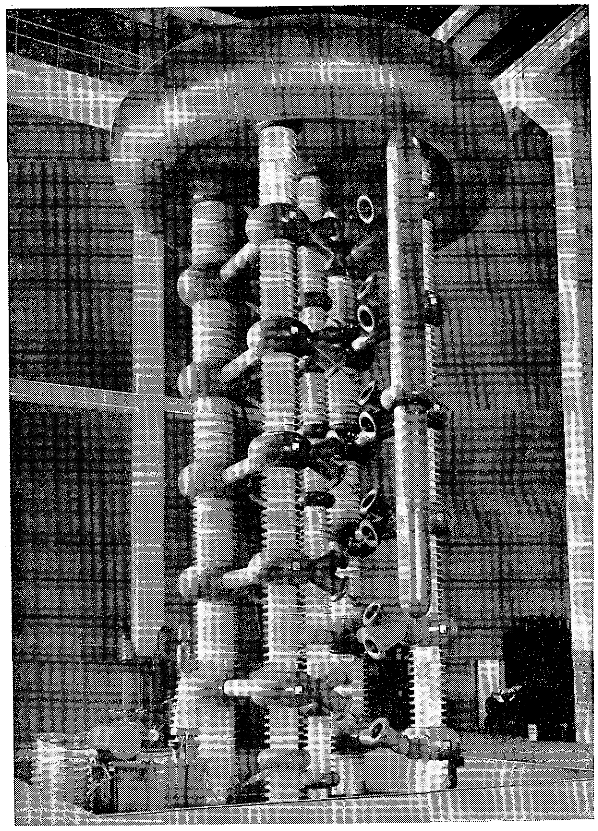

Fig. VII·7. 1,500 kV Cockcroft-Walton

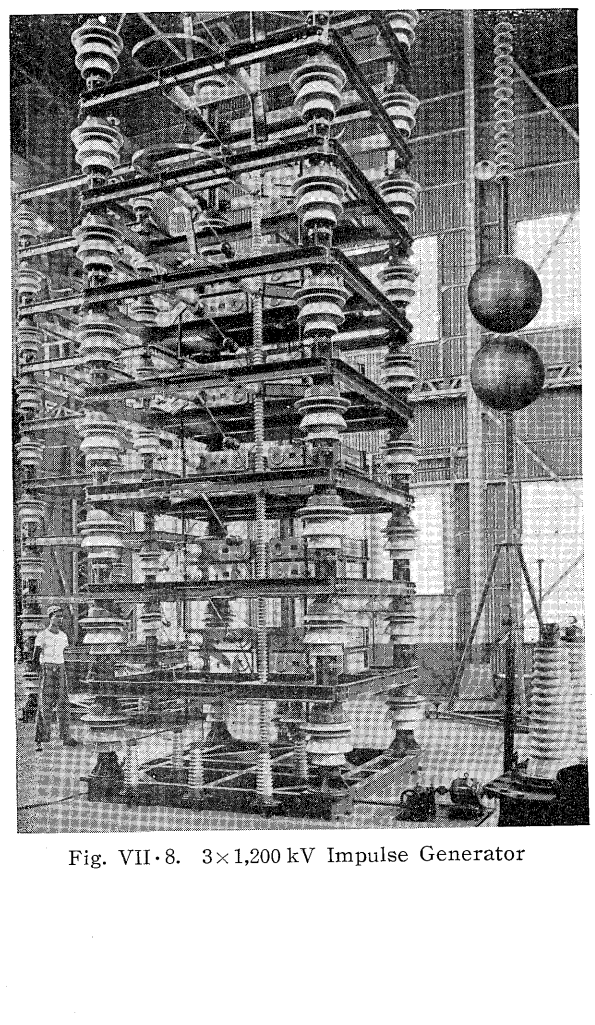

Fig. VII·8. 3×1,200 kV Impulse Generator

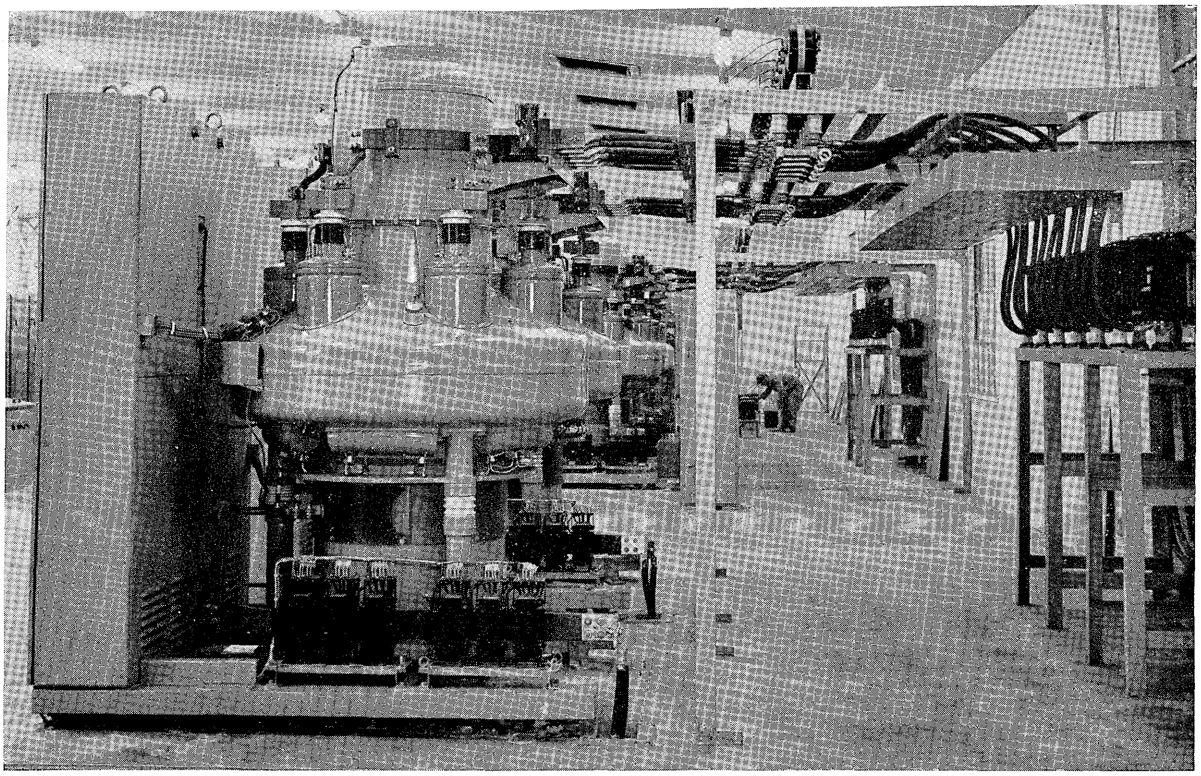

Fig. VIII・1. Pumpless Rectifiers for a Modern Rod Mill (5×750 V 2,000A Unit Kobe Steel Mfg. Co.)

VIII. RECTIFIERS

VIII・1. MERCURY RECTIFIERS

On looking back over the progress made on the mercury rectifier in the past two years, the most remarkable are the application of the sealed-off design to all kinds of apparatus requiring large outputs as well as medium outputs, the single unit current capacity reaching 2,500 amps., and the adoption of the grid control for various purposes, the advantage of which has been taken up to expand the sphere of utilization.

It was in December 1955, that the No. 1 unit (Fig. VIII・2) having the single unit capacity of 2,000/2,500A at 1,500/600 volts was supplied to the substation of the Japan National Railways. Since then, the number of units supplied in the same design has reached 25. With this new type added to old types of 350 A, 750 A and 1,250 A, standard type sealed-off rectifiers are now produced in four kinds as shown in Table VIII・1. The numbers of each type produced in the past two years are shown in the table. The type 2,500 A has adopted air-cooled multi-anode (6 anodes) pattern. The air-cooled type has the following advantages ; the temperature regulating device is simpler and more inexpensive compared with the water-cooled type ; whether cooling water is available or not does not affect the deciding of the location of substation ; there is no electrical corrosion by the air-cooled tank. This choosing of the air-cooled type is in comformity with the trend that rectifier cooling method used for the electric railway and industry are changing into air cooling from the water cooling. The reason for adopting the multi-anodes design lies in: on account of the mercury vapour flow in the vacuum tank it is more suited for ensuring the back-fire proofness and the reliable grid control characteristics; it will cost less in building the unit because of lighter weight and smaller floor space than employing 6 single pole tanks in one installation ; the ignition and excitation devices and temperature regulating devices are much-simpler. Although much discussion is being held about the merits and demerits of multi-anode and single-anode type, the multianode unit built by the Company, as shown in table 1, is smaller sized and less expensive than the single anode one. The anode conductor is arranged coaxially with the cylindrical leading terminal of the grid, and sealed with a system of glass-shrunk-fit, similar to the small capacity unit, but the cathode lead is sealed with glass-shrunk-fit at the bottom of the cathode. This is an entirely new construction and different from smaller capacity units which employs a steel bar cathode brought upward to the tank cover lead from the bottom of the tank