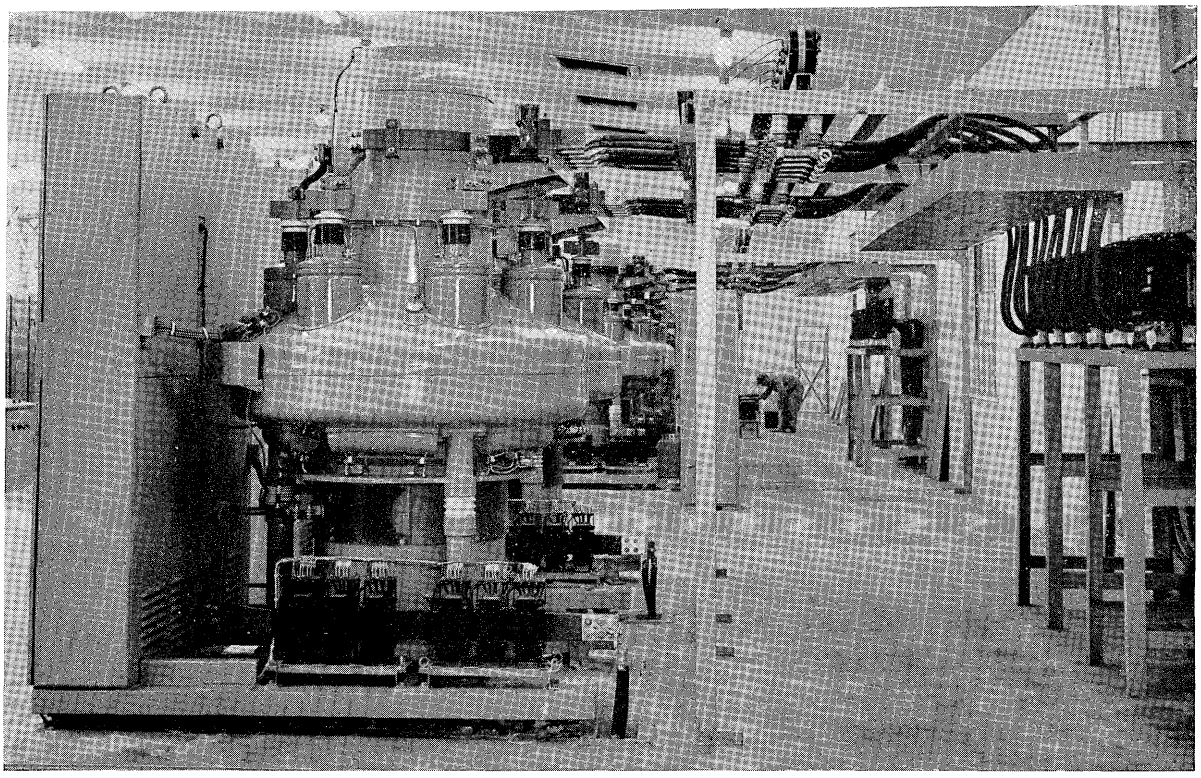


Fig. VIII·1. Pumpless Rectifiers for a Modern Rod Mill (5×750 V 2,000A Unit Kobe Steel Mfg. Co.)

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

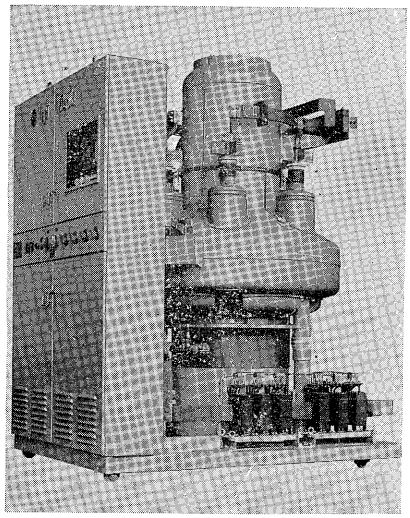


Fig. VIII·2. Air-Cooled Multi-Pole Sealed-Off Rectifier
1,500 V/600 V 2,000 A/2,500 A

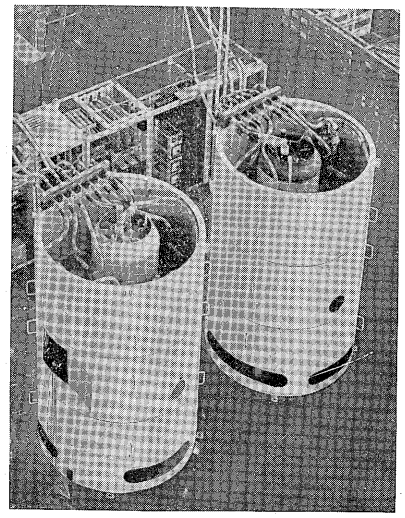


Fig. VIII·3. 1,500 kW 60/150 cycle Static Frequency Changer Set

and sealed there with glass in the same manner as the anode.

It is the latest trend to build a no man substation for the electric railway using air-cooled sealed-off mercury rectifiers. For this, the Company has specially developed bimetal type temperature relays of high dependability for the temperature control of the rectifier tank which has an important bearing on the operation characteristics of the rectifier, thereby assuring the automatic control of the cooling fan, anode heaters and tank heaters. From the no-man substations, advance was made one step further to the building of a no-man outdoor rectifier substation, and a 500 kW at 500 V apparatus of heavy nominal rating was delivered to the Keihan Electric Railway Co.

In compliance with the request of the Japan National Railways, the Company has built 5 sets of air-cooled single-anode type 1,500 V 2,000 kW rectifier of nominal rating. These single-anode units are excitrons, and a special impulse current excitation system is adopted in them by utilizing the anode current change during commutation of the main current. This method has successfully overcomed the phenomena of extinction of exciting current during the flow of large current, which was counted as a defect of the single anode rectifier.

The grid-controlled mercury rectifier has little electric inertia and a large amplifying action, which facilitate quick responsive and high precision automatic control, resulting in an extensive application to the motor speed control as a so-called static Leonard system. The electric drive devices connected with a continuous skelp mill system delivered to Kawasaki Steel Mill Yards of the Japan Steel Pipe Co. is the first static Leonard system of individual operation in our country, where 11 mill motors in the system are each controlled by separate rectifiers. Twelve rectifier units employed for it are of air-cooled multi-anode pumped type and of the outputs ranging from 350, 700, 2,000 amps.

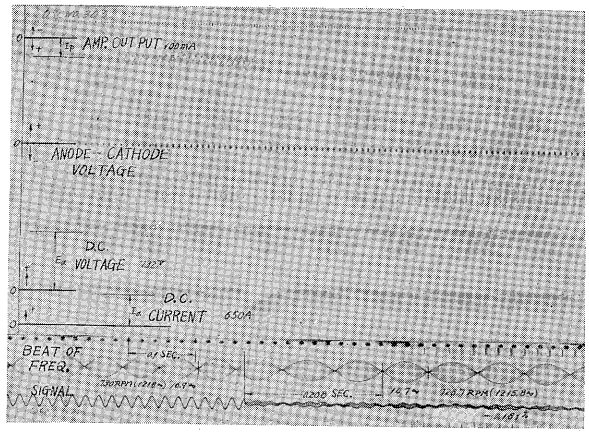
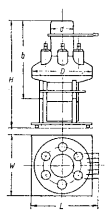


Fig. VIII·4. Quick Response and High Grade Accuracy in the Static Leonard Control of Paper Mill

To the Kobe Steel Mfg. Co., 5 units of 2,000 A air-cooled sealed-off rectifiers were supplied as power sources for a continuous rolling mill system. Phase shifting circuits using d-c excited reactors are used together with electronic amplifiers or magnetic amplifiers for grid control circuits of these installations. The first paper manufacturing machine using a static Leonard unit in Japan was installed in the Hokuetsu Paper Mfg. Co. and an air-cooled sealed-off rectifier type 1,200 A is now in use for it. To satisfy the requirement that the speed fluctuation of the mill motor is to be below 0.5 %, an inductor type a-c tachometer and an electronic amplifier are applied to it. As a result of this method such a fine operation as the speed fluctuation of motor does not exceed 0.2% became available, resulting successfully in the increase of paper making speed and the reduction of paper breakage. Fig. VIII·4 is an oscillogram

Table VIII·1. List of Sealed-Off Rectifiers

	Type		PSL 0311	PSL 0611	PSL 1211	PSL 2011
Capacity	Voltage (V)		1,500/600	1,500/600	1,500/600	1,500/600
	Current (A)		350	700	1,250	20,00/2,500
	Output (kW) nominal or heavy nominal		300/125	500/250	1,000/500	2,000/1,000
Dimension (mm)		D	720	1,015	1,235	1,535
		d	320	460	595	690
		h	1,100	1,590	1,840	2,085
		W	1,000	1,100	1,420	1,700
		L	1,000	1,100	1,420	1,700
		H	1,770	2,170	2,500	2,825
Floor space (m^2)			1.0	1.21	2.02	2.88
Weight	Vessel (kg)		350	500	750	1,300
	Total		450	750	1,100	2,300
Output of cooling fan (HP)		50~	¼	½	1.5	1.5
		60~	¼	¾	1.5	1.5
Air quantity needed (m^3/s)		50~	0.35	0.65	1.4	1.5
		60~	0.4	0.75	1.6	1.65
Delivered during 1955—1956	Railway				21	12
	Industry		1	1	6	13

showing the state of control during the supply source disturbance. The static Leonard system has been also applied to the speed control of machine tools. In Kawasaki Works of our own Company a sealed-off rectifier rated at 750 V 150 kW is adapted for the speed control of a 12 meter turning lathe. In this case one rectifier is used as a rectifier and also as an inverter by changing-over the circuit and suitable operating characteristics are attained including regenerative braking to stop the machine quickly.

A static frequency converter supplied to Nobeoka factory of the Asahi Kasei Co. is composed of 2 1,500 kW 1,500 V sealed-off rectifier tanks using one as rectifier and the other as inverter to change frequency from 50 to 150 cycles. This is a record product as the first, largest 150 cycle high capacity mercury converter in our country operating as a power source for pot motors of rayon industry. (Fig. VIII·3)

A new electric phase shifting device is inserted in the grid control circuit and by its electronic control behaviour, it attains constant output control, and quick protecting action upon occurrence of faults inside and outside of the converter. In fault time rectifier ignition point is quickly shifted to the region of inverter-zone and then brought back gradually to restart automatically. This is a special protective system designed for it. Because of good results of the apparatus, another unit for the extention of the facilities are now under construction.

VIII·2. MECHANICAL RECTIFIERS

This was practically used for the first time as the source for water electrolysis is 1952 at Nobeoka Plant of the Asahi Kasei Co. Since that time, many technical improvements have been made on the basis of experience and now it is finding its use as a reliable converter.

At present it tolals 45 with total current 330,000 A, serving as electrolysis source for production of soda, copper, ammonium persulphate, etc., and it is winning popularity for high efficiency.

The standard S-model is used for 3-phase double way (bridge) 3-Commutating reactor connection system. In this connection system it is required that rectification of a-c. half wave should be finished within 180° electric angle ; moreover, voltage regulation over wide range is rendered difficult, for voltage regulation is effected by the mechanical phase angle control that has a variable closing position of contact.

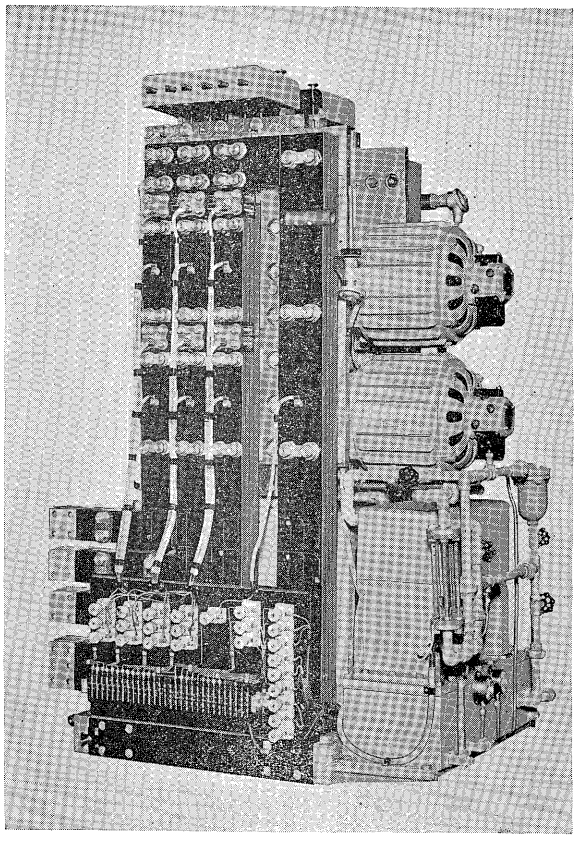


Fig. VIII·5. 12,000 A Contact Mechanism of Coverter

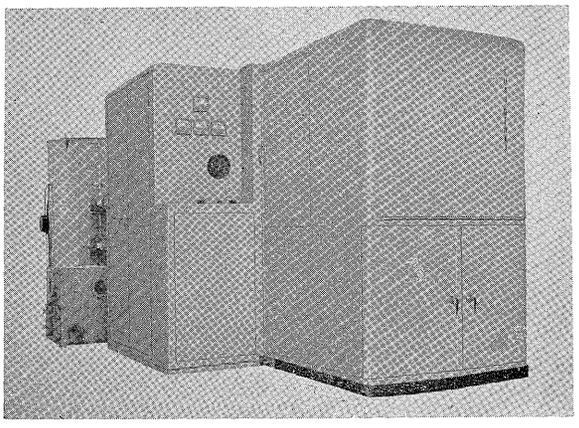


Fig. VIII·6. 12,000 A Mechanical Rectifier

Fig. VIII·5 shows the main mechanism of the standard SS-model. The development of this model has widened the range of rated voltage and current and done away with the restriction of voltage regulation range.

Fig. VIII·6 illustrates a 250 V 12,000 A capacity converter using a ⅄-Y double star connection 6 commutating reactor single way SS-model.

For securing automatic constant current, an automatic magnetic phase angle control system is adopt ed which can automatically adjust the reversing position of commutating reactor, with the closing position uncharged, by contact closing pre-magnetization current.

The current from CT on a-c. side is added to Thoma regulator and through this the closing magnetizing resistance acts automatically so that d-c. current is constant all the time.

To obtain most favourable switching conditions, a silicon diode is used in the shunt paths of opening contacts ; thus the restriking voltage at the time of contact opening can be held down below 2∼3 volts.

As the adopted system permits free adjustment of closing position of contact without regard to the opening position, the closing time voltage can be held nearly to zero ; consequently the allowable time of continuous use of contact has been prolonged several-fold as compared with the conventional S-model.

Recently, a short-circuiter has been perfected that can act at 0.5 ms as contact protector. It is believed that this, together with improvement of contact materials, will make it a reality in the foreseeable future to make restriking with no change of contact in case of back fire. The main features of the new development are as follows :

1) Nearly 100% voltage regulation is enabled by 30% smooth action of automatic magnetic phase angle control and action of one load tap transformer.
2) By simplified system of starting, in only one minute full-load operation can be started with safety.
3) Reliable, stable operation can be secured by periodic inspection in every two years.
4) For the sake of higher stability of operation and simplified maintenance, an automatic overlapping angle control and automatic constant-current device are equipped.
5) Production is possible up to 24,000 A current 1,200 V voltage according to customer's order.

VIII·3. SELENIUM RECTIFIERS

To manufacture the selenium rectifiers our Company employs special deposition method in high vacuum for the formation of the selenium layer.

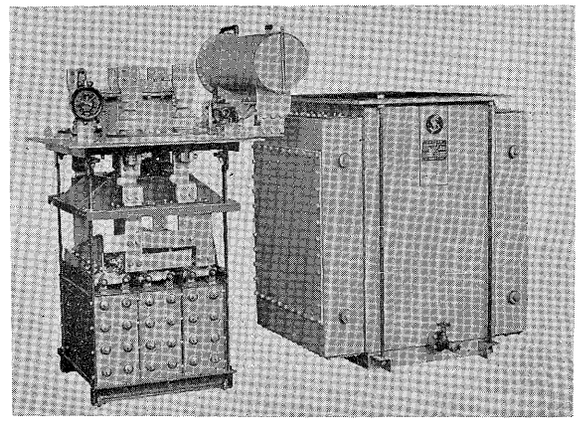


Fig. VIII·7. 90 V 2,000 A Water-Cooled Oil circulating Type Selenium Rectifier for Chemical Analysis

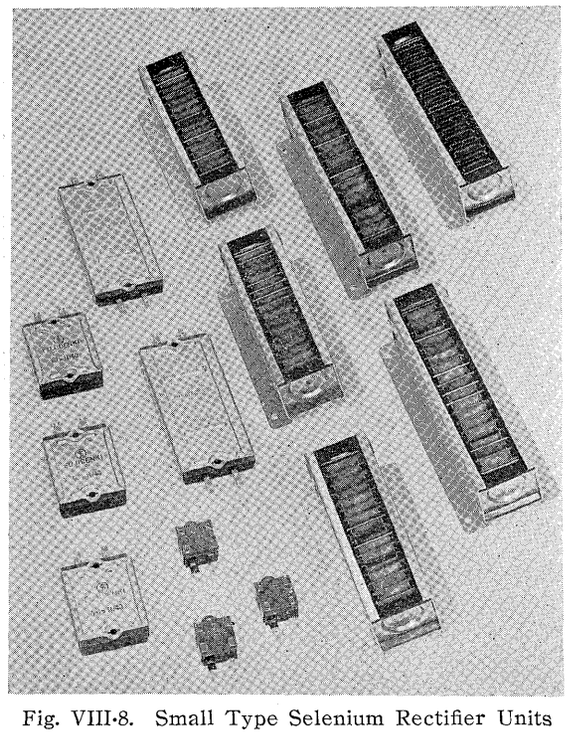


Fig. VIII·8. Small Type Selenium Rectifier Units