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ELECTRICAL EQUIPMENT FOR OXYGEN PLANT USED IN THE IRON AND STEEL INDUSTRY

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I. PREFACE

When oxygen is to be extracted from air, the air feedstock is usually compressed and cooled, liquefied and rectified, and separated into oxygen, nitrogen, and other gases. The first practical air separator was invented and tested by Professor Linde (Germany) at the end of the 19th century. Oxygen production on an industrial basis then became a reality. The Japanese oxygen industry was started in 1910 when the Japan Oxygen Co., Ltd. erected an oxygen plant using the simple air rectifier/separator imported from Germany.

In the past air separators were used mainly in various branches of the chemical industry such as in the manufacture of fertilizer. The volume of air treated by one of these units was approximately 1500 Nm³/hr and the capacity of the related air compressor was only 400 to 500 kw.

The post-war popularity of oxygen steel-making processes has greatly contributed to the use of air separators with larger capacities and higher rectification. The LD converter was first employed by the Yawata Iron & Steel Co., Ltd. in 1957. Since then,this LD converter has become so popular with Japanese iron and steel manufacturers that, after only five or six years, it has replaced the conventional open-hearth furnance.

A large quantity of oxygen of high purity (99.5% or higher) at high pressure (10 kg/cm² or higher) is required for the LD converter. The necessity of producing this quantity of oxygen for use in converters has resulted in the development of large-capacity and high-rectification types of air separators. A large-capacity air separator with an oxygen output of 8000 to 12,000 Nm³/hr and an air input of 45,000 to 68,000 Nm³/hr has become common in recent years. The air compressor used with these separators has a capacity of 5000 to 10,000 kw. In connection with this trend, we, at the Fuji Electric Co., Ltd. have manufactured and supplied a large amount of electrical equipment for oxygen plants in Japanese iron and steel works through the Japan Oxygen Co., Ltd. A summary of the electrical equipment we manufacture for this purpose is given as follows for your information.

II. GENERAL DESCRIPTION OF AIR SEPARATING PLANT

1. Producing Oxygen from Air

The flow sheet of the air separating plant is shown in *Fig. 1*. This method of air separation is generally called the Linde-Fränkel process. Most of the large plants using air inputs of 6000 Nm³/hr or more are usually based on this process.

In this process, the air input is sent to the air filter through the air intake port. A 50 to 60-meter chimney-type intake tube is erected in most iron and steel works so as to be able to obtain the freshest air possible, since the air at these sites is usually highly contaminated. After passing through the air filter, the air is compressed to approximately 5 kg/cm² by the air compressor. A turbo-compressor or a turbo-axial compressor is used for the latter purpose. The compressed air flows through the washing and cooling tower into the air separator. In *Fig. 1*, the portion surrounded by the chain-line is the air separator. The air sent to the air separator is then cooled to −170°C as it passes through the cold stor-

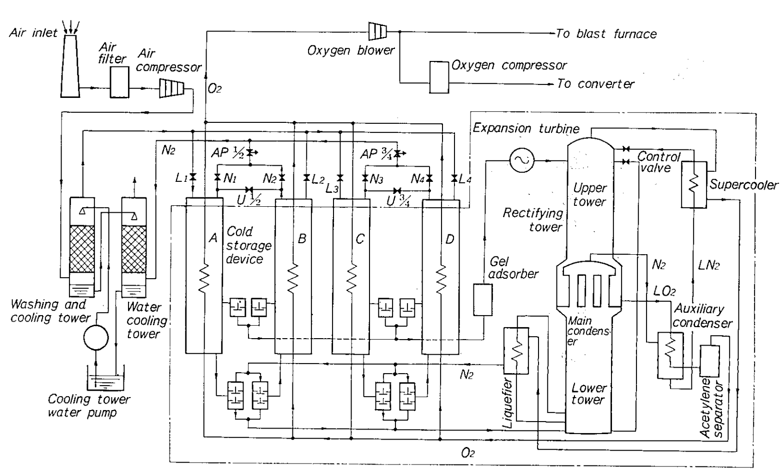

Fig. 1 Flow sheet of air separator plant

age equipment. It then enters the rectifying tower where it is rectified. The oxygen and nitrogen rectified by the separator are returned to the cold storage equipment. The nitrogen is sent to the water cooling tower from the cold storage equipment and serves to cool the cooling water. The oxygen passes through the cold storage equipment where its temperature returns to a normal value. Then the oxygen is compressed to approximately 4 kg/cm^2 by the oxygen blower. If the oxygen is to be used in a blast furnce, it can now be applied directly without any further processing. However, if it is to be used in a converter, it is necessary to compress it further to approximately 30 kg/cm^2.

2. Cold Storage Equipment

The cold storage equipment is a kind of heat exchanger for air (at normal temperature) and nitrogen and oxygen (at low temperatures). The cold storage equipment is a metal shell filled with small stones (approximately 10 mm ϕ). The purpose of the equipment is to cool the compressed air at a normal temperature to -173°C and also to solidify and remove any water or carbonic acid gas in the air input which could disturb rectification. Since a copper coil is used for the oxygen pipe, there is no fear of the oxygen deteriorating because of the entry of air or nitrogen. In *Fig. 1,* assume that the air will flow in the direction shown by the arrow, the cold storage equipment A is warmed by the air at normal temperature, and the cold storage equipment B is cooled by nitrogen and oxygen returning from the rectifier. If the direction of the air current is reversed in the cold storage equipment, cold storage equipment B is then cold and cold storage equipment B is warmed. Hence, heat exchange operation can be carried out by switching the air current direction in the cold storage equipment at intervals of approximately 10 minutes. In addition, the water and carbonic acid gas contained in the air in the cold storage equipment are exhausted together with the nitrogen.

III. ELECTRICAL EQUIPMENT

The electrical equipment for an oxygen plant can be classified as the high-voltage motor, low-voltage motor, high-voltage switchboard, low-voltage switchboard, control panel, and automatic switching panel for the cold storage equipment.

1. High-voltage Motor and Accessories

The high-voltage motor is used to drive the air compressor, oxygen blower, and oxygen compressor. Because of the way in which this motor is used, a squirrel-cage induction motor should be used from structural and maintenance standpoints, since a motor of this type must be operated continusly for several weeks or several months without speed control. However, when considering the influence of the motor on the power source and also the starting torque of the oxygen blower, a wound-rotor induction motor with a motorized brush raising mechanism is commonly used.

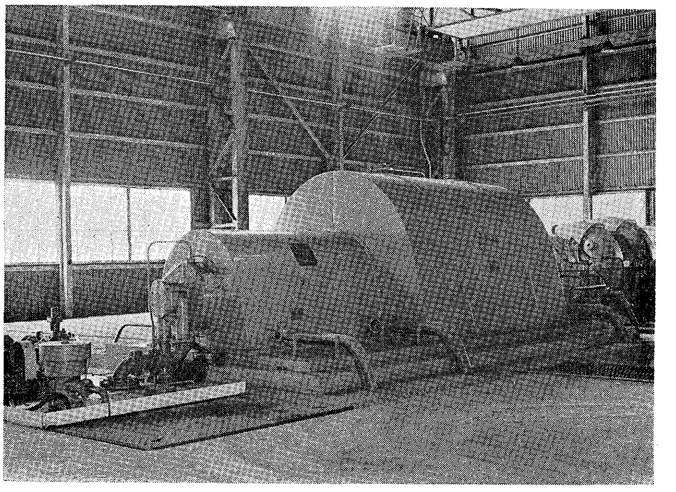

Fig. 2 5400 kw air compressor motor

The most common enclosure for a large-capacity high-speed air compressor motor or oxygen blower motor is a totally-enclosed pipe-ventilated machine whichpro vides forced ventilation of clean, filtered air from a separate fan. The slip ring chamber is compeletely enclosed. The sliding part of the secondary short-circuiting ring is operated using dry lubrication to prevent the motorized brush raising mechanism from malfunctioning due to the entry of dust. This is a very effective method, especially in iron and steel works where a considerable amount of fine dust is present. *Fig. 2* shows a 5400 kw air compressor motor and air compressor.

It is generally difficult to use clean water in an iron works to cool the motor only. However, if circumstances permit, a totally-enclosed water and air cooled motor with a built-in cooler using U-fin pipe should be used. With this cooling system, the motor's own fan circulates the air in the motor and the built-in cooler serves to cool the air by means of the cooling water. Al ternatively, the cooler may be separately installed in the motor foundation pit, or it can be optionally installed on either side of the motor. Hence, this motor-cooling system is superior than the forced ventilation cooling system in the following respects.

(1) There is no need to use a fan and air filter so that the required floor space is reduced, although the dimensions of the motor increace slightly because of the built-in cooler.
(2) There is no need to use a wind tunnel or wind pipe for forced ventilation.
(3) Foundation construction is simplified.

The oxygen compressor is a reciprocating compressor, and is usually operated at comparatively low speeds of 300 to 500 rpm. Therefore, the use of a flywheel may be necessary. If the capacity of the oxygen compressor is quite large, a synchronous motor is usually used in place of a wound-rotor induction motor. In this case, a silicon rectifier controlled by a saturable reactor is used as an exciter. It is of course possible to exchange this type of exciter with a thyristor. *Table 1* gives a list of electrical equipment recently supplied for use in oxygen plants in the iron and steel industry.

For the motor starter, a motor driven liquid resistor or an oil-drum type starter can be used optionally, depending on the motor capacity required.

2. Low-voltage Motor

The low-voltage motor is a squirrel-cage induction motor which is used for driving the air compressor oil pump, oxygen compressor oil pump, expansion turbine oil pump, liquid oxygen circulating pump, cooling tower water pump, and forced ventilating fan for the high-voltage motor, etc. In recent years, the totally-enclosed fan-cooled, E-1 series motor as specified by the IEC (JEM1180) has been widely used as a low-voltage motor for this purpose. The output of the motor is 30 kw or less. Approximately twenty of these motors are used for one oxygen plant.

For returning power to the power source, an induction generator may be coupled with the expansion turbine, but a brake blower is usually used to consume this energy.

3. High-voltage Switchboard

The high-voltage switchboard includes the low-voltage power source transformer panel and the condenser panel for improving the power-factor in addition to the high-voltage motor panel. In most cases, this high-voltage switchboard is equipped with a drawer-type circuit breaker which facilitates maintenance.

Previously, an OCB was generally employed, but in recent years, a MBB (for 3 kv and 6 kv) and a WCB (for 10 kv) have been widely utilized for this purpose. *Fig. 3* shows the high-voltage switchboard.

4. Low-voltage Switchboard

A control-center type switchboard is employed for this purpose, since this type switchboard is compact and can be easily maintained.

This switchboard is divided into two or three sections to be used separately with the air compressor auxiliary equipment, oxygen related auxiliary equipment, and air separator auxiliary equipment, so that maintenance is facilitated.

***Table 1* Supply List**

Year	Customer	Oxygen Productivity (Nm^3/hr)	Main Air Compressor Motor
1955	Kawasaki Steel Corp. (Chiba)	2000	1050 kw 3300 v 3000 rpm
1957	Nippon Kokan K.K. (Kawasaki)	4250	2400 kw 3150 v 3000 rpm
1958	Kawasaki Steel Corp. (Chiba)	3000	2100 kw 3300 v 3000 rpm
1960	Kawasaki Steel Corp. (Chiba)	4200	3100 kw 3300 v 3000 rpm
1960	Nisshin Steel Works Co., Ltd. (Kure)	1000	1100 kw 3300 v 3600 rpm
1960	Nihon Sanso K.K. (Shunan) [Nissin Steel Works Co., Ltd. (Shunan)]	500	440 kw 3300 v 514 rpm
1961	Kawasaki Steel Corp. (Chiba)	4200	3100 kw 3300 v 3000 rpm
1962	Kawasaki Steel Corp. (Chiba)	6000	4250 kw 3300 v 3000 rpm
1963	Kawasaki Steel Corp. (Chiba)	8000	5400 kw 6600 v 3000 rpm
1964	Kawasaki Steel Corp. (Chiba)	8000	5400 kw 6600 v 3300 rpm
1965	Nisshin Sanso K.K. [Nisshin Steel Works Co., Ltd. (Kure)]	5000	2900 kw 6600 v 3600 rpm
1965	Sumitomo Metal Industries, Ltd. (Kokura)	5000	2900 kw 3300 v 3600 rpm
1965	Kawasaki Steel Corp. (Chiba)	8000	5400 kw 6600 v 3000 rpm
1966	K.K. Fukuyama Sanso Center [Nippon Kokan K.K. (Fukuyama)]	12,000	6300 kw 11,000 v 1800 rpm
1966	Nisshin Sanso K.K. [Nisshin Steel Works Co., Ltd. (Kure)]	8000	4000 kw 6600 v 1800 rpm
Now Manfg.	K.K. Fukuyama Sanso Center [Nippon Kokan K.K. (Fukuyama)]	2,1000	6300 kw 11,000 v 1800 rpm
Now Manfg.	Kawasaki Steel Corp. (Mizushima)	8000	4300 kw 11,000 v 1800 rpm

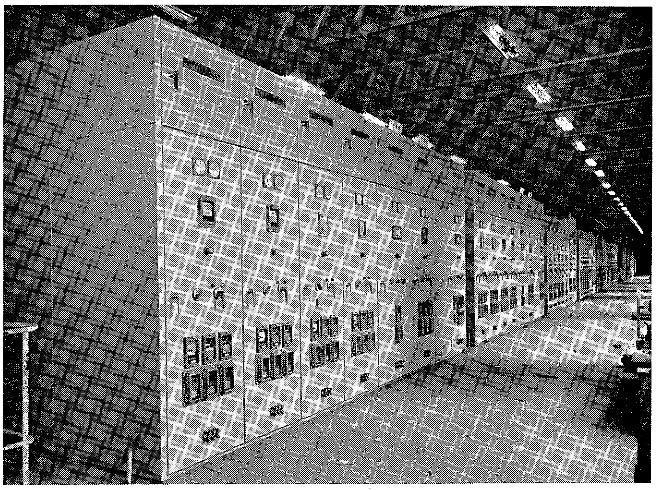

Fig. 3 High tension switch gear

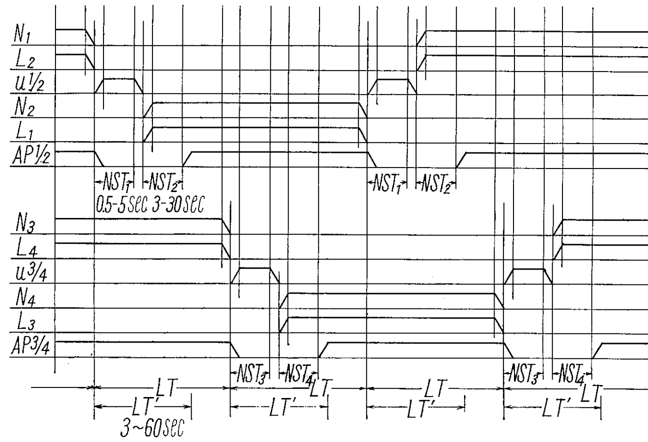

Fig. 4 Time schedule of valve change-over

5. Control Panel

If necessary, machine-side control panels are provided in addition to the control desk. In a plant of this type, it is usually not necessary to interlock the equipment units. However, the starting and stopping conditions for each device are of course interlocked.

6. Automatic Switching Panel for the Cold Storage Equipment

As mentioned previously, the cold storage equipment switches the air current direction approximately every 10 minutes. This is carried out by switching the electromagnetic valves L_1 through L_4, N_1 through N_4, $U_{1/2}$, $U_{3/4}$, and $AP_{1/2}$ through $_{3/4}$ as shown in *Fig. 1* in accordance with the switching schedule shown in *Fig. 4*. In *Fig. 1*, two-system type cold storage equipment is shown, which is the type most widely used by iron and steel works. Two methods are available for switching the air current direction. One method is based on overall automatic operation, while the other method is based on individual operation where each valve is operated with its own switch. With the overall automatic method, the air current is automatically switched when the temperature difference between the cold storage devices *A* and *B* has become higher than a set value. A switching signal is issued by the timer and temperature difference detector. The timer issues switching signals approximately every 5 minutes with which the two cold storage devices are switched alternately. The temperature difference detector uses two (platinum) thermosensitive resistors. These resistors (one per individual cold storage device) are inserted in pairs of cold storage devices.

The temperature difference measured in this manner is recorded by an electronic self-balance type recorder, and the switching signal is issued at the same time. The timer and the temperature difference detector do not issue switching signals at the same time. One is always issued ahead of the other one. Wen the timer signal is issued first, the temperature difference is decreasing. Therefore, there is no fear of switching the air current direction twice by mistake. However, if the detector signal is issued first, the timer signal follows, and the air current direction is switched again by the timer signal. Therefore, the switching operation is not satisfactory. To eliminate this trouble, a special circuit is provided to cancel out the switching signal sent by the timer only when the air current direction has already been switched by the temperature difference detector. In addition, it is also possible to provide switching control by a push-button system instead of a relay system as mentioned above.

Fig. 5 shows the automatic switch relay cubicle. The HH17 type relay is used as a control relay. Maintenance with this type of control relay is very easy, because it is provided with a plug type relay element. The relay panel is enclosed to prevent the entry of dust. The panel is equipped with a hole on the bottom for purging with nitrogen. At the top of the panel there are symbols indicating the valve system and the pilot lamps which indicate when the valves are opening or closing. Important switches such as the switching method selective

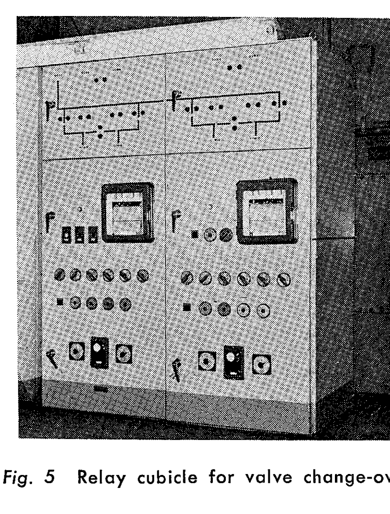

Fig. 5 Relay cubicle for valve change-over

switch, etc. are in form of key switches in order to avoid operating errors. However, lately, these symbols, lamps, and switches are usually mounted together on the operating panel (supplied by Japan Oxygen Co., Ltd.). The timer is of the no-contact type using a thyristor or transistor to improve its reliability. The switching device of this type is one application of the sequence control system with which Fuji Electric has considerable experience. This concept of automatic switching devices for valves of cold storage equipment has been successfully applied in the recent development of automatic valve switching equipment for use with the hot blast stove of a blast furnace.

IV. CONCLUSION

A brief outline of the oxygen plant used in the iron and steel industry and its related electrical exuipment has been given in the foregoing paragraph.

Future trends seem to be toward larger capacity oxygen plants for iron and steel works. In this respect, we electrical equipment manufacturers, should make every possible effort to develop greatly improved and reliable products.

One of the present problems confronting us is the use of a no-contact type control relay.

Fuji Electric, however, has already developed a highly reliable transistorized no-contact control relay. Therefore, we will have no technical problems regarding the development of this new type control relay in the future. Moreover, Fuji Electric has perfected no-contact valve switching equipment for hot blast stoves used with blast furnaces as was mentioned previously.

In view of these achievements, it will not be long before Fuji Electric can develop electrical equipment for use with oxygen plants which is totally free of contacts. Lastly, the writer would like to express his warm thanks to the employees of the Japan Oxygen Co., Ltd. and Chiba Works of the Kawasaki Steel Corporation for their cooperation and assistance in writing this paper.