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INSTRUMENTATION OF AIR SEPARATION PLANT

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I. INTRODUCTION

Air separation plants which separate oxygen, nitrogen, and argon from air and supply them to various processes connected with steel and chemical manufacturing are in great demand and various types are being produced. The main points of a representative process based on Fuji Electric's wide range of instrumentation experience will be discussed here.

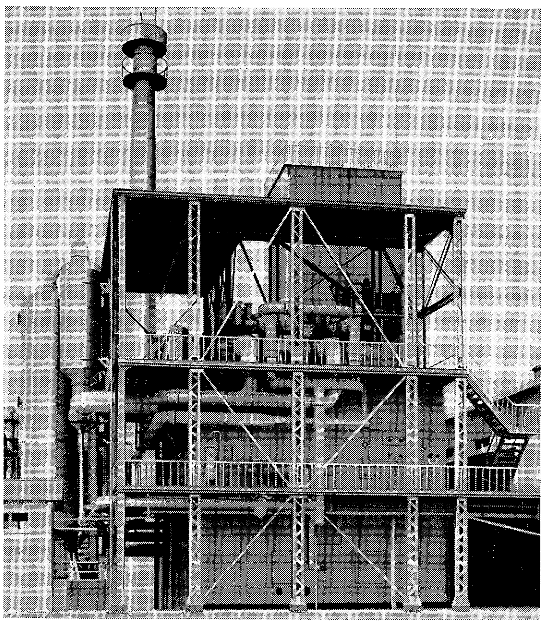

Fig. 1 External view of NR-type outdoor air separation plant

II. OUTLINE OF THE PROCESS

Air separation plants can be divided into complete low pressure types, medium pressure types, and high pressure types depending on application ; an outline of the operation of the first type of air separation plant will be presented here.

The first step is the intake of unpurified air which is filtered to remove any dust particles. The purified air is compressed in an air compressor until it reaches the required pressure of around 5 kg/cm^2 and then sent to an after cooler where it is cooled to about the same temperature as the circulating cooling water.

The cooled compressed air is fed into one side of a pair of regenerative coolers, and is cooled to saturation temperature (−173°C) by the coolant.

After any moisture and carbon dioxide gas has been eliminated, the air is fed via a check valve into the base of the lower part of a fractionating tower. The fractionating tower is of the compound type with two condensors in the upper and lower parts respectively. Compressed air in the lower tower is prefractionated ; liquid air remains at the bottom, while liquid nitrogen goes to the top (oxygen concentration in the liquid air is around 35%). The liquid air is sent into the middle part of the upper tower via an acetylene absorber and liquid-air supercooler, and the liquid nitrogen is sent into the top part of the upper tower via a liquid nitrogen supercooler.

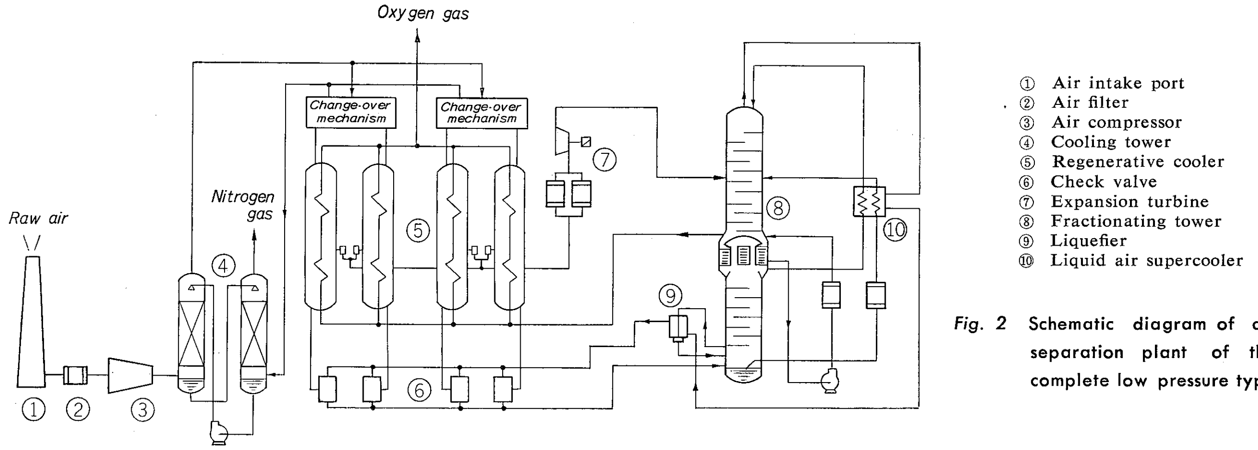

Fig. 2 Schematic diagram of air separation plant of the complete low pressure type

Some of the cooling air is taken from the middle part of the regenerative cooler for the elimination and regeneration of carbon dioxide. After any carbon dioxide has been eliminated by a gel absorber the cooling air is fed into an expansion turbine.

The air which undergoes adiabatic expansion in an expansion turbine is cooled down further and fed into the middle part of the upper fractionating tower. Nitrogen gas remains at the top after fractionation, and high-purity liquid oxygen is left in the condenser at the bottom. The liquid oxygen is fed to a circulating absorber by a liquid oxygen pump so that impurities, such as acetylene, can be eliminated and the liquid oxygen will be safer to handle. The liquid oxygen is taken off from the upper part of the condenser and sent into the coiled pipe of the regenerative cooler. As it rises, the oxygen is heated and is finally taken off at room temperature as the end product.

The nitrogen rises on the outside of the coiled pipe of the regenerative cooler and lowers the temperature of the regenerative coolant after passing through a supercooler and liquefier. It finally leaves the system at room temperature.

III. INSTRUMENTATION

1. Instrumentation Method

The air-pressure-type separation plant is generally used, since it is compact and requires long transmission distances only in special cases. The electronic-type is used when a temperature system or operator is required for observation.

Several points that should be noted particularly concerning instrumentation of air separation plants are as follows:

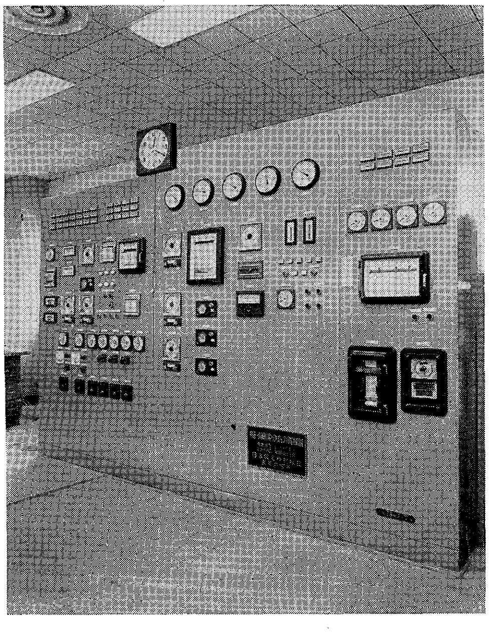

Fig. 3 Central control panel

(1) When oxygen is used for observation, all detection surfaces must be treated against oil (the material of detectors, pressure conduits, and necessary packings must be examined carefully to prevent oxidation).
(2) Flow meter for end product oxygen must be as accurate as possible with correction attachments for temperature and pressure regardless of operating conditions in the plant.
(3) Since the plant is operated at a minimum temperature, great care must be taken in regards to adiabatic treatment and freeze-proofing of the regulating valve and other parts. Thermometer elements must be filled with silicone grease or an inorganic powder to prevent disconnection and insulation deterioration which can result from freezing of moisture.
(4) A turbo-compressor or reciprocating compressor is used for pressure transmission; with the latter, flow will pulsate so that other differences must be minimized by careful instrumentation of the detection element (orifice) and choice of transmitter. As an example, good results are obtained by diminishing the pulsation rate to below 2%. *Fig. 4* shows pulsating flow before and after inhibition.

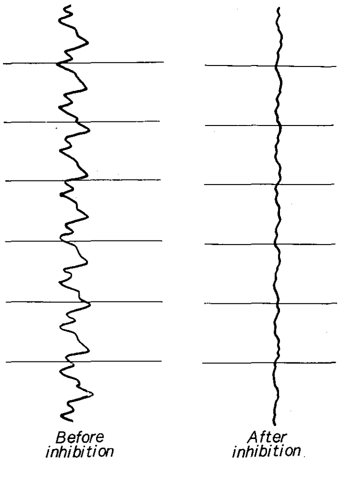

Fig. 4 Pulsating flow

(5) Level observation of liquefied gases such as liquid oxygen requires a pressure conduit to the exterior of the outer adiabatic tank. Deterioration of the difference pressure of the gas will be explained later.

2. Observation Control Points

Since the complete low pressure type air separation plant exhibits a high degree of self-regulation, a comparatively small control system enables efficient and stable operation.

However, since long-term continuous operation is required at temperatures as low as $-200°C$, special consideration is necessary concerning various points of instrumentation. Remote control at all operating valves is necessary if the plant has a large capacity.

Safety mechanisms become complex and supervisory control devices play a very important role in the operation of the plant. Major control points are as follows:

1) Heat regulation among regenerative cooler groups (Regenerative cooler average temperature difference control)

The regenerative cooler performs highly efficient heat exchanging between low-temperature separated gases and unseparated air, and also eliminates impurities in the unpurified air (moisture and carbon dioxide). This operation is the most important factor in deciding the efficiency and life of a separation plant, and therefore it must be watched very closely.

In order that the regenerative cooler groups perform proper heat exchanging, it is necessary to distribute the raw air in accordance with the flow of the separated gas to the regenerative coolers. In the detection of this flow distribution, either flow or temperature can be considered. However, since it is difficult to detect subtle differences in flow because of the time lag and fluctuations will result from regenerative cooler exchanging action, temperature detection is generally used.

In the observation of cooler temperature distribution, almost all the raw air is at saturation temperature (−173°C) as is shown in *Fig. 5* (*a*), and the temperature in each part changes greatly during exchanging the temperature in the middle part, in particular, changes by 40°C to 50°C. The temperature of the middle part best represents the heat exchanging in the regenerative cooler when compared with upper or lower parts.

Observation of this temperature change in a pair of regenerative coolers is shown in *Fig. 5* (*b*). The phases interchange with each other and the average temperature in the middle part of cooler pair remains constant regardless of the exchanging time; variation depends only on the flow ratio of cooler pair.

Therfore, the most suitable flow distribution can be arranged by making the average temperature difference between two groups (or among many

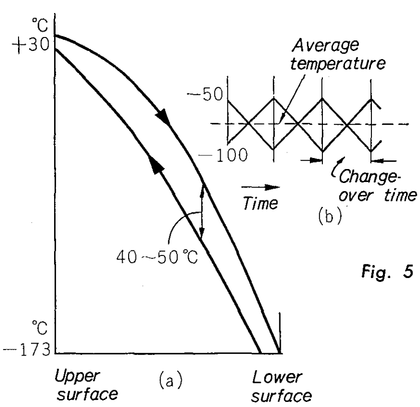

Fig. 5 **Temperature distribution of regenerative cooler**

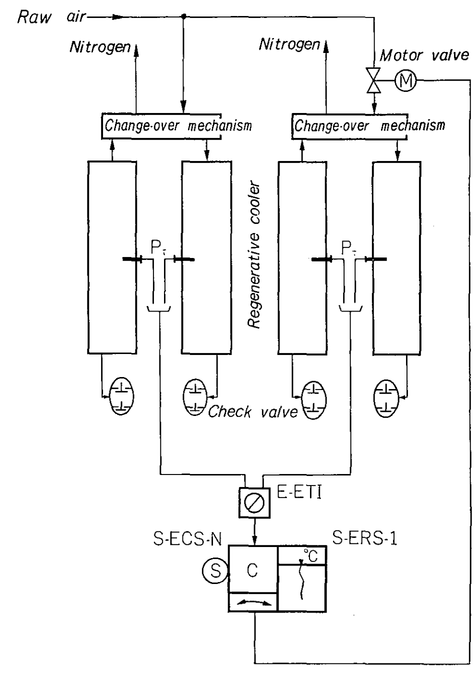

Fig. 6 **Instrumentation diagram of average temperature in cooler**

groups) zero or a constant value. (Japanese Patent No. 250775)

The control devices are meant to regulate the motor operation valve in order to detect the temperature in the cooler middle parts using a platinum temperature measuring resistor. These then obtain the average temperature with a new TELEPERM temperature transmitter (E-ETI), and adjust the temperature difference among the respective groups to zero (or a constant value) using a new TELEPERM horizontal regulation meter (S-ECS-N). Temperature regulation of the regenerative cooler is thus possible.

2) Fractionating tower liquid air level control

The fractionating tower which fractionates and separates oxygen, nitrogen, and argon from air is a compound type. In contrast to usual fractionating towers needing an intermedium for heating or cooling, the compound frrctionating tower performs these operations using the pressure of the raw air and the difference in composition. It, therefore, has only a small degree of control freedom. It also brings about disturbances in the pressure change caused by the periodical exchange of coolers. In order to absorb this pressure change and stabilize the system to enhance the fractionating effect, the level of liquid air in the lower fractionating tower is controlled.

The level transmitter is a TELEPNEU differential pressure transmitter (P-DTD) which operates a controlling valve with a level recording controlling meter (S-PRC) in order to control the upper fractionating tower reflux liquid. Differential pressure is taken off as gas differential pressure by a pressure conduit leading to the exterior of the outer adiabatic tank, as shown in *Fig. 7*.

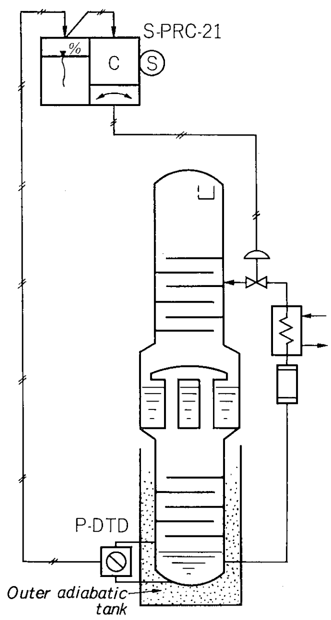

Fig. 7 **Instrumentation diagram of fractionating tower liquid air level**

3) End product oxygen gas flow recording integrating device.

This device is concerned with the product flowmeter mentioned. Since it is used directly for the end product, it must have high-efficiency automatic temperature and pressure compensation.

The device consists of a TELEPERM flow transmitter (MMF II), a patented device developed by Fuji Electric. It requires no differential pressure root extract since its output signal is preroot extract. The new TELEPERM correction operator (E-IOM-PTR) is used as the temperature/pressure correction device and the new TELEPERM pressure transmitter (E-PTH) with platinum temperature measuring resis-

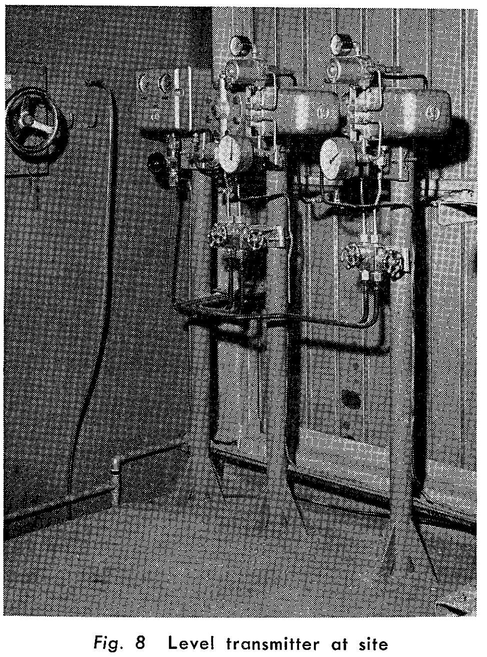

Fig. 8 **Level transmitter at site**

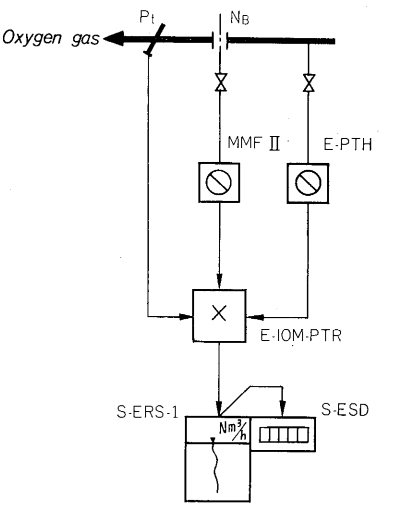

Fig. 9 **Instrumentation diagram of oxygen gas flow**

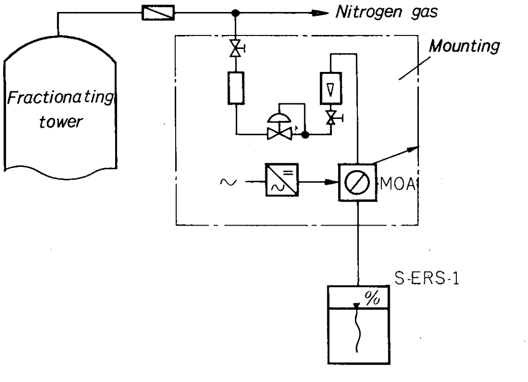

Fig. 10 **Instrumentation diagram of nitrogen gas analyzer**

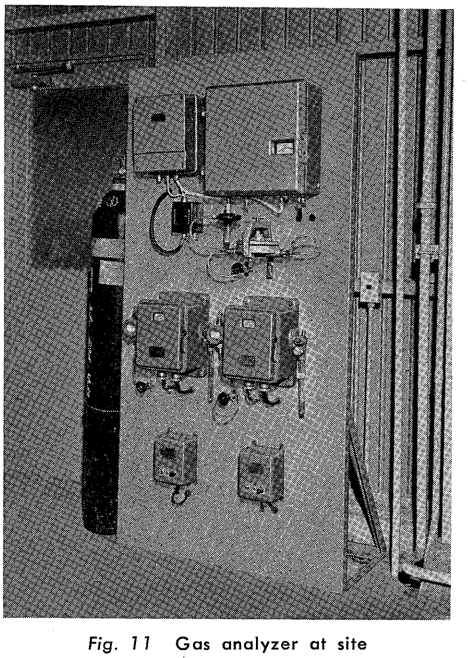

Fig. 11 **Gas analyzer at site**

tor (JIS-0.3 grade) serves as pressure and temperature detector. The receiving device consists of a new TELEPERM S-series automatic recording meter

(S-ERS) and a high-efficiency electronic-type integrating indicator (S-ESD).

Several units are now operating well.

4) Nitrogen gas purity indicator.

This device analyzes the purity of the nitrogen gas that flows out from the top of the upper fractionating tower by observing the oxygen concentration in the nitrogen gas. The device consists of a suitable magnet-type oxygen gas analyzer (MOA-O_2) and S-series automatic recording meter (S-ERS).

5) Temperature supervisory control device (Temperature scanning monitor).

This device is part of the aforementioned safety mechanism. It observes the temperature of the bearing, oil supply, and water supply of rotary machines inside the air separation plant (turbocompressor for raw air, oxygen turbo-compressor, oxygen compressor, and nitrogen compressor). It simultaneously performs temperature call indication at required observation points. Specifications of this device are as follows:

Observation points: Less than 100 points

Scanning method: Transistor-type (Transistor drive relay change-over type)

Scanning point method: At individual points

Scanning speed: 0.5 sec/point

Alarm method: Upper limit burn-out alarm (individual lamp indication type)

Alarm setting method: Pin-board or dial settings

Alarm setting temperature: 0 to 199°C (1°C step)

Temperature call indication: Pushbutton switch plus electronic type indicator

Indication scale: 0 to 200°C

Check circuit: Check source fuse, scanner motion, and deflection amplifier; indication of plant disorder, bell, small lamp and common circular lamps.

Some characteristics of this supervisory control device are as follows:

(1) Concentrated supervisory control with a large detection range possible.
(2) Installation in a compact area possible.
(3) Sequential combination by setting exterior interlocking contact possible.
(4) Equipped with a self-checking circuit to prevent movement error.

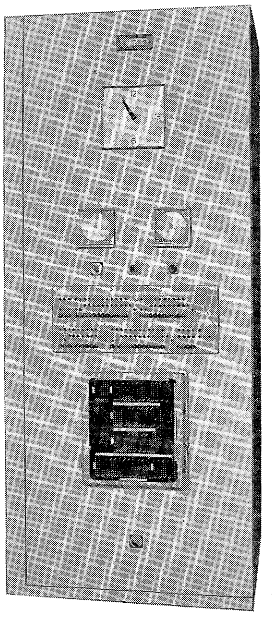

Fig. 12 Scanning monitor panel

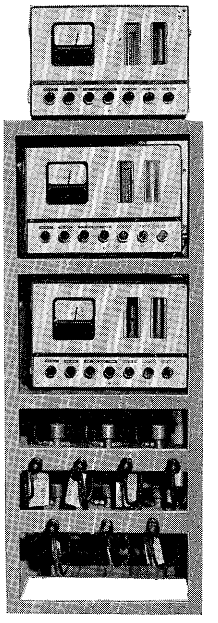

Fig. 13 PPMO_2 gas analyzer

(5) Equipped with 2 deflection amplifiers in its core to enable automatic exchange to spare deflection amplifier when an unexpected accident occurs in the first amplifier in general use.
(6) Operation regardless of whether the detection surface is of the grounded type or not possible since the observation circuit is of the double-cut type.

IV. CONCLUSION

The instrumentation of an air separation plant has been summarized. So far, more than 10 plants have been instrumented by Fuji Electric through the Japan Oxygen Company and all of these plants are operating efficiently.

Two instrumentation problems which must be solved in the future are:

(1) Observation of impurities in liquid oxygen and acetylene, in particular
(2) Still more efficient observation of pulsating flow.

Many oxygen micrometers developed by Japan Oxygen and Fuji Electric are now in operation at various plants.