Technology

Development of Impurity Removal Technology for Crude Neon Gas

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1. Introduction

Neon is widely used as a diluent gas for excimer lasers in the semiconductor manufacturing process[1]. In response to global supply concerns that have become evident following the Russian invasion into Ukraine, formerly a major neon supplier, the Japanese government is strengthening the domestic neon production system from the perspective of economic security. Having received a government grant for this initiative, our company has decided to install a neon purification system in the Kimitsu Sanso Center. This system employs a neon purification method adopted by our company for the first time.

This report provides an overview of the newly developed neon purification process[2)-4)] and describes the design of the VPSA (Vacuum Pressure Swing Adsorption) unit, which utilizes a room-temperature adsorption and vacuum regeneration method to remove impurities such as nitrogen. Our company is the first to adopt a room-temperature VPSA system for the removal of impurities such as nitrogen within a neon purification process.

2. Neon Gas Purification Method

2.1 Raw materials

Neon is present in the atmosphere at a concentration of approximately 18 vol.ppm, and it is purified from crude neon gas, which is obtained from rectifying columns as a non-condensable gas along with nitrogen, helium, and hydrogen during the fractional distillation of the atmospheric air to produce oxygen, nitrogen, and argon. Table 1 shows an example of the composition of crude neon gas.

Table 1 Composition of crude neon gas (example)

Component	Concentration	Boiling point (1 atm)
Neon	49vol.%	−246 ˚C
Hydrogen	2vol.%	−253 ˚C
Helium	15vol.%	−269 ˚C
Nitrogen	34vol.%	−196 ˚C

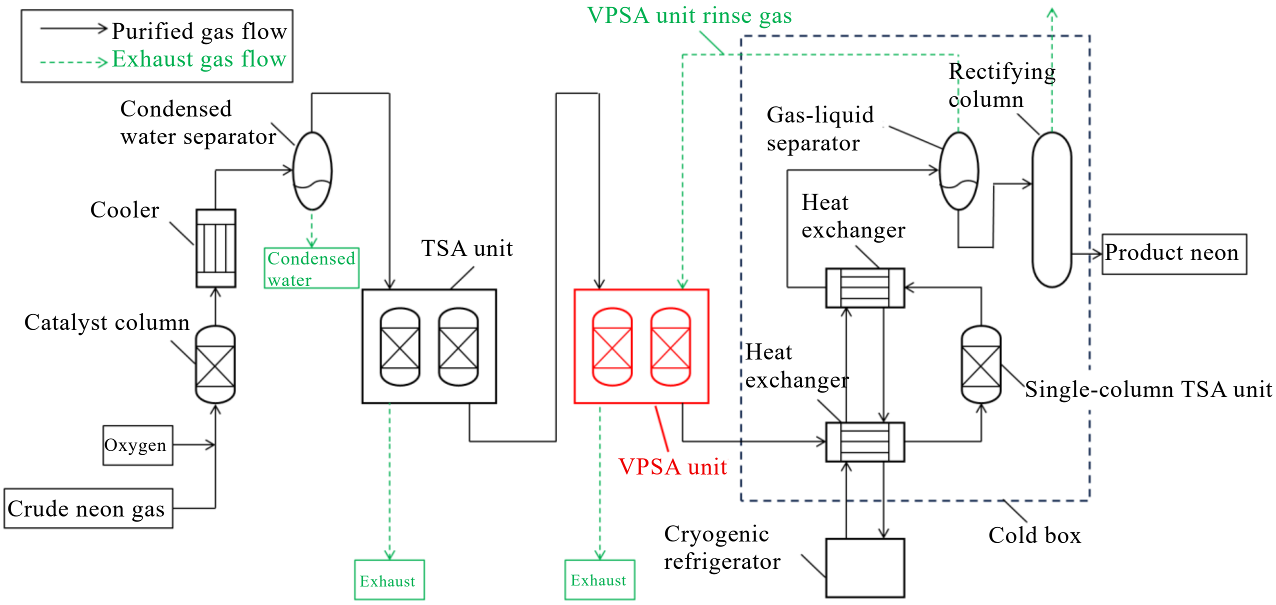

Fig. 1 Neon purification process developed by our company

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2.2 Neon Purification Process Developed by Our Company

Fig. 1 shows the purification process developed by our company. In this process, hydrogen and the majority of nitrogen are removed at room temperature, and then helium and residual nitrogen are removed at the cryogenic temperatures inside a cold box.

The details of each step are described below. In the first step, hydrogen is removed. After oxygen is added to the crude neon gas, the mixture is introduced into a catalyst column to oxidize the hydrogen. This causes the hydrogen and oxygen to react, then they are converted into water (moisture).

In the second step, the water generated by the reaction between hydrogen and oxygen is removed. Since the purified gas from the first step is at a high temperature due to the heat of reaction, it is introduced into a cooler to be cooled, and then the condensed water and the purified gas are separated in a condensed water separator. Subsequently, the moisture is removed using a TSA (Temperature Swing Adsorption) unit, which repeats adsorption and regeneration cycles based on temperature differences.

In the third step, the majority of nitrogen, oxygen, and argon, which is introduced along with the oxygen, is removed from the purified gas obtained in the second step. For this process, the aforementioned VPSA unit is used[2). As a rinse gas for promoting the desorption of impurities during adsorbent regeneration, a nitrogen-free gas with a low neon concentration, which is obtained from the fifth step described later, is used. This enables an improvement in the neon recovery rate[3). Furthermore, removing oxygen and argon in this step reduces the load on the TSA unit in the fourth step described later, thereby allowing for a more compact cold box design[4).

The fourth step removes trace amounts of nitrogen, oxygen, and argon remaining in the purified gas from the third step. From this step onward, operations are conducted inside a cold box. When the gas to be purified is introduced into the cold box, it is cooled to a temperature of 100 K or lower through heat exchange with a circulating refrigerant supplied by a cryogenic refrigerator. Impurity removal in this step utilizes a single-column TSA unit. This adsorption column is designed to maintain its performance by undergoing a regeneration process when the entire system is returned to room temperature, such as during periodic inspections.

The fifth step removes the majority of helium from the purified gas obtained in the fourth step. Since this step is operated at a temperature where neon liquefies, the gas is again heat-exchanged with the circulating refrigerant used in the fourth step to cool it to 44 K or lower, and then introduced into a gas-liquid separator. This separator yields a neon-enriched liquid and a helium-enriched gas. Normally, the helium-enriched gas is exhausted from the system; however, since it contains no nitrogen, it can be utilized as the rinse gas for the aforementioned third step.

The sixth step further purifies the neon-enriched liquid obtained in the fifth step to produce product-grade neon with a purity of 99.99 vol.% or higher. A rectifying column is employed in this step.

Note that, although omitted from Fig. 1, the necessary pressurization for each step is implemented as appropriate.

2.3 Comparison with Conventional Processes

As a method of removing impurities such as nitrogen, a method of performing both gas-liquid separation based on boiling point differences and purification using a TSA unit within a cold box is known[5). In this method, the impurity concentration flowing into the TSA unit is high, which makes the temperature increase during regeneration and the cooling before the start of adsorption frequent, resulting in an increase in the power consumption of the cryogenic refrigerator. Additionally, there is also an issue that the number of pieces of internal equipment increases and the cold box becomes larger.

Processes using a room-temperature VPSA unit are typically disadvantageous in terms of the neon recovery rate because a portion of the purified gas is used as the rinse gas. On the other hand, in the process developed by our company, the loss of neon is suppressed by using gas that is normally exhausted as the rinse gas[3), which realizes purification with lower power consumption and a compact cold box.

3. Design of the VPSA Unit

The nitrogen adsorption isotherms of various adsorbents were measured (Fig. 2), and Adsorbent A, which has the largest effective adsorption capacity, was selected as the adsorbent for this unit. In addition, the required amount of adsorbent was determined based on the results of the VPSA process test conducted by varying the cycle time, regeneration pressure, ambient temperature, and the concentration of impurity components. To increase the neon recovery rate, this unit adopts a process with minimal neon loss that includes multi-stage pressure equalization steps.

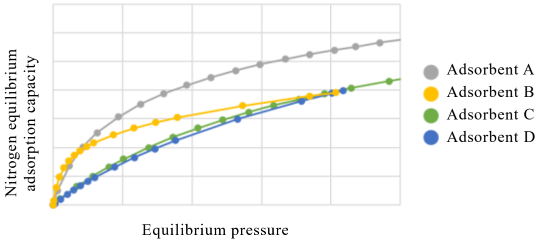

Fig. 2 Results of Adsorption Isotherms Measurements

4. Conclusion

By using a room-temperature VPSA unit to remove impurities such as nitrogen, we have developed a process for purifying neon from crude neon gas that features a more compact cold box and lower power consumption compared to conventional methods.

References
1) Gas Georama 2025. Gas Review, 2024, p. 188.
2) Taiyo Nippon Sanso Corporation. Neon Purification System and Neon Purification Method. Japan Patent No. 7733204. September 2, 2025.
3) Taiyo Nippon Sanso Corporation. Neon Purification System and Neon Purification Method. Japan Patent No. 7599050. December 12, 2024.
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5) Air Liquide. Device and Method for Purifying a Gas Mixture. European Patent Publication EP3406993B1. August 2, 2023.