A new type of condenser-evaporator safely operated in large air separation plant

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A new condenser–evaporator for 30000 m^3/hr air separation plant is developed. Its heat transfer coefficient is increased by 50%. Both its volume and weight are reduced by 1/3 compared with the traditional one. Its total temperature difference for heat transfer is only 0.57K. According to the theoretical analysis, the flow velocity of oxygen gas is increased to 6.74m/s. Thus the oxygen gas could carry the heaviest particles of N_2O of 0.4mm in diameter out of the flow channel in comparison with the traditional products in which the particles of greater than 0.2mm in diameter could not be carried away from the channel.

INTRODUCTION

The condenser- evaporator is also called as the double phase-change heat exchanger. Its importance lies in the fact that all the high purity products of oxygen and nitrogen in oxygen plant are produced in this equipment. In oxygen production plant, acetylene is most likely accumulated in the condenser –evaporator. The behavior of fluid flow in the equipment has a direct influence on the accumulation of acetylene. Therefore, many engineers and experts in the area of air separation are making their efforts now in improving the performance of heat transfer of the condenser–evaporator and in preventing it from explosive possibility. Due to their backward mechanism of heat transfer, the temperature difference of heat transfer of the old type of condenser-evaporator is so large and the heat transfer coefficient is so small that the diameter of the condenser –evaporator is larger than the allowed standard for railway transportation. The distillation column can only be installed in situ, so that the quality of the installation cannot be assured. Additionally the backward mechanism of heat transfer brings about an increase in pressure of the lower distillation column, so that the work consumption of the air compressor becomes larger. In order to meet the requirements for the developments of the iron-steel industry, the modern oxygen plants are expanding to a very large scale during the 1990's. However, the large-scale plants present a demand to increase the size of condenser –evaporator greatly.

But there is a limitation to increase the size of condenser –evaporator due to the difficulties existed in transportation and in construction of very large distillation column. The backward technique of traditional condenser –evaporator could not resolve this contradiction to develop large-scale plants.

A new type of condenser –evaporator was invented, manufactured and installed in an air separation plant with oxygen output of 6500m^3/hr in Hangzhow Iron-Steel Company in 1997', which has been successfully operated for 4 years already. Another large condenser –evaporator was manufactured and installed in Baoshan Iron-Steel Company in 2002', which has been successfully operated for one year already. It has a compact structure and thus meets the urgent requirements for developing large scale oxygen production plants, large scale ethylene production plants and so on.

THE PRINCIPLE

The invention makes a breakthrough in traditional mechanism of nucleation boiling heat transfer in which the liquid flow occupies the most part of the boiling channel. It creates a new mechanism of boiling heat transfer with quasi-annular flow and results in a phenomenon of stimulation heat transfer enhancement, and accordingly it innovates a new structure. Thus it enables the boiling channel to be operated at an optimum state with quasi-annular flow in boiling channel, which is called as stimulation state of boiling heat transfer. Therefore the invented condenser-evaporator is called quasi-annular flow condenser-evaporator. It not only increases the critical heat flux of the boiling channel greatly up to 10000W/m^2, but also increases the heat transfer coefficient up to the maximum and decreases the temperature difference to the minimum of 0.57K compared with the current products. The invention also makes a breakthrough in the traditional mechanism of condensing heat transfer with laminar condensing liquid film, and creates a new mechanism of the enhanced condensing heat transfer with turbulent condensing liquid film. Afterwards, it also innovates a new structure of condensing channel. As a result of above modifications the condensing heat transfer coefficient is remarkably increased and the overall heat transfer performance of the condenser–evaporator has a marked improvement.

As is known, the temperature difference of Dt for the new condenser–evaporator is decreased due to the modification of mechanism of boiling heat transfer, the modification of condensation mechanism and the invention of new coupling method of condensing channel and evaporating channel. Though it benefits to the decrease of energy consumption of the plant, it would bring about decreasing in heat flux of q. However the heat flux of q must be increased greatly in. order to develop large-scale oxygen production plant. Fortunately the heat flux of q for the new condenser–evaporator is able to increase greatly due to the increase of product of (h · Dt).

THE MAIN TECHNICAL PARAMETERS

In the December of 2002’, a new condenser-evaporator of 30000m^3/hr air separation plant was manufactured and installed in Baoshan iron steel company to replace the original one which was imported outside of China. The volume of the old one was too large to be installed between the upper and lower distillation columns. Due to mismatch of the distillation column with the condenser-evaporator, the oxygen output of the old plant was only 20000 m^3/hr and never attained 30000 m^3/hr. The diameter of the new condenser-evaporator is reduced by 1200 mm (the relative ratio of 25%). Thus it could be installed into the distillation column so as to simplify the piping and the instillation process.

All the main technical parameters of the new condenser–evaporator are superior to the current products. In comparison with the designing standard set by the most advanced companies in the world, the heat transfer coefficient is increased by 50%, the output of the oxygen production is increased by 15~20%. The total temperature difference for heat transfer is only 0.57K, which is the minimum one among the same products currently operated in the world. The most outstanding characteristic of the new product is its recovery ability of oxygen purity after an undesired shut down of electric power system. It takes only 20 minutes for recovery in comparison with 3 to 4 hours of the recovery time for old products. The oxygen output of the new product attains 30000 m^3/hr more. The power consumption of the new product is reduced by 6.18%.In following tables, the specific volume is defined as the volume of the condenser-evaporator required for 1 m^3 of oxygen gas output when the total temperature difference of heat transfer of the condenser-evaporator is 1 K. So is the definition of the specific weight or the specific surface area. According to the theoretical analysis, the flow velocity of oxygen gas in the narrow channel is increased to 6.74m/s. Thus the oxygen gas could carry the heaviest particles of N_2O of 0.4mm in diameter out of the flow channel to prevent it from accumulating inside the flow passage. In comparison with the traditional products the particles of greater than 0.2mm in diameter could not be carried away from the channel.

Table 1 The main technical performance indices of new condenser –evaporator in comparison with the traditional products for 6000m^3/hr oxygen plant

Technical parameters	New condenser Evaporator	traditional Main condenser
Total heat transfer coefficient($W/m^2.K$)	930	620
Total heat transfer temperature difference(K)	0.57	1.2－1.4
Pressure of lower column(MPa)	0.42	0.5
Purity of oxygen gas(O_2%) above	99.8	99.7
Purity of nitrogen gas(N_2%) above	99.99	99.99
Output of oxygen gas(m^3/h)	6600	6000

Table 2 The operating performance of new condenser–evaporator in comparison with the traditional products

Technical parameters	New condenser evaporator	Traditional products
Starting period	14~16 hours	20~24 hours
Operability	Convenient	Difficult
Safety	Good	General
Contamination of heat transfer surface	Not easy	Easy
Blockage in tube	No	Yes for sintered tube type
Energy consumption	Reduced by4.2%	Large
Operation state	Stable	Not stable
Adjust- ability	Good	Bad
Recovery period after shutdown	20 minutes	At least 3 hours
Continuous running time	More than2 years	Less than 2 years

Table 3 Feasibility of manufacture of new condenser –evaporator in comparison with the traditional products for 6000m^3/hr plant

Technical parameters	new condenser-Evaporator	Traditional products	Reduced by (%)
Manufacturing procedure	Simple	Complicated	
Specific* volume（L/m^3O_2K）	0.531	1.0296	48.4%
Specific* weight（kg/m^3O_2K）	0.6435	0.9724	33.8%
Specific* Surface area（m^2/m^3O_2K）	0.3645	0.559	44.8%
Cost r (RMB1000 Yuan)	514	754	31.8%

Table 1 and Table 2 show the main technical performance indice and the operation performance of the new condenser-evaqporator which was installed in a 6500 m^3/hr oxygen plant in Hangzhow Iron-steel Company, respectively. The data were collected from the original records in the factory.Table 3 shows the advantages of the new condenser- evaporator in manufacturing of the 6500 m^3/hr oxygen plant.Table 4 shows the fluid flow parameters and heat transfer coefficient of both 6500 m^3/hr oxygen plant in Hangzhow Iron-steel Company and the 30000 m^3/hr oxygen plant in Baoshan Iron-Steel Company .In the 30000 m^3/hr oxygen plant in Baoshan Iron-Steel Company ,the total amount of carbon-hydrogen mixtures is only 80 ppm, which is lower than allowed value.

The invention has been successfully applied in large-scale oxygen production plants, whose outstanding performances are superior to all the current products in the world.

Table 4 The fluid flow parameters and heat transfer coefficient for two products

	Boiling channel (Oxygen)			Condensing channel (Nitrogen)		
	Heat transfer coefficient ($W/m^2.K$)	Oxygen vapor flow velocity (m/s)	Reynolds number	Heat transfer coefficient ($W/m^2.K$)	Nitrogen vapor flow velocity (m/s)	Reynolds number
New products	2200	6.74	4400	3600	1.94	11150
Old products	1500	1.88	2200	1960	0.92	6700

CONCLUSION

By changing the boiling and condensing mechanism of heat transfer and accordingly modifying the structure of boiling and condensing channels the new condenser –evaporator has become more efficient to operate, more compact in structure, advantageous to environmental protection, beneficial to energy saving and economical in manufacturing costs. Its working state is stable, easier to achieve normal state from start and convenient to be adjusted, and could be rapidly recovered after an undesired shut down. The authors are grateful to the State Natural Science Foundation for the financial support to the projects of 50176036 and 502766048.

REFERENCES

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