Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Development of A Gas Stripping Unit to Improve the Contaminant Removing Capability

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1. Introduction

Hydrogen and fission gases dissolved in the reactor coolant shall be removed for preventing hydrogen explosion and radiation exposure during reactor shutdown. Typically, the gas stripper of Chemical and Volume Control System (CVCS) has been designed to remove dissolved fission gases by a minimum decontamination factor of 1000 under the operation condition. This is to maintain occupational radiation exposure ALARA and minimize release of radioactive gases to the environment.

Operating nuclear power plants have been requiring better efficiency and greater processing capacity of gas stripper to reduce their outage durations, and small reactors and especially Small Modular Reactors (SMRs) need a compact design for the CVCS gas stripper to minimize the overall system arrangement space because of bulky size and high energy consuming design of the conventional Gas Stripper.

The purpose of this paper is to suggest a new design of gas stripper using vacuum and to evaluate the effects of the gas stripper design on operating conditions and size compared with APR1400.

2. Gas Stripper

This section deals with the evaluation results and layout of newly designed vacuum gas stripper compared with the current gas stripper.

2.1 Current Gas Stripper

As shown in Fig. 1, the gas stripper system consists of gas stripper column, heat exchangers, pumps, associated piping and a steel-made square piping structure that supports all components in the unit. The influent stream is preheated at a predetermined temperature by a heat recovery exchanger and a preheater. Gas stripping of influent liquid occurs in the stripper column. The stripping steam is generated by heating the degassed process fluid with steam. Heat exchangers are a shell & tube type and are mounted vertically with their channel heads at the bottom for complete drainage and maintenance [1].

The degassed liquid is pumped from the bottom of the column through the heat recovery exchanger and the aftercooler and discharged to the volume control tank or the holdup tank. The stripped gases are discharged through the condenser to the gas waste management system.

As shown in Fig. 2, the overall dimensions of gas stripper process unit are 3,048 mm (width) x 3,048 mm (length) x 7,720 mm (height) [2].

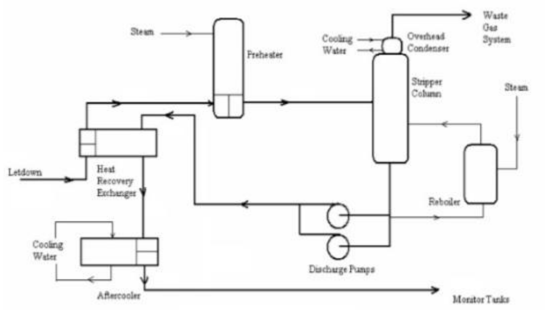

Fig. 1. Current Gas Stripper Schematic (APR1400)

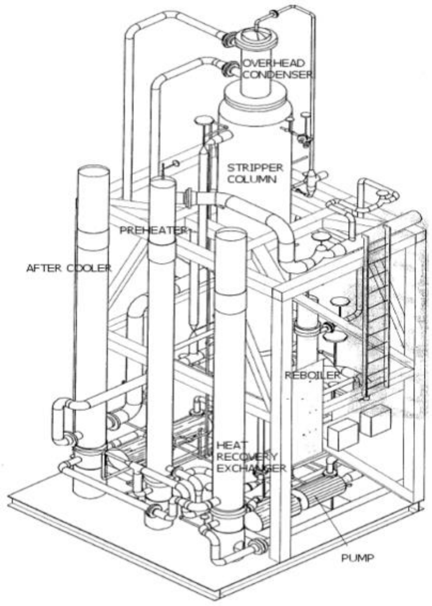

Fig. 2. Current Gas Stripper process unit

2.2 Vacuum Gas Stripper Evaluation

The mechanism of vacuum degasification is based on the Henry's law and the Le chatelier's principle [3]. Gases are dissolved in solutions. Since the dissolution is an equilibrium process, the equilibrium constant for this equilibrium is introduced. The equilibrium constant shows that the concentration of a solute gas in a solution is directly proportional to the partial pressure of gas above the solution. This is known as the Henry's law as follows.

$$y^* = p^*/p_T = mx$$

Where,
y^*: gas molar fraction in gas phase
p^*: gas partial pressure in gas phase
p_T: total pressure of gas phase
m: Henry's constant
x: gas molar fraction in solution

The Le Chatelier's Principle explains the state of dynamic equilibrium. It determines the changes to the location of equilibrium if concentration, pressure or temperature is changed. If a dynamic equilibrium is disturbed by changing the conditions, the location of equilibrium moves to counteract the change.

In general, the process flow of the gas stripper and vacuum stripper is heated by a heating medium to enhance the stripping efficiency based on the Le Chatelier's Principle.

The design of the vacuum gas stripper was evaluated using a computer code simulation to see if it satisfies APR1400 design requirements [4]. The evaluation results demonstrated that the vacuum gas stripper can be properly designed with a vacuum of approximately 0.1 bar (absolute) to meet the performance requirements [4]. The schematic diagram of the vacuum gas stripper is shown in Fig. 3.

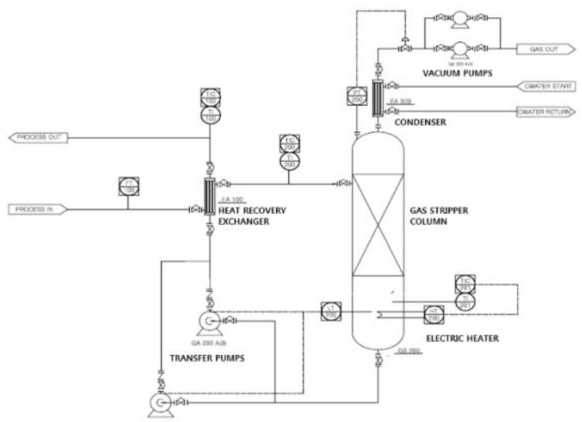

Fig. 3. Vacuum Gas Stripper schematic

Since the required heat load is reduced by operating at a temperature significantly lower than the conventional steam heating gas stripper, the process unit of the vacuum gas stripper would be quite optimized and simplified. It has a heat recovery exchanger without preheater and aftercooler. An electrical immersion heater is used to heat up the fluid in the column, improving the stripping efficiency. Transfer pumps are used to transport the stripped process fluid, and the vacuum pumps are additional needed.

2.3 System Layout Evaluation

The overall dimensions of the vacuum gas stripper process unit are 2700 mm (width) x 2500 mm (length) x 7725 mm (height) including support structure. Therefore, the envelope for the vacuum gas stripper is reduced to about 60% compared with the conventional steam heating gas stripper process unit [4].

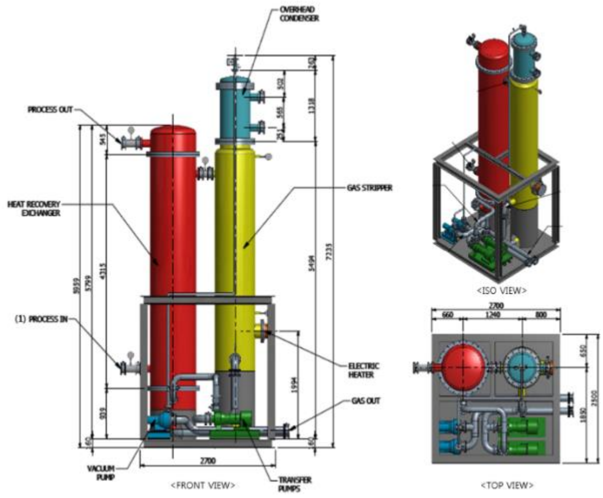

Fig. 4. Vacuum Gas Stripper process unit layout

3. Conclusions

A new concept design of gas stripper using vacuum was suggested. An evaluation for the new vacuum gas stripper design has shown. There are the following benefits compared to the existing gas stripper of APR1400:

1. Increased capability to remove contaminants can reduce the plant's outage duration due to the reduced heat up and cooldown time by using the vacuum gas stripper.
2. The simplified and downsized process unit using the vacuum can ensure a safe operation and easy maintenance under a limited space.
3. Operating at a lower pressure and temperature minimizes the heating units and saves energy to lower the operating costs.
4. Vacuum gas stripper can be applied to optimize CVCS design for small reactors.

REFERENCES

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