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Design of Experimental Apparatus for Aging of TEDA-Impregnated Activated Carbon

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1. Introduction

During the operation of nuclear power plants (NPP), various radioactive gaseous wastes, Methyl Iodine, are generated. Air Cleaning Unit (ACU) as an Engineering Safety Features (ESF) is adopted to remove toxic and radioactive gases.

ACU in NPP composed to various components to clean air such as pre-filter, HEPA filter and adsorber. Adsorber is filled with TEDA (Tri-Ethylene-Di-Amine) impregnated activated carbons (TEDA-AC), and TEDA-AC has been chosen as an absorbent to remove the radioiodine under normal and accident condition. The TEDA-AC adsorber performance is important role in NPP to keep providing the fresh air into main control room.

This study deals with the design of the experimental facility to verify the aging characteristics of TEDA-AC as and to confirm the validity of replacement period of TEDA-AC under the plant operating conditions.

2. Experimental Facility Design

In order to understand performance of TEDA-AC in ACU, two kinds of experiment apparatus were designed. One is an empirical experiment apparatus and the other is lab-scale apparatus.

The empirical experiment apparatus herein referred to as actual ACU is designed to investigate the performance of TEDA-AC in adsorber under certain temperature, humidity and poisoning concentrations.

The lab-scale apparatus will be conducted to understand characteristics of TEDA-AC at various conditions, such as wide range of the temperature, humidity, and poisoning concentrations.

2.1 Semi-plant scale test facility

The test facility is shown in Fig 1. It is composed of test duct and blower. Duct includes the following components in the same order as ACU: strainer for uniform distribution of air velocity profile, demister for removes entrained liquid droplets, heater for temperature control, pre-filter, HEPA filter and Type III adsorber. Duct is primarily of square cross section, 610×610 mm^2.

Design process is deliberated on the distance between components in duct, and type and size of adsorber.

The distances between each component were determined in accordance with ASHRAE [2]. The distance affects to air velocity field of upstream of components.

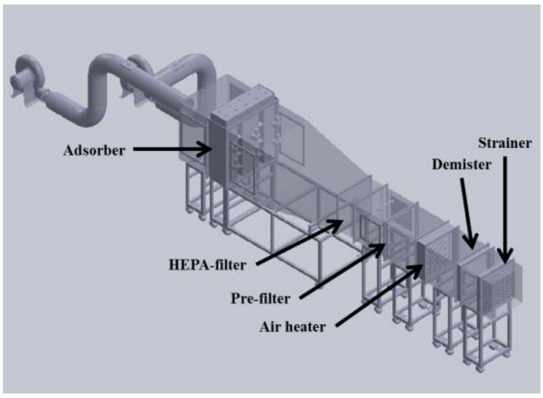

Fig 1. 3D drawing of empirical experiment facility

Type III adsorber is characterized as consisting of multiple beds of AC, fixed in place, and sized to process a given volume of air or gas. The bed is fabricated using perforated sheet and structural pieces, into a welded assembly. Air enters the upstream face of the bed, passes through the packed adsorbent and exit from the downstream face. Fig 2 illustrates a schematic drawing for a Type III adsorber.

Design requirement is as follows: 0.5 sec residence time corresponding to 0.2 m/s face velocity, 4 inch bed thickness, and 160 CFM air flow.

Prior to adsorber design process, the following assumptions were made in calculating the bed size. (1) Air is uniformly flow into the inlet of adsorber. (2) Air velocity through the bed and canister is same because of same pressure drop. Therefore, the flow rate is proportional to the area of the flow path. (3) The packing density of the bed and canister is same as well as no variation of TEDA-AC packing density along the vertical direction of bed. (4) Effective area of perforated sheet is same to each upstream and downstream of bed and canister.

Actual canister size (2 inch inner diameter and 4 inch thickness) of ACU is adopted to canister design.

In order to determine the size of adsorber, size of bed has to be determined by using residence time (eq.1) is defined in code [1].

$$T = t(A\text{-}B)/Q_{bed} \qquad \text{(eq.1)}$$

where.
T = Residence time, sec
t = Thickness of adsorption bed, m
A = Gross sheet area of all sheets on inlet side or outlet side, whichever is smaller, cm^2
B = Total area of baffles, blanks and margins of all sheet, cm^2
Q_{bed} = Flow into the beds, m^3/h

From the result of calculation, the size of adosrber was determined. The size of adsorber and canister are 965.2 ×965.2 ×312.4 mm^3 (Width×Height×Length).

A reservoir of makeup adsorbent to allow for settling shall cover the entire top section of adsorber. The height of reservoir is 90 mm is to meet rule of minimum volume of adsorbent equivalent to 5% of the bed volume [1].

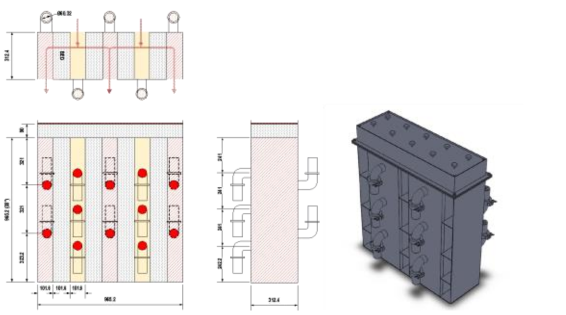

Fig 2. Schematic and 3D drawing of Type III adsorber

The flow analysis is conducted to investigate the flow field in designed adsorber, using CFX program as flow analysis code. The geometry which used in CFD analysis is similar to empirical facility adsober as shown in Fig 3. The boundary conditions were set the pressure for inlet and flow rate for outlet condition. Canisters and beds were simulated as porous media.

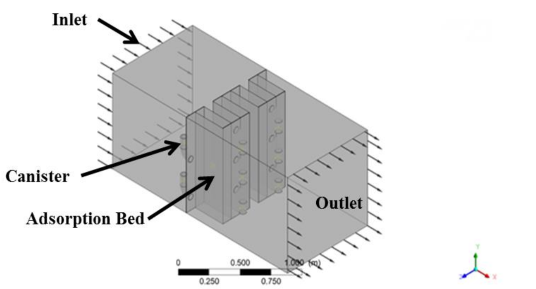

Fig 3. Adsorber geometry for CFD analyis

As shown in Fig 4, velocity of canister and bed is converged to 0.65 m/s. This indicates that the flow can be uniformly distributed to the canister and bed and the sampling with canister can be representative of the bed. Since the bed is modeled with 100% open area, the face velocity would be converged to 0.2 m/s which is a design target with the consideration of the real open area.

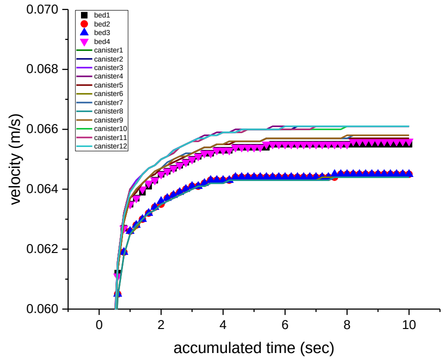

Fig 4. Velocity profile in each canister and beds

2.2 Lab-scale test facility

The lab-scale apparatus were composed of test section and systems for injection of poisoning gases as shown in Fig 5. The test section is installed vertical downward to prevent Channeling as settling the AC by gravity. It includes an adsorber bed for performance of TEDA AC at various combined conditions, such as temperature, humidity, and high concentration of poisoning gases.

Residence time can be met by flow the carrier gas (air) into inlet of test section and controlling the fan speed. Air temperature will controlled to make sure by control the heating blower. In addition, the poisoning gas injection system and humidity supply system are installed to ensure the test condition. The amount of TEDA-AC of adsorber bed is sufficient for analysis physical properties and BET test.

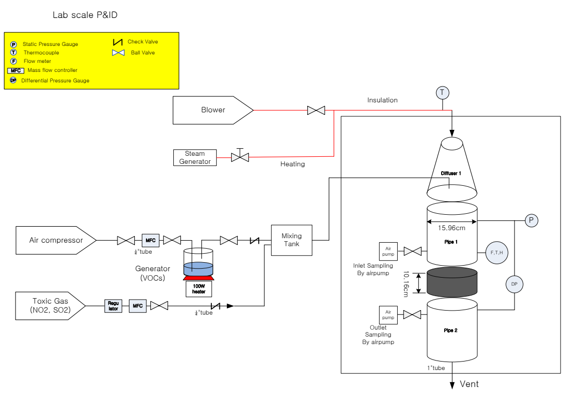

Fig 5. Lab-scale apparatus P&ID for one test section

3. Summary

There are two different facility prepared for understanding the TEDA-AC aging in NPP condition. One is the semi-scale test facility to verify the performance of TEDA-AC with plant operating conditions. This facility design was performed, according to actual ACU for repeatability. The other is the lab-scale test facility to understand the characteristics of TEDA-AC. This is designed to perform the test at various combined conditions.

The experiment is expected to provide quantitative data that can be used for verifying aging characteristics of TEDA-AC and for confirming the validity of replacement period of the TEDA-AC under the plant operating conditions.

ACKNOWLEGEMENT

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