DESIGN OF COVER GAS PURIFICATION SYSTEM FOR FAST BREEDER REACTOR

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INTRODUCTION: A 500 MW(e) Prototype Fast Breeder Reactor (PFBR) is a liquid metal cooled fast breeder reactor under advanced stage of integrated commissioning at Kalpakkam, India. Radionuclides, Xenon and Krypton are expected to be present in the cover gas in the case of a fuel pin failure. The radioactive level of the gaseous effluents from a nuclear power station depends on the performance of the cover gas purification techniques in use. The use of delay tanks as a means to reduce the radioactive level of the gaseous effluents of a nuclear reactor is possible, but this is not practical for large gas flow rates required to be maintained during reactor operation with failed fuel pins in the form of gas leakers. PFBR adopts cryogenically cooled activated charcoal adsorption for Cover Gas Purification System (CGPS) with a decontamination factor of 10^4. Dynamic Adsorption of Xenon and Krypton on activated charcoal has been investigated in a pilot plant to establish various design parameters for Cover Gas Purification System for Fast Breeder Reactor. The paper details the various experiments conducted in pilot plant and design of cover gas purification system for Fast Breeder Reactor.

1. OVERVIEW

During the operation of Fast Breeder Reactor, radioactive isotopes of noble gases Xenon and Krypton are formed as fission products and are trapped inside the fuel pin. In case of a fuel pin failure, these gaseous fission products are released from the fuel to the primary sodium coolant and are finally released into the cover gas. The most reliable technique to remove these radioactive gases is by the adsorption on activated charcoal. The process-taking place is called Dynamic Adsorption. The radionuclides which are of major concern is ^{133}Xe and ^{85M}Kr with a half-life of 5.24 days and 4.5 hours respectively [1]. Decontamination factor is the ratio of initial contamination to the level after decontamination. The internationally accepted decontamination factor for the purification system is 10^4 which is achieved by sufficient residence time for ^{133}Xe and ^{85M}Kr [2] in the adsorption bed. It is necessary that adsorption column needs to be adequately sized to meet this required residence time specific to the particular active element. The critical property of the adsorption bed associated with the retention period of a particular element is the Dynamic Adsorption Coefficient (DAC) which increases exponentially as the operating temperature of the bed is decreased. Thus the residence time increases significantly at cryogenic temperatures. To achieve the necessary delay of transportation of fission gases in activated charcoal at room temperature, the size of adsorber needs to be large enough to contain several tones of activated charcoal. As mentioned above, low temperature operation increases DAC which reduces the activated charcoal requirement from several tons to few kilograms. The compilation of various experimental results on DAC values conducted for other reactor programs were given in literature [3]. All these experiments were conducted near to room temperature and the results were extrapolated to cryogenic temperatures. Hence, it is necessary to conduct experiments at cryogenic temperatures in order to obtained accurate DAC values for sizing of adsorption column.

2. DESCRIPTION OF FACILITY

Dynamic Adsorption of Xenon and Krypton on activated charcoal has been investigated in a pilot plant to establish various design parameters of Cover Gas Purification System (CGPS) for PFBR. The flow sheet of CGPS pilot plant facility is shown in Figure 1. The CGPS pilot plant consists of gaseous argon tank, diaphragm compressor, shell and tube heat exchanger, liquid nitrogen bath, adsorption column containing activated charcoal, impurity injection facility and gas chromatograph for monitoring the samples. Since the heat exchanger, liquid nitrogen bath and adsorber bed were required to be operated at cryogenic temperature, they were kept in separate Cold Boxes (CB). The experiments were conducted by injecting Xenon / Krypton in argon. The variation in the DAC as a function of temperature was studied by varying the temperature of the adsorber bed from ambient to 130 K. The various parametric studies were conducted to obtain the optimum operating conditions like flow and adsorber bed pressure. Dynamic Adsorption of Xenon and Krypton on activated charcoal has been experimentally estimated in a pilot plant for the temperature ranging from ambient to cryogenic temperature to establish the various design parameters for Cover Gas Purification System for Fast Breeder Reactor.

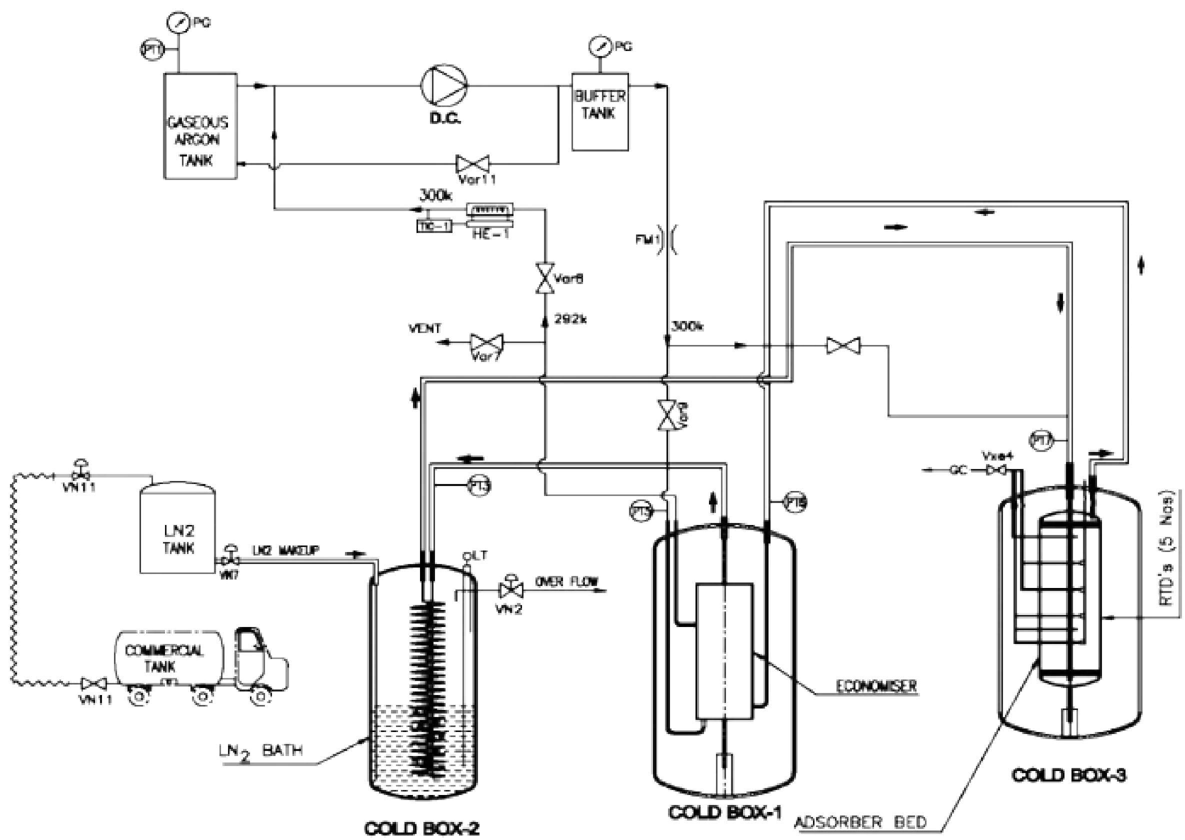

Fig. 1. Flow Sheet of CGPS Pilot Plant

3. ADSORBER BED

The adsorber bed is shown in Figure 2. In order to monitor the movement of Xenon and Krypton through the activated charcoal, the bed was provided with samplers at different levels along with resistance temperature detector (RTD) to record the temperatures. The various sampling points are connected via a common outlet to the on-line gas chromatograph for detection of breakthrough of Xenon / Krypton.

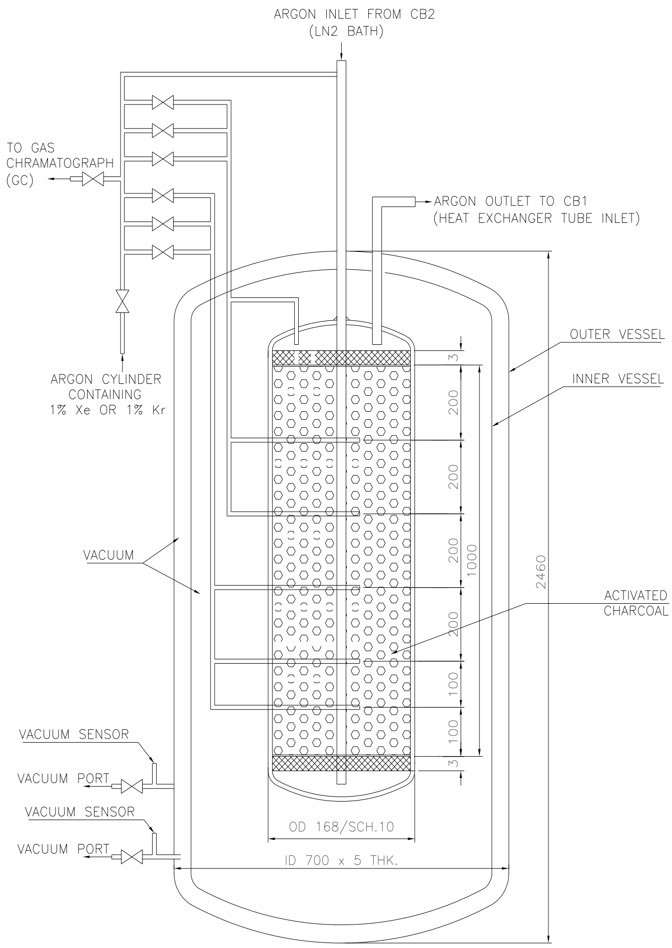

Fig. 2. Adsorber bed

4. EXPERIMENTS CARRIED OUT

The various parametric studies were conducted to understand the effect of flow rate and effect of pressure on DAC. Further experiments were carried out with optimised flow rate and pressure. The argon cover gas was cooled to the required adsorber bed temperatures and it was circulated through an adsorber bed. Xenon or krypton were separately injected along with argon cover gas to establish their DAC values at various adsorber bed temperatures.

A plot for comparing DAC of Xenon and Krypton is shown in Figure 3. It is evident that the DAC values of Xenon is higher than Krypton from room temperature to cryogenic temperature. Even though DAC values of Xenon and Krypton are closer at room temperature, at cryogenic temperature variation is too large. The experimental data obtained on DAC values for Xenon and Krypton in CGPS pilot plant were fitted to obtain empirical correlations with respect to temperature. These correlations were used to compute the DAC values at operating temperature of CGPS. The empirical correlations obtained are presented in Table 1.

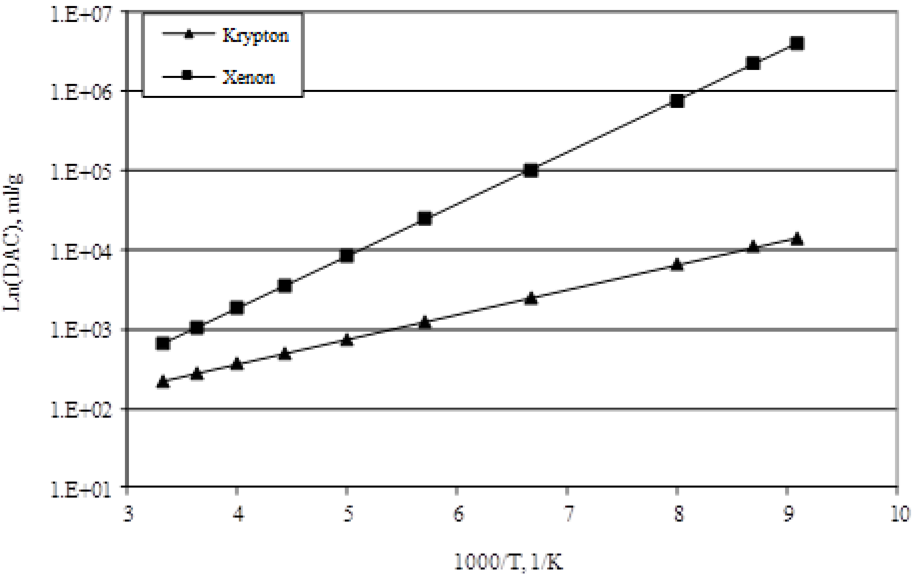

Fig. 3. Comparison of DAC values for Xenon & Krypton on activated charcoal

TABLE 1. CORRELATION FOR DAC OF XENON AND KRYPTON ON ACTIVATED CHARCOAL AT DIFFERENT TEMPERATURE

Experiments	Adsorbant	Correlation
CGPS pilot plant	Xenon	LN(DAC) = (1000/T) X 1.516 + 1.4212
CGPS pilot plant	Krypton	LN(DAC) = (1000/T) X 0.7232 + 2.9969

5. DESIGN OF ADSORBER BED FOR FBR

The delay time required for Xenon and Krypton in the adsorbed bed is 70 days and 2.5 days respectively to obtain a decontamination factor of 10^4. The design flow rate of cover gas through the adsorber bed is 30 m^3/h. Using these parameters along with the appropriate DAC values, the amount of activated charcoal required at various temperatures was computed and it is shown in Figure 4.

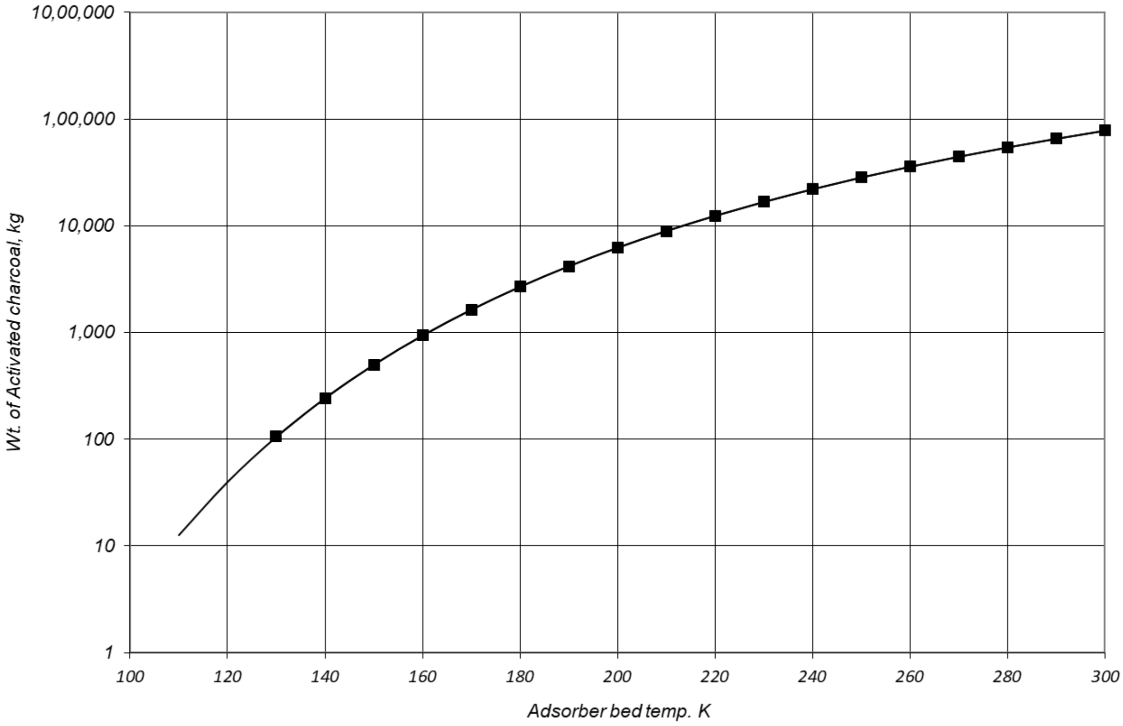

Fig. 4. Weight of activated charcoal required for FBR

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