# Adsorptive Natural Gas Storage for Vehicles Approach for Actual Application

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## ABSTRACT

Limited studies have focused on the thermal performance of the storage system under dynamic conditions. In the present study, investigation of the thermal characteristics of adsorptive natural gas (ANG) storage system has been studied during its dynamic discharge process. It has been observed that a significant drop in bed temperature takes place during the discharge of the gas at different flow rates e.g. 1, 5, 10 l/min. To reduce the retention of the gas during the discharge process, bed preheating was carried out at different elevated temperature. It has been observed that the amount of desorption improved significantly as a result of bed preheating.

**Keywords:** ANG, CNG, NGV, storage.

## 1. INTRODUCTION

Because of relatively low pressure, ANG has some obvious advantages related to the weight, shape, safety, and cost of the storage vessel [1-5]. The enhancement of ANG storage capacity is seriously affected by the increase and decrease in temperature during the charging and discharging cycles respectively[6,7]. Mota has studied thermal energy supply to the storage tank to enhance the discharge capacity, employing a jacketed tank [8]. The thickness of the high pressure storage vessel also reduces the efficiency of the jacket to provide thermal energy to the tank [9-13]. In this study, thermal energy was supplied to the inside of the tank employing helical tube, immersed in the adsorption bed. That way affected positively to enhance the heat transfer within the storage tank and improvement in the characteristics of the discharging was recorded. It was done to improve the heat transfer process within the storage tank in order to get better discharge properties of the storage system.

## 2. EXPERIMENTAL

### A. 2.1. Material:

According to the research made by the Atlanta Gas Light Adsorbent Research Group (ARLARG) [14], the best performing adsorbent materials are active carbons derived from bioresources. These materials have a naturally occurring pore structure that can be optimized for the adsorption of the methane in natural gas [15-19]. The method of densifying or compacting the adsorbent is also critical to achieve acceptable performance. Proprietary densification techniques were developed during the course of the research to form solid carbon monoliths and briquettes that match the profile of the tank for easy insertion [10].

**Adsorbent:**

It is used as a bed in the adsorption cell with the following specification:

Manufacturer: Starchem

Particle shape: granular

Mesh Size: 2.36 x 0.50 (mm)

Apparent Density (AD): 360g / liter

Apparent density: 0.42 - 0.52 g/cc

Ash content: < 3%

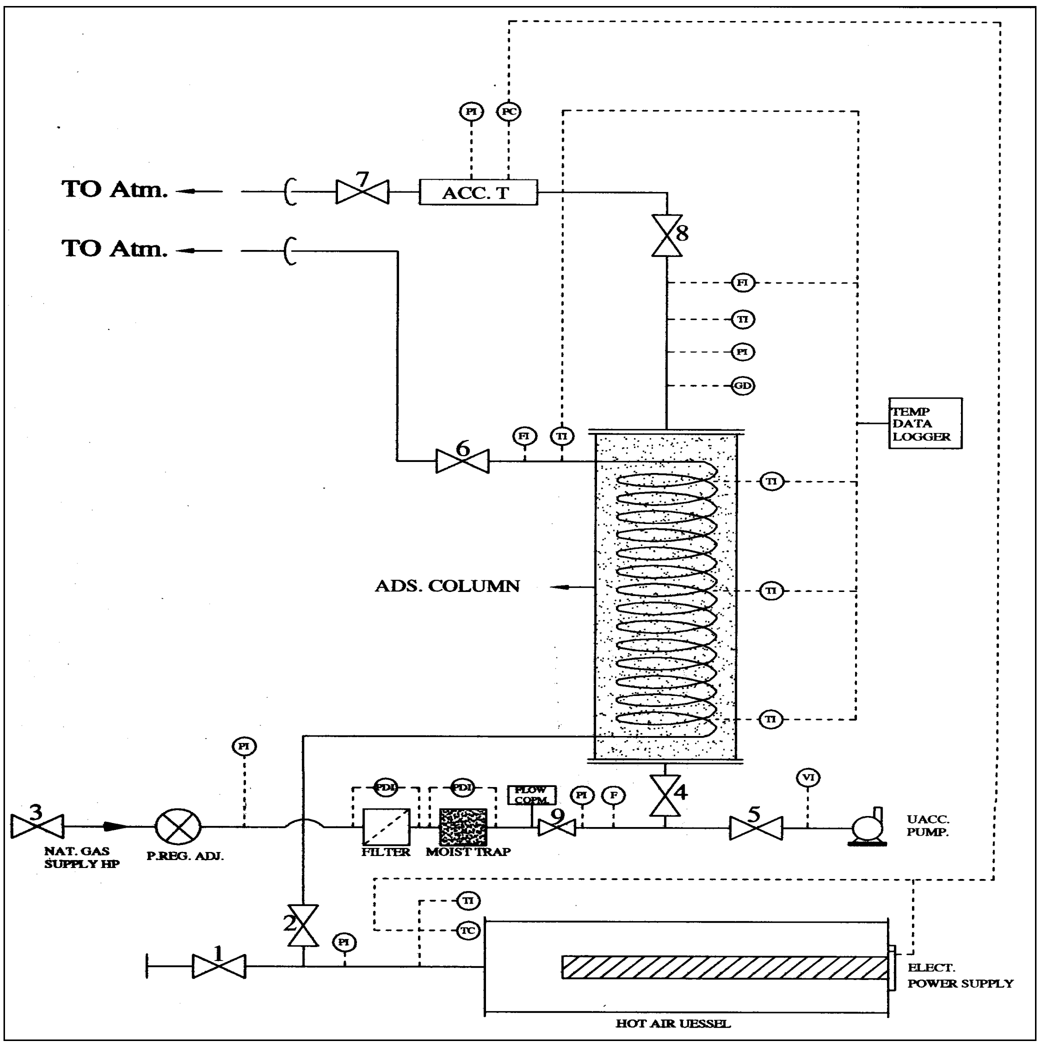


Figure 1. Schematic diagram of the experimental setup.

## 2.2. Experimental Setup:

Hot air was used as a heating media to provide thermal energy to rise the temperature of the adsorption bed. The Schematic diagram of the experimental setup is shown on Figure1. The experimental setup consists of adsorption Cell, where the adsorption and desorption processes takes place. Pressurized hot Air Vessel, to provide high temperature air during preheating of the adsorbent bed. The air was supplied to this vessel employing a compressor. Pressure of the air inside the vessel was controlled employing automatic control system. Data Logger (manufactured by "FLUKE" model (2625), to register the temperature history of different channels. Gas Detection Equipment (manufactured by GMI company), this equipment provide the concentration of the gas in the air.

## 3. RESULTS AND DISCUSSION

### 3.1. Thermal behavior of the adsorbent at dynamic conditions (without preheating):

Examination of the plot at Figure 2 indicates that the rate and the extent of temperature drop were greater for faster discharge than for slower discharge. During discharge at flow rate of 1.0 l/min, bed temperature drops from 35°C to the minimum value of –10 °C in 16 minutes.

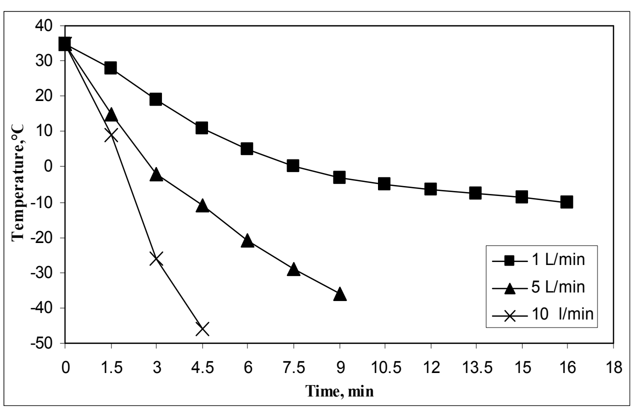


Figure 2. Temperature drop during dynamic discharge (no-preheating).

At a moderate discharging rate of 5.0 l/min, temperature drops from 35°C to the minimum –36 °C in 9 minutes. During discharging at a fast rate, e.g. 10.0 l/min, a temperature fall of 78°C (from 35°C to the minimum value of –48 °C) takes place in 4.5 minutes. As the ambient is the only source of heat, natural convection heat transfer occurs between the storage tank and the ambient. The amount of heat supplied to the tank through natural convection is very small to eliminate the drop in temperature.

### 3.2. Thermal behavior of the adsorbent at dynamic conditions (with preheating):

Figure 3 indicates that during discharge at flow rate of 1.0 l/min, bed temperature drops from 160°C to 85° C in 20 minutes. While at moderate discharging rate of 5.0 l/min, temperature drops from 160°C to the minimum 65° C in 10 minutes. When discharging at 10.0 l/min, which depicted a fast rate, a temperature fall of 125°C (from 160°C to the minimum value of 35 °C) takes place in 6 minutes. The heat is supplied to the inside of the tank through helical tube, which was immersed in the adsorption bed. Although the drop in temperature was higher for preheated system compared to without preheating system. but the preheating step achieved the advantage of avoid the deep freeze temperature which affected positively on the amount of natural gas retained in the tank after

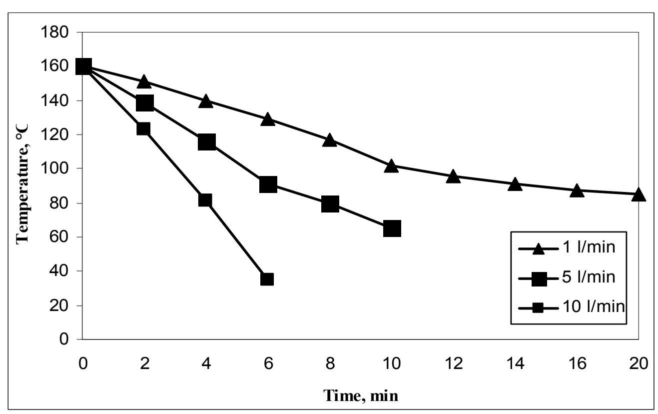


Figure 3: The temperature drop during isothermal discharge (with preheating).

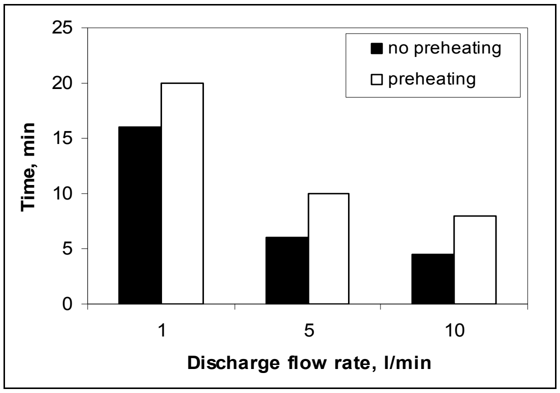


Figure 4. Discharge Time at preheating and no-preheating Conditions.

depletion and consequently of the discharge capacity was enhanced. In additional amount pre-supplied heat was to the adsorbent results in the slower rate of temperature drop than in the dynamic discharge. It indicates more stability in the desorption rate. When the discharge time at dynamic conditions employing preheating is compared to that without preheating, (figure 4). An increase in the discharge time was recorded, which indicates an additional amount of gas was delivered within the same discharge flow rate and the remaining amount of the gas in the tank at depletion was decreased.

## 4. CONCLUSIONS

The desorption temperature profiles strongly depend on the adsorption pressure, material used as an adsorbent, and the flow rate during the desorption process. It is probable that the temperature fluctuations can be mitigated with improved adsorbent properties and for real applications, an efficient system of heating must be considered to increase desorption velocities. In terms of fuel economy, the ANG system had a better performance during dynamic discharge employing preheating. The results showed that the storage capacity obtained under preheating conditions was higher than under dynamic conditions without preheating, due to the extraction of additional amount of retained gas, which added to an attractive economic value of the ANG storage system.

## 4. ACKNOWLEDGEMENT

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