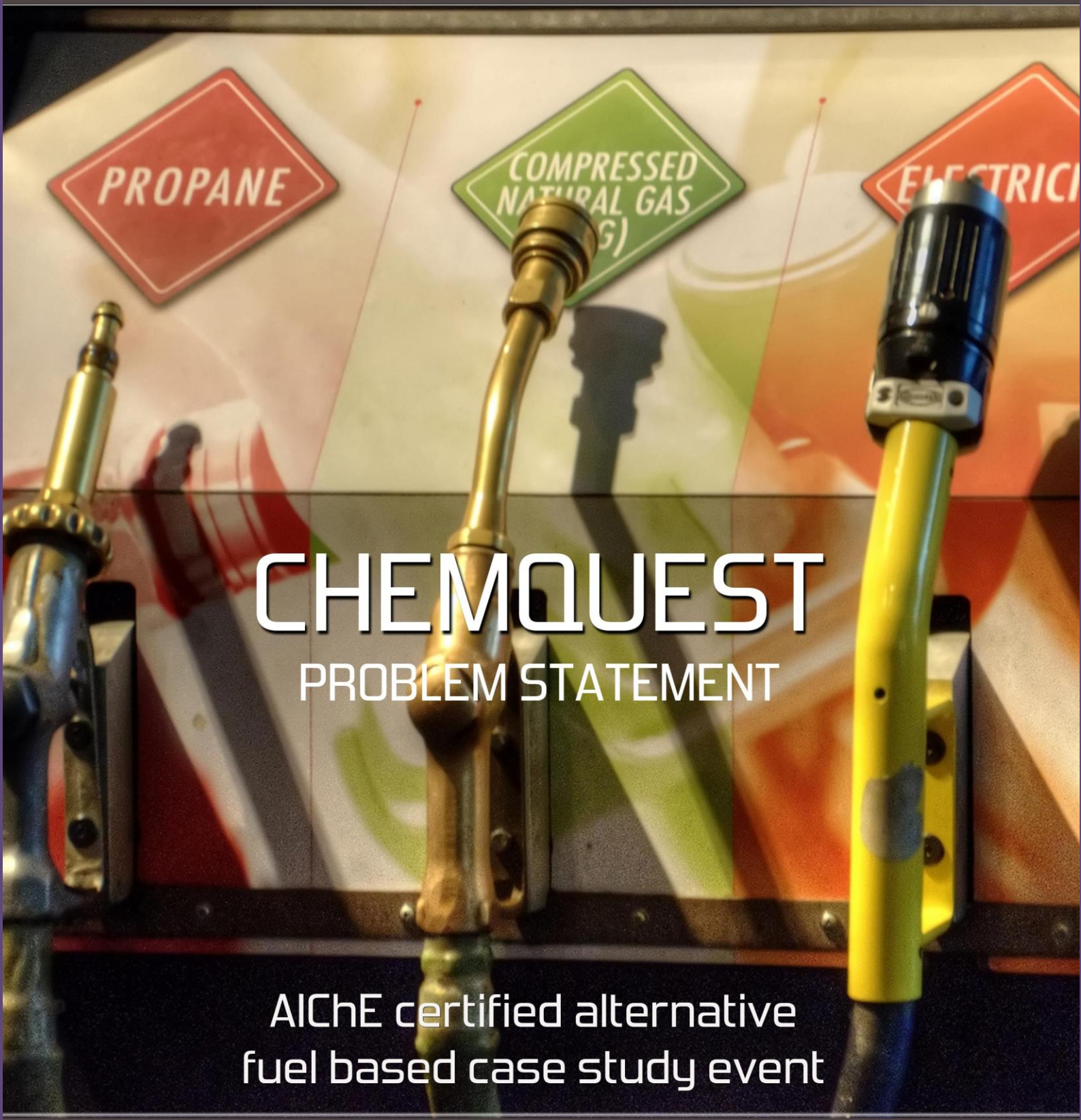
Kshitij 2014



CHEMQUEST

PROBLEM STATEMENT

AIChE certified alternative
fuel based case study event

Indian Institute Of Technology, Kharagpur

Designing an Adsorbed Natural Gas System for Vehicular Transportation

Background:

With the increasing demand on reducing CO_2 emissions many alternate vehicular fuels are currently being assessed around the world. Hydrogen and natural gas are the two primary candidates that show potential in this area. Although the development of a hydrogen based economy is desirable, the infrastructure for hydrogen manufacture and storage are still in the development stages. Natural gas however is already used in the form of compressed natural gas (CNG) for vehicular use in Indian and many countries around the world. Natural gas has been identified as an attractive alternate fuel due to reduced emissions and its abundant availability in nature. It is a cleaner burning fuel when compared with traditional hydrocarbon based products.

Therefore, development of natural gas based vehicles is a subject of considerable research and practical interest today. While using CNG the gas is stored at a pressure of about 20 MPa. Technologies based on CNG involve multistage compression technologies and have to contend with associated safety issues to the high pressures. Further the low volumetric energy density of natural gas limits its driving range. In order to overcome these drawbacks, an alternate technology based on adsorbed natural gas (ANG) is under development. In the ANG system, natural gas is adsorbed a suitable micro-porous adsorbent at a moderate pressure range of 3.5 - 4.0 MPa. Although CNG is used for vehicular and public transportation in India and China, technologies based on ANG have yet to be developed and implemented at a commercial scale.

Performance of an ANG system depends on the type of adsorbent and its charging and discharging characteristics. In order to make the ANG system economically feasible the target delivery capacity of 180 Vg/V_b (at STP conditions) as set by the United States Department of Energy (DOE) should be achieved. Here V_g is the volume of gas and V_b is volume of the canister (packed bed) in which the adsorbent pellets are stored. The target implies that the adsorbent bed of volume V_b should contain 180 times the volume of gas (at STP conditions) when the gas is compressed to 3.5 MPa at 298 K.

For the present problem statement we will assume that V_g is the volume of methane gas. Note that natural gas contains other higher hydrocarbons and the exact composition of the gas will vary from the source.

Among the available adsorbents, activated carbons have emerged as the most promising candidate for ANG based technology. More recently materials such as metal organic frameworks (MOFs) have also

shown promise as potential materials to meet the storage targets. To give a broader perspective, the search for new materials begins in the laboratory where suitable adsorbents for methane storage are synthesized. The first step is the measurement of an adsorption isotherm at 298 K upto pressures of 3.5 MPa to assess the materials storage capacity. Subsequently the powder material has to be pelletized using appropriate binders before being used in a packed bed container which can be installed on an onboard delivery canister for vehicular use. There are associated storage losses during pelletization and at the canister level (due to inherent porosity in the packed bed). These usually reduce the adsorption capacity of the material. Further there are large heating effects associated with adsorption (exothermic) and desorption (endothermic) during charging the adsorbent for storage and discharge respectively. These heat effects have to be effectively managed to improve the efficiency of storage and discharge.

Problem:

Given the above details for developing a technology based on ANG, design an appropriate onboard canister assembly that can be used to drive a four wheeler for a distance of 200 km. Assume that you have access to pure methane while carrying out your design. Your design should include the following:

1. Choice of an appropriate adsorbent material and reasons for choosing the same.
2. Amount of adsorbent material that will be used, and the complete canister assembly design that will yield a target driving distance of 200 km.
3. In your final recommendation indicate the issues associated with using a typical natural gas stream which contains about 90% methane and other heavier hydrocarbons.
4. Technical bottlenecks that you envisage while implementing an ANG based technology and how you plan to overcome them.