

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the previous chapters, the physical properties of the commercial adsorbents, consisting of the static adsorption capacity and the crystallinity patterns, were determined. Additionally, the laboratory-scaled gas adsorption system was constructed in order to investigate the water vapor removal from the natural gas feed using the multi-layer adsorber. As the results of the adsorption experiments, the water adsorption breakthrough curves were established and the effects of the humidity levels and the contact time on the breakthrough curves (time) were observed. Moreover, the Langmuir model and the Linear model were used to establish the equilibrium adsorption isotherm, compared to the experimental data. The equilibrium adsorption isotherm obtained from the adsorption of the entire bed at various humidity levels was also employed in the mathematical adsorption models.

Based on the results from the experiments under specific conditions and the mathematical models, the conclusions were as follows:

Firstly, the silica gel adsorbent had higher adsorption capacity than the MolSiv 4A because the silica gel had higher pore volume (Howe-Grant and Kroschwitz, 1992). However, the silica gel had weaker adsorption force compared with the MolSiv 4A because the structure of the silica gel offered lesser polarity force to water, or lesser water affinity. In addition, the water was desorbed from the Silica gel at the lower temperature than that of the MolSiv 4A. As a result, the MolSiv 4A required higher temperature for the regeneration than the silica gel adsorbent.

Secondly, the size of the adsorbents pellet did have an effect on the heat transfer area and regeneration temperature. Since the smaller the particle size was, the larger the heat transfer area was, and the lower the regeneration temperature required. Therefore, to achieve better heat and mass transfer areas, the adsorbent should be always as small as possible, and comparable with the pressure drop limitation (Campbell, 1992).

Thirdly, the equilibrium adsorption isotherm in Figure 5.7 for water on the multi-layer adsorber showed a slight upward curve pass the plateau representing monolayer coverage. This adsorption isotherm result should be mainly contributed from and dominated by the 96 % by volume of MolSiv 4A. Since the adsorption isotherm was analogous to the Type II Brunauer isotherm, it indicated that there was a continuous progression with increasing loading from monolayer to multilayer and then to capillary condensation (Ruthven, 1984). Furthermore, the slight upward adsorption isotherm curve present at higher humidity should be an effect of the Silica gel due to its higher adsorption capacity at higher humidity. Finally, the Langmuir model and the Linear model were successfully adopted to establish the equilibrium adsorption isotherm to best fit the experimental data at the humidity of lower than 52%RH and above 52%RH, respectively.

Fourthly, it was found that the water breakthrough was accelerated with an increase in the humidity level of the feed inlet and/or with a decrease in the contact time. This acceleration of the breakthrough time resulted from higher water loading.

Finally, the recently developed mathematical adsorption models were demonstrably accurate to predict the adsorption capacity and moderately acceptable for the prediction of the breakthrough time for water adsorption from the natural gas onto the multi-layer adsorber under the experimental conditions. However, the theoretical breakthrough time was found to be very sensitive to the value of overall mass transfer coefficient (k or k_e). The results of the mathematical models suggested that the k_e of approximate 1.0×10^{-4} was practically acceptable for all experimental case scenarios. Although the mathematical models were also able to predict the adsorption capacity very accurately, their estimation of the breakthrough time was quite shorter than that from the experiments by about 27% in average. This difference of the breakthrough time from between the theoretical models and the experiments could be from the errors in the experiments, such as channeling effect, the accuracy and responding time of the humidity analyzer, and inadequate accuracy of equilibrium adsorption isotherm due to the limitations of the apparatus at low humidity level. However, the theoretical breakthrough curves still illustrated the same trend and pattern corresponding to the curves from the experiments. This

indicated that the experimental equilibrium adsorption isotherm considerably played an important role in controlling the adsorption behaviors on the multi-layer adsorber.

6.2 Recommendations

Since, there is still room for improvement for the future study of the adsorption of water from the natural gas on the multi-layer adsorber. As a result, the following recommendations would be useful for the future work.

- 1) In order to develop the adsorption models to be more representative and more accurate, more experiments on the adsorption isotherm should be performed, especially at low humidity level. A single adsorption isotherm explaining the entire curve shall make the overall adsorption model more flexible to adjust the layer thickness.
- 2) The dispersion and concentration profile in r and θ directions should be taken into account to make theoretical breakthrough time closer to the experimental.
- 3) The model sensitivity analysis should be done to evaluate other parameters that may significantly affect on the characteristic of breakthrough curve or time, such as diffusivity coefficient, void fraction, and temperatures.
- 4) A special analyzer, such as dew point meter, shall be provided to measure the water content in the effluent gas so that the adsorber efficiency can be determined.
- 5) If time allows, it is recommended that the deactivation test be conducted in order to predict the life of the adsorbents.