

**Mathematical Modelling of Membrane based Carbon Dioxide Removal from
Natural Gas using Spiral Wound Membrane**

by

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Dissertation submitted in partial fulfilment of
the requirement for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

JANUARY 2014

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr Nurhayati Mellon)

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January 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Syazwani Balqis Bt Dilah)

ABSTRACT

This Dissertation covers the introduction, literature review, methodology, results, discussions and some recommendations for the project entitled “Mathematical Modelling of Membrane Based Carbon Dioxide Removal from Natural Gas using Spiral Wound Membrane”. Recently, many modelling of membrane is carried out to improvise the current membrane used for separation of carbon dioxide from the raw natural gas but the recent research studies mostly focussed on the development and optimization of Hollow Fibre membrane for sweetening of natural gas instead of the traditional Spiral Wound membrane. Thus, this project aims to develop a mathematical model of Spiral Wound membrane for natural gas treatment with three parameters to analyse: feed temperature, feed pressure, and permeate pressure. Model is developed based in cross-flow model derived by Weller and Steiner for gas separation by using spiral wound membrane through MATLAB. The base operating condition used in for the model is according to literature review from various sources including journals and books. The model proves that feed and permeate pressure has great influence on the membrane performance. The influence of the operating conditions (feed pressure, permeate pressure and CO₂ composition in the feed stream) on the design parameters (membrane area, methane loss, methane recovery and concentration of CO₂ removed) has been studied. It is shown that increase in feed pressure and low permeate pressure leads to higher rate of permeation thus reducing membrane area, improving methane recovery, minimizing methane loss and more CO₂ is removed due to greater driving force across the membrane. Higher CO₂ content in the feed shows decline in membrane performance. In conclusion, the mathematical modelling of spiral wound membrane using Weller and Steiner method has proven its ability to compute the desired performance modelling for the separation of CO₂ from natural gas.

ACKNOWLEDGEMENT

First of all, I would like to say that this Final Year Project (FYP) would not have been successful without support and cooperation accorded to me by my FYP Supervisor, Dr. Nurhayati Mellon from Chemical Engineering Department. Therefore, I would like to take this opportunity to express my sincere gratitude to her who has willingly helped me without failing to motivate, guide, advice and gives many encouragement.

Besides, I would like to thank Allah SWT for all His blessings. I would like to express greatest gratitude to Dr. Narahari Marneni, Senior Lecturer of Fundamental and Applied Science department who continuously gives guidance and advices especially to accomplish the objective of this project.

Last but not least, I would also like to express my appreciation to my family members who has given me moral support to make sure the project is carried out successfully.

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ABBREVIATIONS AND NOMENCLATURES

US	United States
CH₄	Methane
CO₂	Carbon Dioxide
H₂S	Hydrogen Sulphide
C₃₊	Heavier Carbon
N₂	Nitrogen
He	Helium
H₂	Hydrogen
CO	Carbon Monoxide
ppm	Parts per million
Btu/scf	British unit per standard cubic feet
°C	Degree Celsius
ODE	Ordinary Differential Equation
FYP I	Final Year Project 1
FYP II	Final Year Project 2
<i>L_f</i>	Flowrate of feed stream (cm ³ (STP)/s)
<i>L_r</i>	Flowrate of retentate stream (cm ³ (STP)/s)
<i>V_p</i>	Flowrate of permeate stream (cm ³ (STP)/s)
<i>x_f</i>	Composition of feed
<i>x_r</i>	Composition of retentate
<i>y_p</i>	Composition of permeate
<i>p_h</i>	Pressure of high pressure feed side (cmHg)
<i>p_l</i>	Pressure of low pressure permeate side (cmHg)
<i>t</i>	Thickness of membrane (cm)
<i>α_{AB}</i>	Ideal separation factor
<i>P'_A</i>	Permeability of A (cm ³ (STP).cm/(s.cm ² .cmHg)
<i>P'_B</i>	Permeability of B (cm ³ (STP).cm/(s.cm ² .cmHg)
<i>θ</i>	Total fraction of permeate

θ^*	Fraction of permeate up to value of x
i	Fraction of stream composition
i_f	Fraction of stream composition at the feed
i_r	Fraction of stream composition at the retentate
u_f	value of u at $i = i_f = \frac{x_f}{1-x_f}$
A_m	Membrane area (cm^2)