

**STUDY OF CARBON-DIOXIDE CAPTURE PROCESS  
USING AQUEOUS AMMONIA**

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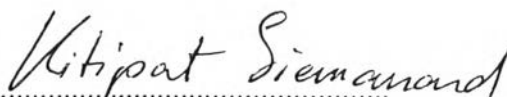
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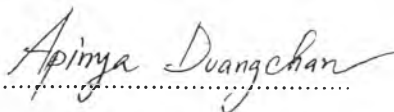
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## ABSTRACT

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Carbon dioxide (CO<sub>2</sub>) emissions to the atmosphere have become an issue for many industries, especially coal-fired power plants, due to their contribution to global warming. Many research projects are presently involved the development of effective solvents to combat these severe environmental problems. Aqueous ammonia is a solvent that has been proposed as a replacement to conventional aqueous monoethanolamine (MEA) in post-combustion CO<sub>2</sub> capture. In this study, an aqueous ammonia based CO<sub>2</sub> capture process was simulated by Aspen Plus simulator for capturing about 90 % by weight of CO<sub>2</sub> with a purity of 98 % by weight from a post-combustion flue gas based on a 180 MW<sub>e</sub> coal-fired power plant. The simulation of this process was performed to meet the ammonia emission standard. An ammonia-based simulation process consists of two parts: the CO<sub>2</sub> absorption process and the ammonia abatement process. To minimize the energy consumption of the process, heat integration was applied by adding a Heat Exchanger Network (HEN). HEN was designed using stage-wise model (Yee and Grossmann, 1990) and validated using the Aspen Plus simulator. Furthermore, capital investment and annual costs were investigated using Aspen Plus Cost Estimator, and some economic parameters (Hassan *et al.*, 2007) to assess the feasibility of this process based on standard environmental regulations. The results showed that the performance of actual aqueous ammonia plants using process integration reduced the energy requirement from a “non-integrated process by 58 % on the heaters, coolers and

electrical units, resulting in a theoretical decrease of 47 % in the annual cost of utilities, compared to the cost without process heat integration.

## บทคัดย่อ

อัครวิทย์ จงปิติทรัพย์: การศึกษากระบวนการดักจับแก๊สคาร์บอนไดออกไซด์โดยใช้ตัว  
ดักจับสารละลายแอมโมเนีย (Study of CO<sub>2</sub> capture process using aqueous ammonia) ฝศ.ดร.  
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ปัจจุบันการปลดปล่อยแก๊สคาร์บอนไดออกไซด์จากโรงงานอุตสาหกรรมออกสู่บรรยากาศเป็นปัญหาอย่างมากที่ส่งผลกระทบต่อสภาวะโลกร้อน โดยเฉพาะอย่างยิ่งแก๊สที่ปล่อยออกมาจากโรงงานไฟฟ้าถ่านหิน ดังนั้นจึงมีการพัฒนาประสิทธิภาพของตัวทำละลายเพื่อแก้ปัญหาสิ่งแวดล้อมที่มีเพิ่มมากขึ้นในปัจจุบัน สารละลายแอมโมเนียถือเป็นสารละลายทางเลือกหนึ่งที่สามารถใช้ทดแทนสารละลายมอนอเอทาโนลามีนในการดักจับแก๊สคาร์บอนไดออกไซด์จากเทคโนโลยีถ่านหินสะอาดหลังการเผาไหม้ ในการศึกษาที่ใช้แอสเพนพลัส (Aspen Plus) ในการจำลองการดักจับ 90 เปอร์เซ็นต์ ของแก๊สคาร์บอนไดออกไซด์จากแก๊สไอเสียในโรงงานไฟฟ้าถ่านหินขนาด 180 เมกกะวัตต์และ ความบริสุทธิ์ 98 เปอร์เซ็นต์โดยน้ำหนักของแก๊สคาร์บอนไดออกไซด์ก่อนการจัดเก็บ โดยใช้สารละลายแอมโมเนีย การออกแบบกระบวนการดักจับแก๊สคาร์บอนไดออกไซด์มีมาตรฐานของการปล่อยแก๊สแอมโมเนียออกสู่สิ่งแวดล้อมน้อยกว่า 2 กิโลกรัมต่อชั่วโมง โดยกระบวนการดักจับแก๊สคาร์บอนไดออกไซด์โดยใช้สารละลายแอมโมเนียแบ่งเป็น 2 ส่วนย่อย ได้แก่ กระบวนการดูดซับแก๊สคาร์บอนไดออกไซด์และกระบวนการลดการปลดปล่อยแอมโมเนียสู่บรรยากาศ การแลกเปลี่ยนพลังงานความร้อน โครงร่างตาข่าย (Heat integration network) ใช้ในการลดการใช้พลังงานของการกระบวนการดักจับแก๊สคาร์บอนไดออกไซด์ซึ่ง โมเดลที่ใช้ได้แก่ Stage-wise model (Yee and Grossman, 1990) อีกทั้งได้มีการตรวจสอบข้อมูลที่ได้จากการแลกเปลี่ยนพลังงานความร้อน โครงร่างตาข่ายกับแอสเพนพลัส (Aspen Plus) เพื่อหาความไม่แน่นอนในเชิงตัวเลขของกระบวนการดักจับ มากไปกว่านั้นค่าใช้จ่ายในการลงทุนและต้นทุนการดำเนินงานประจำปีคำนวณจากแอสเพนพลัส (Aspen Plus) และตัวแปรบางตัวเพื่อบ่งบอกถึงความเป็นไปได้ของกระบวนการดักจับแก๊สคาร์บอนไดออกไซด์นี้ ผลการทดลองนี้แสดงให้เห็นว่าประสิทธิภาพโรงงานดักจับแก๊สคาร์บอนไดออกไซด์โดยใช้สารละลายแอมโมเนียที่ผ่านการแลกเปลี่ยนพลังงานความร้อน โครงร่างตาข่ายสามารถลดความต้องการทางด้านพลังงานได้ถึง 58 เปอร์เซ็นต์เมื่อเทียบกับกระบวนการที่ไม่ผ่านการแลกเปลี่ยนความร้อน โครงร่างตาข่าย อีกทั้งในเชิงทฤษฎียังสามารถลดต้นทุนการดำเนินงานประจำปีได้ถึง 47 เปอร์เซ็นต์

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**LIST OF ABBREVIATIONS**

|        |   |
|--------|---|
| CCC    | Cryogenic carbon capture                  |
| CPIG   | Ideal gas heat capacity                   |
| DHVLDP | Heat of vaporization                      |
| DNLDIP | Liquid density                            |
| EPA    | Environmental protection agency           |
| GAMS   | The general algebraic modeling system     |
| GWP    | Global warming potential                  |
| HEN    | Heat integration network                  |
| HFCs   | Hydrofluorocarbons                        |
| IPCC   | Intergovernmental panel on climate change |
| KLDIP  | Liquid thermal conductivity               |
| KVDIP  | Vapour thermal conductivity               |
| MULDIP | Liquid viscosity                          |
| MUVDIP | Vapour viscosity                          |
| MUVDIP | Liquid vapour pressure                    |
| NETL   | National energy technology laboratory     |
| NRTL   | Non-random two liquid model               |
| PFCs   | Perfluorocarbon                           |
| PCC    | Post combustion capture                   |
| PC     | Post combustion                           |
| RCSTR  | Continuous stirred-tank reactor           |
| RTIL   | Room-temperature ionic liquid             |
| SIGDIP | Liquid surface tension                    |
| TCI    | Total capital investment                  |



**LIST OF SYMBOLS**

|                 |                          |
|-----------------|--------------------------|
| $K_0$           | Apparent absorption rate |
| $n_{CO_2}$      | mol of $CO_2$            |
| $P_0$           | Partial pressure         |
| $\alpha_{CO_2}$ | $CO_2$ loading           |
| $\eta$          | Viscosity                |