VOT 74060

ENERGY CONVERSATION IN GAS SEPARATION APPLICATION USING CARBON ABSORPTION & PRESSURE SWING ADSORPTION (PSA) SYSTEM

(PENJIMATAN TENAGA DALAM APLIKASI PEMISAHAN GAS DENGAN MENGGUNAKAN KARBON MOLEKUL DAN SISTEM PENYERAPAN KARBON HAYUNAN BERTEKANAN (PSA))

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RESEARCH VOTE NO:
74060

Jabatan Termo-Bendalir
Fakulti Kejuruteraan Mekanikal
Universiti Kejuruteraan Mekanikal

2004

ABSTRACT

ENERGY CONSERVATION IN GAS APPLICATION USING CARBON ADSORBENT AND PRESSURE SWING ADSORPTION (PSA) SYSTEM

(Keywords: microporous carbon, adsorbents, pyrolysis, PSA, activated carbon)

Various types of microporous carbon adsorbents have been prepared from Malaysia carbonaceous solid waste, the oil palm shell for the purpose of gas separations. It is an advantage to utilize the precursor by converting into useful adsorbents since it can be obtained easily and abundantly in the country. Chars or carbon molecular sieves (CMS) and activated carbons were prepared in laboratory fluidized and fixed bed reactors by physical and chemical treatments, which included carbonization in nitrogen flow, CO_2 activation and chemical impregnation followed by chemical activation. The effects of various processing parameters, such as temperature, hold time and CO_2 flow rate on the porosity development have been studied. Besides, different preparation methods, i.e. double - and single - step and chemical agents, i.e. $CuCl_2$ and K_2CO_3 were used in this study to produce different series of activated carbons. The characterization of microporous carbons was carried out by a static volumetric - physisorption analyzer to determine various characteristic parameters from the analysis of adsorption isotherms. Here, N_2 and CO_2 have been used as the adsorbates at 77 and 298 K, respectively. Almost all of the carbons appeared to be highly microporous with good and comparable quality activated carbons and chars with CMS characteristics. Single - step CO_2 activation was found to be economical and efficient method in preparing activated carbons compared to double - step method. In the separation of CO_2 and CH_4 binary gas mixture, a laboratory scale PSA - like adsorber system was designed with the use of microporous carbons to adsorb CO_2 from the gas stream. The adsorption capacity and kinetic selectivity of CO_2 and CH_4 on microporous carbon adsorbents were obtained from the breakthrough profiles analysis. The suitable selected activated carbon has shown very good separation of CO_2 and CH_4, especially at a higher gas flow rate and moderate adsorption pressure in the experiments. CMS produced from oil palm shell for oxygen - selective air separation by simple techniques have followed the Fickian diffusion model in the O_2 and N_2 adsorption rate testing by volumetric technique. Although the average kinetic selectivity of O_2 and N_2 for CMS samples prepared was lower than the commercially available CMS, but they have demonstrated fast diffusion rate and comparable capacity for O_2 adsorption.

Key researchers :

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Mr. Tan Jaan Soon
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Mr. Ahmad Anas Yusof

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Vot No. : 74060

ABSTRAK

PENJIMATAN TENAGA DALAM APLIKASI PEMISAHAN GAS DENGAN MENGGUNAKAN KARBON MOLEKUL DAN PENYERAPAN KARBON HAYUNAN BERTEKANAN (PSA)

(Kata kunci: karbon mikroporous, penjerapan, pirolisis, penjerapan ayunan, karbon teraktif)

Pelbagai jenis karbon penjerap gas berliang - mikro telah dihasilkan daripada bahan sisa berkarbon di Malaysia, iaitu tempurung kelapa sawit untuk tujuan pemisahan gas. Ia adalah satu kelebihan jika bahan ini dapat diguna untuk dijadikan bahan penjerap gas yang berguna kerana ia boleh diperoleh dengan mudah dan banyak di negara kita. Arang atau karbon penapis molekul dan karbon teraktif telah dihasilkan dengan menggunakan reaktor - reaktor di makmal serta teknik - teknik fisikal dan kimia. Teknik tersebut termasuklah karbonisasi atau pirolisis dalam aliran gas nitrogen, pengaktifan dengan CO_2 dan campuran bahan kimia diikuti dengan pengaktifan secara kimia. Parameter - parameter pemprosesan yang mempengaruhi pembentukan struktur liang, seperti suhu, masa penetapan dan kadar alir CO_2 telah dikaji dan dikenalpasti. Selain itu, cara pemprosesan yang berbeza, iaitu secara satu langkah dan dua langkah serta penggunaan bahan kimia yang berlainan, seperti $CuCl_2$ dan K_2CO_3 telah dilaksanakan dalam kajian ini untuk menghasilkan pelbagai siri karbon teraktif. Analisis penentuan sifat - sifat karbon berliang - mikro telah dijalankan dengan menggunakan peralatan penjerapan gas secara isipadu tetap untuk mendapatkan pelbagai ciri - ciri bagi struktur liang daripada keputusan garis sesuhu penjerapan. Untuk ini, gas nitrogen pada suhu 77 K dan karbon dioksida pada suhu 298 K telah digunakan sebagai bahan terjerap. Hampir keseluruhan karbon yang terhasil mempamerkan struktur berliang mikro dan karbon teraktifnya adalah berkualiti serta arangnya mempunyai ciri - ciri karbon penapis molekul. Pengaktifan secara satu langkah dengan CO_2 telah dikenalpasti sebagai cara yang ekonomi dan berkesan dalam menyediakan karbon teraktif jika dibandingkan dengan pengaktifan secara dua langkah. Dalam aplikasi pemisahan gas CO_2 dan CH_4, satu sistem penjerap berskala makmal telah direka dengan menggunakan konsep operasi penjerapan ayunan tekanan untuk menjerap gas CO_2 daripada aliran campuran dengan bantuan karbon penjerap berliang - mikro yang dihasilkan. Kapasiti penjerapan dan pemilihan secara kinetik bagi CO_2 dan CH_4 dalam karbon penjerap berliang - rnikro telah ditentukan dengan menganalisis graf - graf tembus masa. Bagi karbon teraktif yang terpilih, keputusan telah menunjukkan bahawa kesan pemisahan yang sangat baik telah berlaku untuk CO_2 dan CH_4, terutamanya pada kadar alir yang lebih tinggi dan tekanan penjerapan yang sederhana di dalam eksperimen - eksperimen itu. Karbon penapis molekul yang dihasilkan daripada tempurung kelapa sawit dengan teknik yang mudah ini untuk tujuan pemisahan udara telah didapati mengikut model resapan Fickian dalam kajian kadar resapan O_2 dan N_2 dengan menggunakan peralatan penjerapan gas yang sama seperti di atas. Walaupun pemilihan kinetik untuk O_2 dan N_2 bagi karbon penapis molekul yang dihasilkan lebih rendah daripada karbon penapis molekul komersial, tetapi ia telah menunjukkan kadar resapan yang cepat dan kapasiti penjerapan O_2 yang setanding.

Penyelidik utama :
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Mr. Tan Jaan Soon
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Tel. No. : 07-5534650
Vote No. : 74060

Project Activities	2002												2003												2004		2005	
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	S1	S2	S1	S2
1. Literature review and study			O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O □								
2. Processing rig modification and set-up					O	O □																						
3. Experiments – carbon adsorbents processing						O	O	O □																				
4. Experiments – products characteristics analysis						O	O	O	O □																			
5. Experiments – products gas adsorptive analysis								O	O	O	O □																	
6. Products data collection/conclusions										O	O	O □																
7. Design, model and set up pressure swing adsorption (PSA) unit and processes												O	O	O	O □													
8. PSA system testing – energy, cost, operating parameters optimization															O	O	O □	O										
9. Experiments – gas separation applications																		O	O	O	O	O □						
10. Overall experimental analysis, data collection and summary																					O	O	O	O □				
11. Thesis/papers writing																								O	O	O □		
12. Presentation																										O □		
Technology Transfer Activities																												
1. Techno-economic feasibility and market studies for the developed system and products																										O	O	
2. Commercialization concepts and negotiation																										O	O	

□ Planned milestone
S1: First Semester
S2: Second Semester

Benefits Report Guidelines

A. Purpose

The purpose of the Benefits Report is to allow the IRPA Panels and their supporting experts to assess the benefits derived from IRPA-funded research projects.

B. Information Required

The Project Leader is required to provide information on the results of the research project, specifically in the following areas:

- Direct outputs of the project;
- Organisational outcomes of the project; and
- Sectoral/national impacts of the project.

C. Responsibility

The Benefits Report should be completed by the Project Leader of the IRPA-funded project.

D. Timing

The Benefits Report is to be completed within three months of notification by the IRPA Secretariat. Only IRPA-funded projects identified by MPKSN are subject to this review. Generally, the Secretariat will notify Project Leaders of selected projects within 18 months of project completion.

E. Submissin Procedure

One copy of this report is to be mailed to :

IRPA Secretariat
Ministry of Science, Technology and the Environment
14th, Floor, Wisma Sime Darby
Jalan Raja Laut
55662 Kuala Lumpur

Benefit Report

1. Description of the Project

A. Project identification

1. **Project number : 02-02-06-0044 AE229 (vot 74060)**
2. **Project title : Energy Conservation in Gas Separation Application Using carbon Absorbents & Pressure Swing Adsorption (PSA) System**
3. **Project leader : Prof Dr Farid Nasir Ani**

B. Type of research

Indicate the type of research of the project (Please see definitions in the Guidelines for completing the Application Form)

☐ Scientific research (fundamental research)

☐ Technology development (applied research)

☒ Product/process development (design and engineering)

☐ Social/policy research

C. Objectives of the project

1. Socio-economic objectives

Which socio-economic objectives are adressed by the project? (Please indentify the sector, SEO Category and SEO Group under which the project falls. Refer to the Malaysian R&D Classification System brochure for the SEO Group code)

Sector :	**Energy**
SEO Category :	**Division 2:Economic Development-Energy Supply(S20500)**
SEO Group and Code :	**S20504-Conservation and efficiency**

2. Fields of research

Which are the two main FO: Categories, FOR Groups, and FOR Areas of your project? (Please refer to the Malaysia R&D Classification System brochure for the FOR Group Code)

a. Primary field of research

FOR Category :	**Applied Sciences and Technologies**
FOR Group and Code :	**F10602 -Manufacturing and process technologies and engineering**
FOR Area :	**Separation Technologies**

b. Secondary field of research

FOR Category :	**Engineering Sciences**
FOR Group and Code :	**F10706-Agricultural Engineering**
FOR Area :	**By-product Utilization**

D. Project duration

What was the duration of the project ?

36 Months

E. Project manpower

How many man-months did the project involve?

3-36 Man-months

F. Project costs

What were the total project expenses of the project?

RM 180,000.00

G. Project funding

Which were the funding sources for the project?

Funding sources	Total Allocation (RM)
IRPA	**180,000.00**

II. Direct Outputs of the Project

A. Technical contribution of the project

1. **What was the achieved direct output of the project :**

For scientific (fundamental) research projects?

- ☐ Algorithm
- ☐ Structure
- ☒ Data
- ☐ Other, please specify : _____

For technology development (applied research) projects :

- ☒ Method/technique
- ☐ Demonstrator/prototype
- ☐ Other, please specify : _____

For product/process development (design and engineering) projects:

- ☒ Product/component
- ☐ Process
- ☐ Software
- ☐ Other, please specify : _____

2. How would you characterise the quality of this output?

- ☐ Significant breakthrough
- ☒ Major improvement
- ☐ Minor improvement

B. Contribution of the project to knowledge

1. How has the output of the project been documented?

- [/] Detailed project report
- [ ] Product/process specification documents
- [ ] Other, please specify : _____

2. Did the project create an intellectual property stock?

- [ ] Patent obtained
- [ ] Patent pending
- [/] Patent application will be filed
- [ ] Copyright

3. What publications are available?

- [ ] Articles (s) in scientific publications How Many: _____
- [/] Papers(s) delivered at conferences/seminars How Many: _____
- [ ] Book
- [ ] Other, please specify : _____

4. How significant are citations of the results?

- [ ] Citations in national publications How Many: _____
- [/] Citations in international publications How Many: _____
- [ ] None yet
- [ ] Not known

lll. Organisational Outcomes of the Project

A. Contribution of the project to expertise development

1. How did the project contribute to expertise?

- ☐ PhD degrees — How Many: _____
- ☑ MSc degrees — How Many: _____
- ☐ Research staff with new specialty — How Many: _____
- ☐ Other, please specify: _____

2. How significant is this expertise?

- ☑ One of the key areas of priority for Malaysia
- ☐ An important area, but not a priority one

B. Economic contribution of the project?

1. How has the economic contribution of the project materialised?

- ☐ Sales of manufactured product/equipment
- ☐ Royalties from licensing
- ☑ Cost savings
- ☐ Time savings
- ☐ Other, please specify : _____

2. How important is this economic contribution ?

- ☐ High economic contribution — Value: RM_____
- ☐ Medium economic contribution — Value: RM_____
- ☑ Low economic contribution — Value: RM_____

3. When has this economic contribution materialised?

- [x] Already materialised
- [ ] Within months of project completion
- [ ] Within three years of project completion
- [ ] Expected in three years or more
- [ ] Unknown

C Infrastructural contribution of the project

1. What infrastructural contribution has the project had?

- [ ] New equipment Value: -
- [ ] New/improved facility Investment : RM _____
- [ ] New information networks
- [ ] Other, please specify: _____

2. How significant is this infrastructural contribution for the organisation?

- [ ] Not significant/does not leverage other projects
- [ ] Moderately significant
- [x] Very significant/significantly leverages other projects

D. Contribution of the project to the organisation's reputation

1. How has the project contributed to increasing the reputation of the organisation

- [ ] Recognition as a Centre of Excellence
- [ ] National award
- [x] International award
- [ ] Demand for advisory services
- [ ] Invitations to give speeches on conferences
- [ ] Visits from other organisations
- [ ] Other, please specify: _____

2. How important is the project's contribution to the organisation's reputation ?

- [ ] Not significant
- [ ] Moderately significant
- [x] Very significant

1V. National Impacts of the Project

A. Contribution of the project to organisational linkages

1. Which kinds of linkages did the project create?

- [ ] Domestic industry linkages
- [ ] International industry linkages
- [x] Linkages with domestic research institutions, universities
- [ ] Linkages with international research institutions, universities

2. What is the nature of the linkages?

- [ ] Staff exchanges
- [ ] Inter-organisational project team
- [ ] Research contract with a commercial client
- [x] Informal consultation
- [ ] Other, please specify: _____

B. Social-economic contribution of the project

1. Who are the direct customer/beneficiaries of the project output?

Customers/beneficiaries:	Number:
_____	_____
_____	_____
_____	_____

2. How has/will the socio-economic contribution of the project materialised ?

- [ ] Improvements in health
- [ ] Improvements in safety
- [ ] Improvements in the environment
- [x] Improvements in energy consumption/supply
- [ ] Improvements in international relations
- [ ] Other, please specify: _____

3. How important is this socio-economic contribution?

- [ ] High social contribution
- [x] Medium social contribution
- [ ] Low social contribution

4. When has/will this social contribution materialised?

- [ ] Already materialised
- [ ] Within three years of project completion
- [x] Expected in three years or more
- [ ] Unknown

Date: **Signature:**

End of Project Report Guidelines

A. Purpose

The purpose of the End of Project is to allow the IRPA Panels and their supporting group of experts to assess the results of research projects and the technology transfer actions to be taken.

B. Information Required

The following Information is required in the End of Project Report :

- Project summary for the Annual MPKSN Report;
- Extent of achievement of the original project objectives;
- Technology transfer and commercialisation approach;
- Benefits of the project, particularly project outputs and organisational outcomes; and
- Assessment of the project team, research approach, project schedule and project costs.

C. Responsibility

The End of Project Report should be completed by the Project Leader of the IRPA-funded project.

D. Timing

The End of Project Report should be submitted within three months of the completion of the research project.

E. Submission Procedure

One copy of the End of Project is to be mailed to :

IRPA Secretariat
Ministry of Science, Technology and the Environment
14th Floor, Wisma Sime Darby
Jalan Raja Laut
55662 Kuala Lumpur

End of Project Report

A. Project number : 02-02-06-0044 AE229 (vot 74060)

Project title : Energy Conservation in Gas Separation Application Using carbon Absorbents & Pressure Swing Adsorption (PSA) System

Project leader: Prof Dr Farid Nasir Ani

Tel: 607-5534650 **Fax: 607-5566159**

B. Summary for the MPKSN Report (for publication in the Annual MPKSN Report, please summarise the project objectives, significant results achieved, research approach and team strucure)

Project Objectives

The objectives of this project are to design, develop and produce suitable carbon adsorbents (activated carbons and carbon molecular sieves) that have good separation efficiency by advanced process treatments and to identify the characteristics of the carbon adsorbents for its feasibility in various gas separation applications and improvement in energy and cost savings of separation system designs. After all of that is done, work focus on to construct, fabricate, and design a laboratory pressure swing adsorption (PSA) unit with optimization of energy conservation and the process effectiveness in various gas separation applications. Finally, we will take attention on to preview the commercialization opportunity and the economic values of the PSA system and the locally produced carbon adsorbents in many related industrial sectors.

Significant results achieved:

A research is successfully done to approve that oil palm shell is a good raw material in preparation of carbon adsorbents for gas separations.

The research approach was carried by following steps:

1. Literature surveys and proposal writing
2. Carbon adsorbents preparation
3. Adsorbents characterization with gas adsorption analysis
4. Pressure swing adsorption (PSA) designing and modeling
5. Gas separation applications
6. Reports writing and conclusion

The project team structure:-

1. Prof. Farid Nasir Bin Hj. Ani
2. Tan Jaan Soon
3. Prof. A. V. Bridgwater University of Aston, United Kingdom.
4. Prof. Kouichi Miura, Kyoto University, Japan.
5. Prof. Takao Masuda, Hokkaido University, Japan.
6. Katsuyasu Sugawara, Akita University, Japan.
7. Hayashi, University of Sydney NSW 2006, Australia.
8. Professor Ir Dr. Wan Ramli Wan Daud, Universiti Kebangsaan Malaysia, Malaysia.
9. Dr. Wan Ashri Wan Daud, Universiti Malaya, Malaysia.

C. Objectives achievement

- **Original project objectives** (Please state the specific project objectives as described in Section ll of the Application Form).

1. To design, develop and produce suitable carbon adsorbents (activated carbons and carbon molecular sieves) that have good separation efficiency by advanced process treatments.
2. To identify the characteristics of the carbon adsorbents for its feasibility in various gas separation applications and improvement in energy and cost savings of separation system designs.
3. To construct, fabricate, and design a laboratory pressure swing adsorption (PSA) unit with optimization of energy conservation and the process effectiveness in various gas separation applications.
4. To preview the commercialization opportunity and the economic values of the PSA system and the locally produced carbon adsorbents in many related industrial sectors.

- **Objectives Achieved** (Please state the extent to which the project objectives were achieved)

1. Design, develop and produce suitable carbon adsorbents (activated carbons and carbon molecular sieves) that have good separation efficiency by advanced process treatments.
2. Identifying the characteristics of the carbon adsorbents for its feasibility in various gas separation applications and improvement in energy and cost savings of separation system designs.
3. Construct, fabricate, and design a laboratory pressure swing adsorption (PSA) unit with optimization of energy conservation and the process effectiveness in various gas separation applications.

- **Objectives not achieved** (Please identify the objectives that were not achieved and give reasons)

1. To preview the commercialization opportunity and the economic values of the PSA system and the locally produced carbon adsorbents in many related industrial sectors.

D. **Technology Transfer/Commercialisation Approach** (Please describe the approach planned to transfer/commercialise the results of the project)

1. Collaborations with local industries and the ministry of environment and various related bodies are necessary in order to access the information and the research carried out.
2. Universiti Teknologi Malaysia intend to invite the entrepreneur and government for products and system demonstration.
3. Participation in local and international exhibition on research findings.

E. Benefits of the Project (Please identify the actual benefits arising from the project as defined in Section lll of the Application Form. For examples of outputs, organisational outcomes and sectoral/national impacts, please refer to Section lll of the Guidelines for the Application of R&D Funding under IRPA)

- **Outputs of the project and potential beneficiaries** (Please describe as specifically as possible the outputs achieved and provide an assessment of their significance to users)

  1. Conversion of solid wastes to industrial applicable (separation technology) products.
  2. Substantial reduction in waste volume.
  3. The application of pyrolysis process in producing useful microporous carbonaceous materials.
  4. Production of various gases by gas adsorption process using the adsorbents produced.
  5. Utilization of Malaysian palm oil industry's solid wastes, which is about 13.2 million tonnes being produced annually, and it was estimated that about 1120kg of oil palm shells are produced per hectare of oil palm planted area.

- **Organisational Outcomes** (Please describe as specifically as possible the organisational benefits arising from the project and provide an assessment of their significance)

  1. Industrial organisation or government will be more support on many projects in UTM, especially in pyrolysis and environmental project.
  2. To make UTM as center study of Pyrolysis of Solid Wastes and Energy Source Materials.

- **National Impacts** (If known at this point in time, please describes specifically as possible the potential sectoral/national benefits arising from the project and provide an assessment of their significance)

  1. Economic development, research and technology aspects in Malaysia will be further expanded.
  2. Arising self - confident to develop new products from no use wastes.

F. Assessment of project structure

- **Project Team** (Please provide an assessment of how the project team performed and highlight any significant departures from plan in either structure or actual man-days utilised)

  Prof. Farid Nasir Bin Hj. Ani
  Tan Jaan Soon
  Prof. A. Williams
  Prof. Dr G.E. Andrews
  Dr B.M. Gibbs
  Dr P.T. Williams
  Prof. A.V. Bridgwater
  Prof Kouichi Miura
  Prof Takao Masuda
  Dr Toshitaka Funazukuri
  Dr Katsuyasu Sugawara
  Dr Yoshihito Shirai
  Dr Mohamed Ismail Abdul Karim
  Dr Herri Susanto

- **Collaborations** (Please describe the nature of collaborations with other research organisations and/or industry)

  Department of Fuel and Energy
  University of Leeds, United Kingdom

  University of Aston, United Kingdom

  New Energy and Industrial Technology Development Organization (NEDO):
  Kyoto University, Japan
  Chuo University, Japan
  Akita University, Japan
  Kyushu Institute of Technology, Japan
  Universiti Putra Malaysia, Malaysia
  Institute of Technology Bandung, Indonesia

F. Assessment of project structure

- **Project Team** (Please provide an assessment of how the project team performed and highlight any significant departures from plan in either structure or actual man-days utilised)

Professor Farid Nasir Bin Hj. Ani
Tan Jaan Soon
Professor A. V. Bridgwater University of Aston, United Kingdom.
Dr. Kouichi Miura, Kyoto University, Japan.
Dr. Takao Masuda, Hokkaido University, Japan.
Katsuyasu Sugawara, Akita University, Japan.
Hayashi, University of Sydney NSW 2006, Australia.
Professor In Dr. Wan Ramli Wan Daud, Universiti Kebangsaan Malaysia, Malaysia.
Dr. Wan Ashri Wan Daud, Universiti Malaya, Malaysia.

- **Collaborations** (Please describe the nature of collaborations with other research organisations and/or industry)

G. Assessment of Research Approach (Please highlight the main steps actually performed and indicate any major departure from the planned approach or any major difficulty encountered)

H. Assessment of the Project Schedule (Please make any relevant comment regarding the actual duration of the project and highlight any significant variation from plan)

I. Assessment of Project Costs (Please comment on the appropriateness of the original budget and highlight any major departure from the planned budget)

J. Additional Project Funding Obtained (In case of involvement of other funding sources, please indicate the source and total funding provided)

L. Other Remarks (Please include any other comment which you feel is relevant for the evaluation of this project)

Date : **Signature :**

I. **Assessment of Project Costs** (Please comment on the appropriateness of the original budget and highlight any major departure from the planned budget)

J. **Additional Project Funding Obtained** (In case of involvement of other funding sources, please indicate the source and total funding provided)

K. **Other Remarks** (Please include any other comment which you feel is relevant for the evaluation of this project)

Date : **Signature :**

UNIVERSITI TEKNOLOGI MALAYSIA
Research Management Centre

PRELIMINARY IP SCREENING & TECHNOLOGY ASSESSMENT FORM

(To be completed by Project Leader submission of Final Report to RMC or whenever IP protection arrangement is required)

1. **PROJECT TITLE IDENTIFICATION** :

ENERGY CON ENERGY CONSERVATION IN GAS APPLICATION USING CARBON ADSORBENT AND PRESSURE SWING ADSORPTION (PSA) SYSTEM Vote No: 74060

2. **PROJECT LEADER** :

Name : Prof Dr Farid Nasir Ani

Address : Jabatan Termo-Benbalir, Fakulti Kejuruteraan Mekanikal, Universiti Teknologi Malaysia, 81310 Skudai, Johor Darul Takzim.

Tel : 607-5534650 Fax : 607-5566159 e-mail : ***farid@fkm.utm.my***

3. **DIRECT OUTPUT OF PROJECT** *(Please tick where applicable)*

Scientific Research	Applied Research	Product/Process Development
☐ Algorithm	☑ Method/Technique	☑ Product / Component
☐ Structure	☐ Demonstration / Prototype	☐ Process
☑ Data		☐ Software
☐ Other, please specify	☐ Other, please specify	☐ Other, please specify
_____	_____	_____
_____	_____	_____
_____	_____	_____

4. INTELLECTUAL PROPERTY *(Please tick where applicable)*

☐ Not patentable	☐ Technology protected by patents
☐ Patent search required	☐ Patent pending
☐ Patent search completed and clean	☐ Monograph available
☑ Invention remains confidential	☐ Inventor technology champion
☐ No publications pending	☐ Inventor team player
☐ No prior claims to the technology	☐ Industrial partner identified

5. LIST OF EQUIPMENT BOUGHT USING THIS VOT

	Unit	Price/unit	Total Price (RM)
1. Power supply	1	2,630.19	2,630.19
2. Resistance box	1	1,082.86	1,082.86
3. High purity cylinder regulator	1	1,500.00	1,500.00
4. Nitrogen regulator	1	260.00	260.00
5. Stainless steel equipment	1	3,360.00	3,360.00
6. Crelex vortex blower	1	1,765.00	1,765.00
7. Blue white flow meter	1	1,400.00	1,400.00
8. Flowmeter	1	1,382.00	1,382.00
9. AC motor	1	85.00	85.00
10. PV2R1-08 Vane Pump	4	4,420.00	4,420.00
		Total	**17,885.05**

6. STATEMENT OF ACCOUNT

a)	APPROVED FUNDING	RM : 180,000.00
b)	TOTAL SPENDING	RM : 177,484.25
c)	BALANCE	RM : 2,515.75

7. TECHNICAL DESCRIPTION AND PERSPECTIVE

Please tick an executive summary of the new technology product, process, etc., describing how it works. Include brief analysis that compares it with competitive technology and signals the one that it may replace. Identify potential technology user group and the strategic means for exploitation.

a) Technology Description

The utilization of Malaysia oil palm wastes in the production of carbon adsorbents has gained attention in gas purification and separation technologies. This abundant and easily get raw material has given an advantage to the country in developing related technologies and industries in an economic way. The use of carbon adsorbent in the pressure swing adsorption (PSA) applications has been known to be a energy saving and cost effective method in various gas separation applications compared to conventional cryogenic separation technology. The development in PSA separation system and the adsorbent design has been a great improvement and continue effort world widely since last few years. Besides, the important of PSA as the major unit operation has shown its feasibility and capability in various fields, such as petrochemicals, chemicals, biochemical, environmental, and oil and gas industries. Therefore, there is a great opportunity for Malaysian researchers to involve in the nanotechnology and energy conservation research and help Malaysia in further one step in this challenging world.

b) Market Potential

1. Conversion of solid wastes (no use) to industrial applicable (separation technology) products.
2. Substantial reduction in waste volume.
3. The application of pyrolysis process in producing useful microporous carbonaceous materials.
4. Production of various gases by gas adsorption process using the adsorbents produced.
5. Utilization of Malaysian palm oil industry's solid wastes, which is about 13.2 million tonnes being produced annually, and it was estimated that about 1120kg of oil palm shells are produced per hectare of oil palm planted area.

c) Commercialization Strategies

1. Collaborations with the local industries and the ministry of environment and various related departments is necessary in order to excess to information and the research carried out.
2. Universiti Teknologi Malaysia will invite the entrepreneurs and government and demonstrate this product.
3. Participation in National and International Exhibition, such as INATEX Exhibition, ITEX Exhibition, and Geneva International Exhibition.

Signature of Projet Leader :- Date :-

_____ _____

8. RESEARCH PERFORMANCE EVALUATION

a) FACULTY RESEARCH COORDINATOR

Research Status	( )	( )	( )	( )	( )	( )
Spending	( )	( )	( )	( )	( )	( )
Overall Status	( )	( )	( )	( )	( )	( )
	Excellent	Very Good	Good	Satisfactory	Fair	Weak

Comment / Recommendations :

_____

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…… Name : ……

Signature and stamp of JKPP Chairman Date : ……

b) RMC EVALUATION

Research Status	( )	( )	( )	( )	( )	( )
Spending	( )	( )	( )	( )	( )	( )
Overall Status	( )	( )	( )	( )	( )	( )
	Excellent	Very Good	Good	Satisfactory	Fair	Weak

Comments :-

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Recommendations :

☐ Needs further research

☐ Patent application recommended

☐ Market without patent

☐ No tangible product. Report to be filed as reference

…….. Name : …….

Signature and Stamp of Dean / Deputy Dean Date : …….

Research Management Centre

UNIVERSITI TEKNOLOGI MALAYSIA

BORANG PENGESAHAN
LAPORAN AKHIR PENYELIDIKAN

TAJUK PROJEK : ENERGY CONSERVATION IN GAS APPLICATION USING CARBON ADSORBENT AND PRESSURE SWING ADSORPTION (PSA) SYSTEM

Saya _____TAN JAAN SOON_____
(HURUF BESAR)

Mengaku membenarkan **Laporan Akhir Penyelidikan** ini disimpan di Perpustakaan Universiti Teknologi Malaysia dengan syarat-syarat kegunaan seperti berikut :

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UNIVERSITI TEKNOLOGI MALAYSIA

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Nama & Cop Ketua Penyelidik

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