PJP/2002/FKM(3)

CARBON MOLECULAR SIEVE FROM WASTE MATERIAL (COCONUT SHELL, OIL PALM SHELL, PLASTIC BAG)

SAFARUDIN GAZALI HERAWAN

IMRAN SYAKIR B. MOHAMAD

MOHD HAIZAL B. MOHD HUSIN

AHMAD ANAS B. YUSOF

ERNIE BT. MAT TOKIT

FACULTY OF MECHANICAL ENGINEERING

ACADEMIC SERVICE CENTRE

KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

MELAKA

2003

ABSTRACT

Coconut shell and oil palm shell are an agricultural waste material found abundantly in Malaysia. Since the characteristics of coconut shell and oil palm shell were found suitable for preparing activated carbon, these materials also have the potential to be prepared into useful and valuable product. This research, the concern is to make use of coconut shell or oil palm shell which it mixed with plastic bag to prepare the carbon molecular sieve, however due to the limitation of time and grant, these materials is prepared for a carbon adsorbent, which applied for hydrocarbon gas storage in this case the Liquefied Petroleum Gas LPG as a gas feeder. This sample was prepared at a laboratory scale fixed-bed reactor, which is blanketed by a vertical furnace where pyrolysis took place. Nitrogen gas was used to obtain an inert atmosphere in the reactor. A suction blower was used to remove volatile matter as well as other gases during carbonization process. The samples were prepared in the different peak temperature and amount of the plastic bag which it mixed with them. CO_2 activation also was used to investigate the effect of it in the sample. This research work will attempt to find a suitable solution to solve the environmental problems by utilizing the waste materials and to look into the industrial aspect of adsorption process for gas storage.

Keywords: Gas Storage; Carbon Adsorbent; Waste Material

ACKNOWLEDGEMENTS

Alhamdulillah, with His Mercy and Blessings, this study was finally completed. The authors pleasure to express thank to Professor Dr. Abu B. Abdullah, Dean of University-Industry Centre, Associate Professor Abd. Salam Md. Tahir, Dean of Faculty of Mechanical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM) and Ministry of Education for giving us opportunity to conduct this research.

The authors are grateful to Associate Professor Lt. Kol. Ir. Mohd Hazani B. Hj. Shafie, Deputy Dean of Research and Post Graduate Study, Faculty of Mechanical Engineering, also Staffs of the Faculty of Mechanical Engineering, Academic Service Centre, and University-Industry Centre, KUTKM, for their assistance and co-operation in carrying out the research in one way or another. Special thanks are due to Professor Dr. Farid Nasir Hj Ani of the Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM) for his consultancy and laboratory facilities.

May Allah reward and bless all of them. Finally the authors are expressing our sincere gratitude to Allah once again who made the research to complete.

TABLE OF CONTENT

TABLE OF CONTENT

1.0 INTRODUCTION

Carbon adsorbent is a type of carbon produced through exposing a source material such as wood or bone to very high temperatures in the presence of steam, air, or carbon monoxide. Activated carbon is very good at removing or adsorbing contaminants and is used in water filters, to decolor solutions, and is sometimes administered to poisoning victims.

The waste materials that are mixed of coconut shell or palm shell and plastic bag are found in large quantities will be used as a carbon adsorbent. Carbon adsorbent has been shown to be applicable for treatment of a wide variety of environmental contaminants. When properly applied, the adsorption process will remove pollutants for which it is designed (Shepherd, A., 2001).

Shepherd, A.(2001) also stated that the activated carbon will function as a carbon adsorption where the contaminated gas will be attracted to and accumulated on its surface. In evaluating the effectiveness of the carbon adsorption by using the waste material, the characteristics of the application will be considered first. This will help in obtaining a strong adsorption. In this case, the researcher will take into consideration where the molecules of a contaminant tend to adsorb most strongly in areas where the pore diameter of the adsorbent is close to the molecular diameter of the compound.

The importance of its role has been looked as a demolition of a clean environment. With these characteristics, studies will be carried out to investigate its adsorption capacity as a fuel carbon adsorbent that is applicable for hydrocarbon gas storage that is widely used in the automotive area (Burchell, 1995). For example, utilizing the activated carbon in controlling pollutants emissions in natural gas storage tank (Robinson), Liquefied Petroleum Gas (LPG) and Gasoline storage tank (Air Resources Board, 1997) and Proton-Exchange Membrane (PEM) Fuel Cell Vehicle (James, 1996).

From CATF Review Newsletter (1995), two researchers reported that results indicate adsorbents may become a practical means of on-board fuel storage and the work on these adsorbents for natural gas has been going on since the early 1980s. Robinson stated that the Absorbed natural gas (ANG) is an interesting alternative to Compressed Natural Gas (CNG) since the same amount of natural gas can be stored at much lower pressure (500 psi or 30 atm) in a thinner walled tank filled with activated carbon and this provides more energy than gasoline on a weight basis.

2.0 LIQUEFIED PETROLEUM GAS (LPG)

LPG is a natural occurring and refined hydrocarbon which is most often stored as a liquid under pressure. It is usually transported in bulk and pressurized vessels. It is a naturally occurring material and is also produced through the refining process for other hydrocarbon such as petrol and diesel (Calor Gas).

Researchers used LPG in application of alternative vehicle fuel, which have benefits include total elimination of smoke and virtual elimination of smell. It also contributes to a much quieter and smoother running engine. As well as the environmental benefits, compared to other alternative fuels LPG combines high performance with economy, making it the best current alternative to petrol or diesel fuels (Calor Gas).

Carbon adsorbent as a gas storage media for LPG is an alternative way to overcome the disadvantages of pressurized vessel such as high pressure flammable gas content, dimension of gas tank, and other dangerous aspects.

3.0 STATEMENT OF THE PROBLEM

Preparing a carbon adsorbent from waste material, which well enough capability for adsorbing LPG.

This problem can be overcome by conducting these steps as follows:

1. Design and develop the experimental rig for preparing carbon adsorbent
2. Prepare carbon adsorbent from waste materials such as coconut shell, oil palm shell, plastic bag that is treated in the difference conditions
3. Design and develop the carbon adsorbent test bed for carbon adsorbent that is connected with a Hydrocarbon Gas Detector to determine adsorption ability for LPG
4. Study the effect of carbonization, activation, and plastic bag on carbon adsorbent pore structure due to capability to adsorb LPG.

4.0 METHODOLOGY

This research has been conducted by designing and developing the experimental rig for preparing carbon adsorbent, which are consisted of a reactor, tube furnace, suction blower and some accessories as a first stage. At the same time, the carbon adsorbent test bed is designed and developed, which has a column adsorber for carbon adsorbent and is connected online with a Gas Detector to determine the breakthrough curves for LPG that can lead to determine adsorption selectivity for LPG.

Next stage is preparing carbon adsorbent from waste material such as coconut shell or oil palm shell and mixed with plastic bag using the experimental rig, which is processed by conventional method using pyrolysis technique. By varies the peak temperature of the sample, the optimization of it can be achieved. This process is carried out in a laboratory scale, fixed bed reactor, which blanketed by tube furnace where the pyrolysis take place. Nitrogen gas is used to obtain an inert atmosphere in the reactor and CO_2 gas is used to activate the sample. A suction blower is used to remove volatile matter as well as other gases during the process as shown in Figure 1.

For application purpose, carbon adsorbent test bed has been developed as shown in figure 2. It is clear that the apparatus consists of two column (empty column and carbon adsorbent bed, which is blanketed with heating tape), temperature control for heating the sample due to desorption process, timer for calculating the adsorption time up to saturated condition, and gas detector in %Gas to detect the flue gas after exposes to the sample. The breakthrough curve can be used to obtain the data on the capacity and selectivity of the adsorption happened. The experiment will stop when the curves show the breakthrough (inlet =outlet concentration) for LPG at 5 ml/min of feeding.

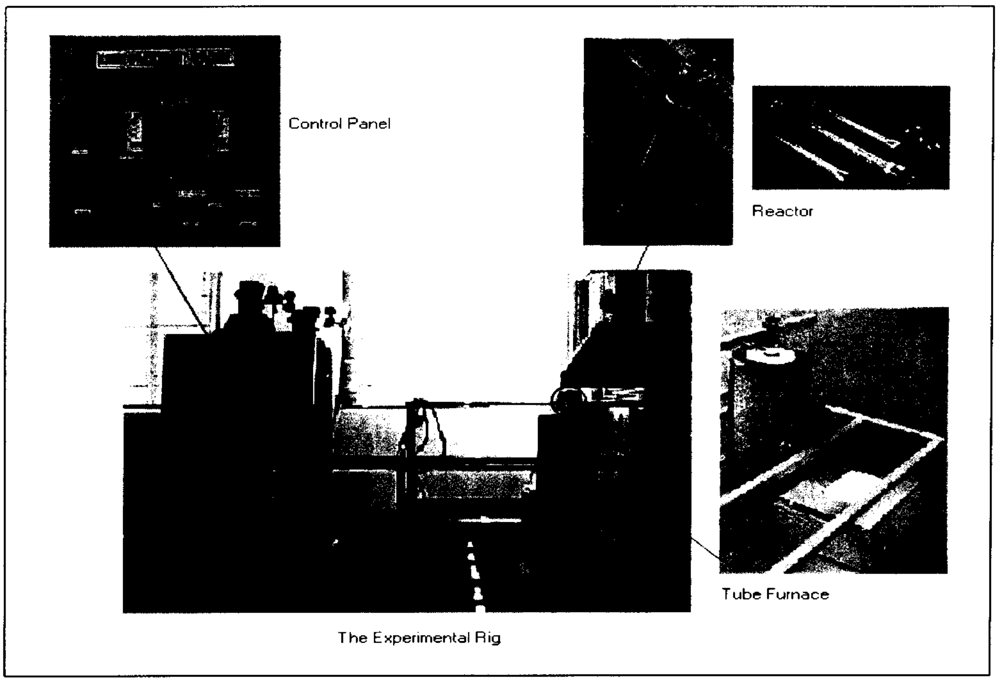


Figure 1. The Experimental rig for producing carbon adsorbent

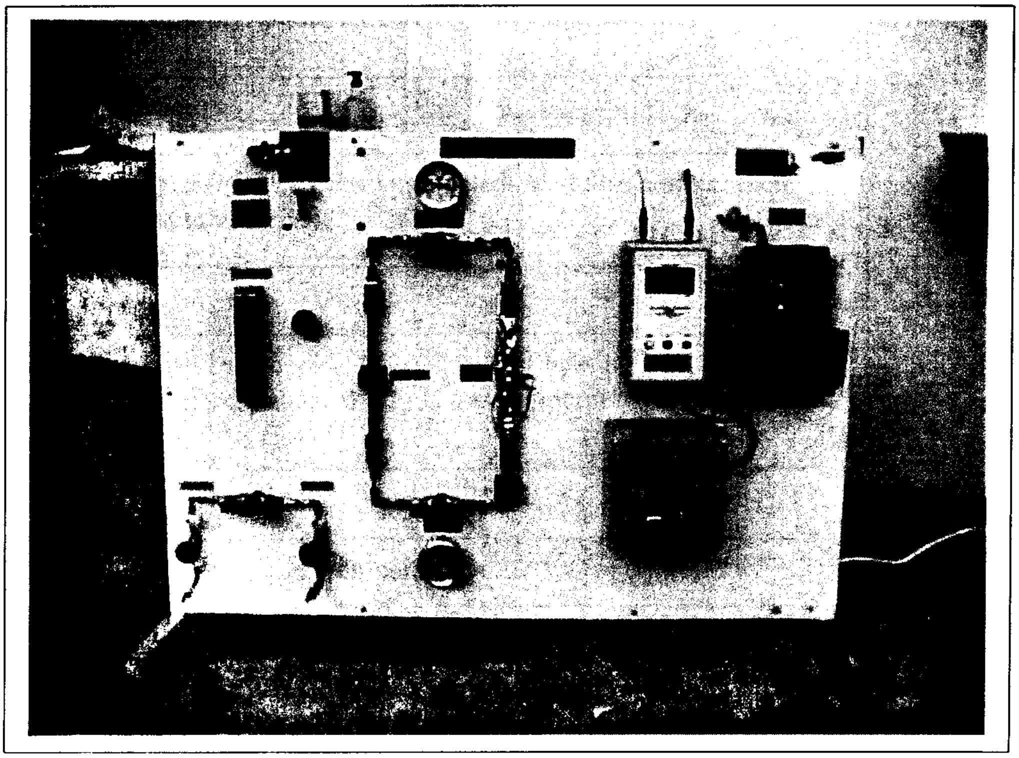


Figure 2. Carbon adsorbent test bed

4.1 Preparation of Carbon Adsorbent

The waste materials as a raw material are oil palm shell, coconut shell, and plastic bag. Oil palm shell or coconut shell were crushed and sieved to a size of 250 – 425 μm separately. About 50 grams of each formed particles were fed in the reactor. The char was prepared at 10°C/min of the heating rate, up to 600°C, 700°C, and 800°C and was maintained for 60 minutes in 1.5 l/min of N_2 (99.98% of purity from Linde) flow. The main flow chart of carbon adsorbent preparation can be seen in Figure 3 that describes the procedure of the preparation.

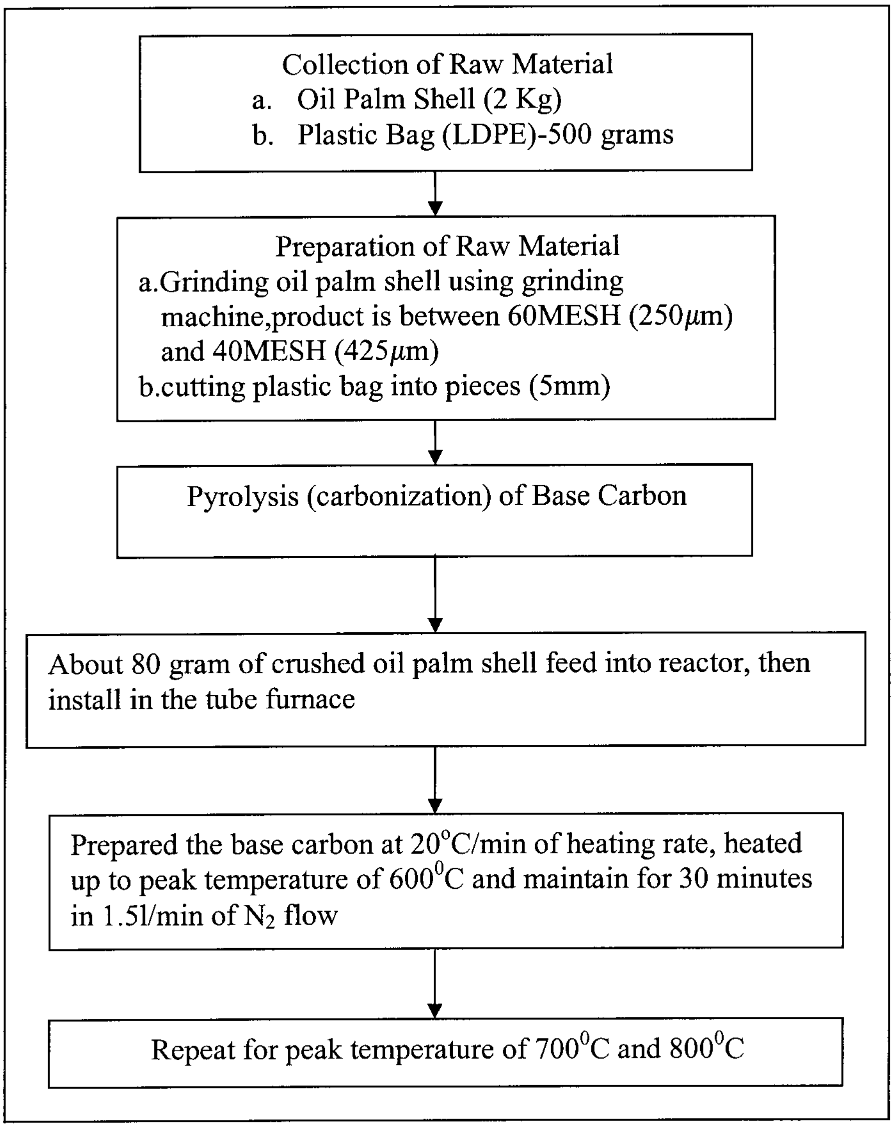


Figure 3: Experimental procedure

The chars then were mixed with 10%wt of plastic bag. The aim of this method is to observe the effect of plastic bag in the char due to adsorption capacity of LPG. The mixed char then was placed in the same reactor and heated at 10°C/min of the heating rate, up to peak temperature in the 200 ml/min of N_2 flow and was maintained for 60 minutes, and then N_2 was switched off and changed to CO_2 flow at 162 ml/min for 30 minutes.

5.0 RESULTS AND DISCUSSION

The results obtained from carbon adsorbent test bed which applied in four the samples are summarized in Figure 4. More time to reach inlet concentration (Co) can be concluded that more LPG is adsorbed in carbon adsorbent. As shown in Figure 4, the time to reach Co decreases from 600°C to 800°C in correspondence with increasing peak temperature for both chars of oil palm shell and coconut shell. The increasing peak temperature actually can shrink the pore structure of char (Safarudin, 2000), therefore the smaller pore structure of char is not suitable for adsorbing LPG.

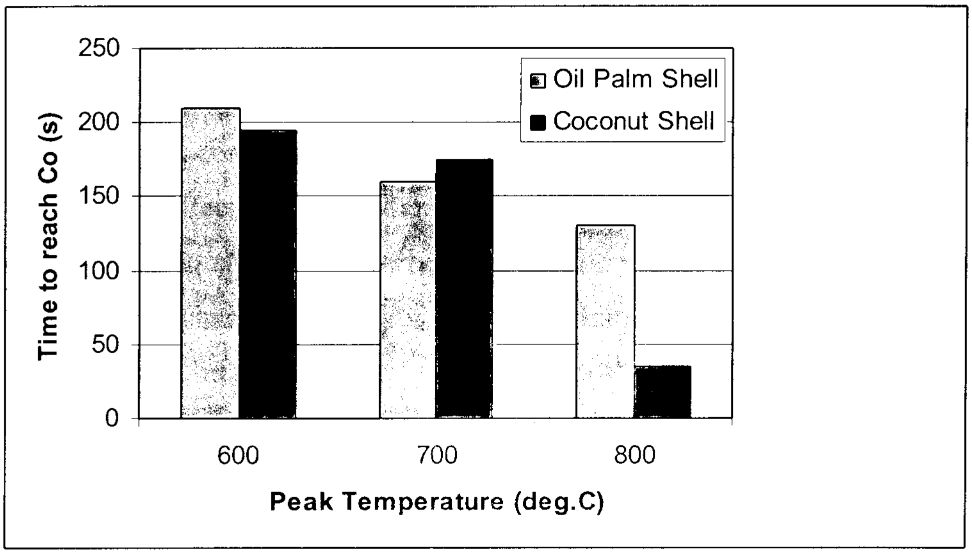


Figure 4. Time to reach Co for chars of oil palm shell and coconut shell at varies peak temperature

However, the adsorption of LPG at coconut shell char dramatically decreases from 700°C to 800°C as comparison with oil palm shell char. It might be concluded that the adsorption of LPG do not appropriate with higher peak temperature for coconut shell char especially and both of them generally.

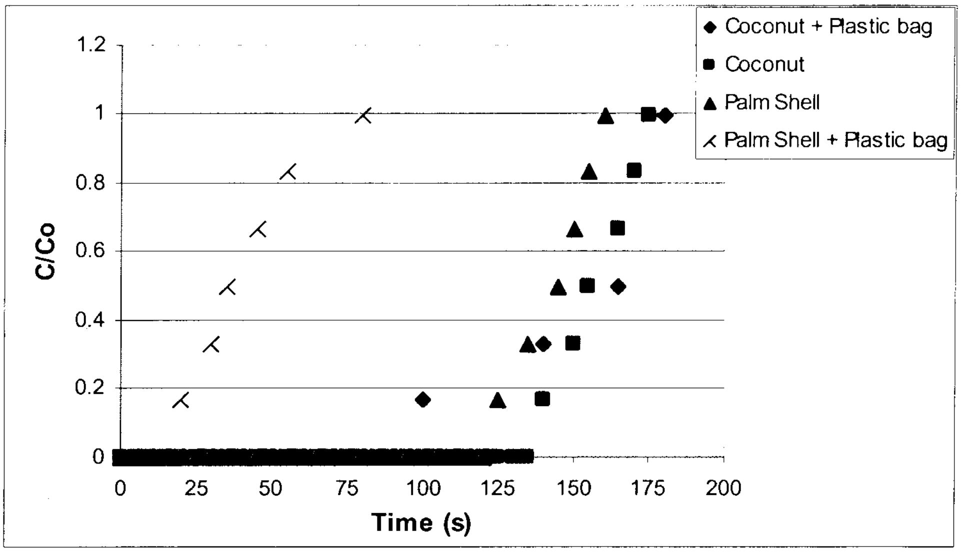


Figure 5. Breakthrough curve vs time for oil palm shell and coconut shell char, and both chars mixed with plastic bag.

The breakthrough curves for these four carbon adsorbents are displayed in Figure 5, which shows the breakthrough curves of carbon adsorbents that are subjected to LPG. As shown in this figure, coconut shell char adsorbs more LPG than oil palm shell char. The plastic bag indeed effect the both chars unfortunately in different results. The plastic bag in coconut shell char can increase the adsorption of LPG, however in case of mixed oil palm shell char; the adsorption of LPG dramatically decreases. This could be happened due to the pore structure of carbon adsorbent (Safarudin, 2000).

The average pore diameter of coconut shell char is bigger than oil palm shell at the same procedure of preparation (Safarudin, 2000) therefore the smaller pore size can reduce the capability to adsorb LPG. The plastic bag might block or shrink the pore structure of the char. For oil palm shell char, this effect results the reduction of LPG adsorption. Somehow, the existing of plastic bag in coconut shell char dedicates appropriate condition that can result the increasing capability for adsorbing LPG.

6.0 CONCLUSION

The experimental rig and carbon adsorbent test bed were successfully developed and both of them can be used to prepare carbon adsorbent and analysis to determine adsorption ability for LPG, respectively.

Waste material (coconut shell, oil palm shell, and plastic bag) can be used for producing carbon adsorbent for LPG gas storage media since all the samples show capability to adsorb LPG, unfortunately the capacity is still low. It is found that coconut shell mixed with plastic bag shows a higher capability to adsorb LPG than the other samples. However, this research is still need to continue to explore more finding to achieve a better result in the future work.

REFERENCES

1. Air Resources Board. *Motor vehicle LPG test program*, http://www.ard.ca.gov/fuels/altfuels/lpg/mvlpge/mvlpge.htm (accessed September 2003) (1997).

2. Burchell, Tim. *Carbon materials for advances technologies*, http://www.americancarbonsociety.org/CMATbook.html (accessed July 2003) (1995).

3. Calor Gas Home Page, http://www.calorgas.ie/ (accessed October 2003).

4. CATF Review Newsletter. *New promise for adsorbents in gaseous fuel storage.* http://catf.bcresearch.com/catf/review/issue_20/promise.htm (accessed August 2003) (1995).

5. James, Brian D., Baum, George N., Lomax, Franklin D., Jr., Thomas, C.E. (Sandy), and Kuhn, Ira F., Jr. *Comparison of Onboard Hydrogen Storage for Fuel Cell Vehicles.* Ford Motor Company (1996).

6. Robinson, Ken, Mieville, Rodney L., Jasionowski, Walter J., and Butt, John B. *Natural gas storage with bonded carbon*, http://www.megacarbon.com/techlit/Ang.html (accessed August 2003).

7. Safarudin Gazali Herawan. *Characterisation and Analysis of Carbon Molecular Sieve from Oil Palm Shell.* Master of Mech Eng. Thesis, Universiti Teknologi Malaysia (2000).

8. Shepherd, Austin. *Activated carbon adsorption for treatment of VOC emissions.* Presented at the 13th Annual EnviroExpo, Boston (2001).

LIST OF PUBLICATIONS

1. Safarudin Gazali Herawan, Imran Syakir bin Mohamad, Mohd Haizal bin Mohd Husin, Ahmad Anas bin Yusof, Ernie Mat Tokit, and Farid Nasir bin Hj Ani (2003). "Carbon Adsorbent from Waste Materials (Coconut Shell, Oil Palm Shell, Plastic Bag) for Hydrocarbon Gas Storage". Conference in conjunction with IPTA Research and Development Exposition 2003, Kuala Lumpur, 2 – 5 October 2003.

2. Safarudin Gazali Herawan, Imran Syakir bin Mohamad, Mohd Haizal bin Mohd Husin, Ahmad Anas bin Yusof, Ernie Mat Tokit, and Farid Nasir bin Hj Ani (2003). "Carbon Adsorbent from Waste Materials (Coconut Shell, Oil Palm Shell, Plastic Bag) for Hydrocarbon Gas Storage". Exhibitor in IPTA Research and Development Exposition 2003, Kuala Lumpur, 2 – 5 October 2003.

3. Safarudin Gazali Herawan, Imran Syakir bin Mohamad, Mohd Haizal bin Mohd Husin, Ahmad Anas bin Yusof, Ernie Mat Tokit, and Farid Nasir bin Hj Ani (2003). "Hydrocarbon Gas Storage from Carbon Adsorbent using Waste Materials". Malaysia Science and Technology Congress 2003 (COSTAM), Kuala Lumpur, 23 – 25 September 2003. (abstract only).

4. Safarudin Gazali Herawan, Imran Syakir bin Mohamad, Mohd Haizal bin Mohd Husin, Ahmad Anas bin Yusof, Ernie Mat Tokit, Imanurezeki Mohamad, and Farid Nasir bin Hj Ani (2003). "Carbon Adsorbent Prepared from Waste Materials for LPG Gas Storage Media". Symposium of the Malaysian Chemical Engineers (SOMChe2003), Pulau Penang, 29 & 30th December 2003.

LIST OF PUBLICATIONS (PRINCIPAL RESEARCHER)

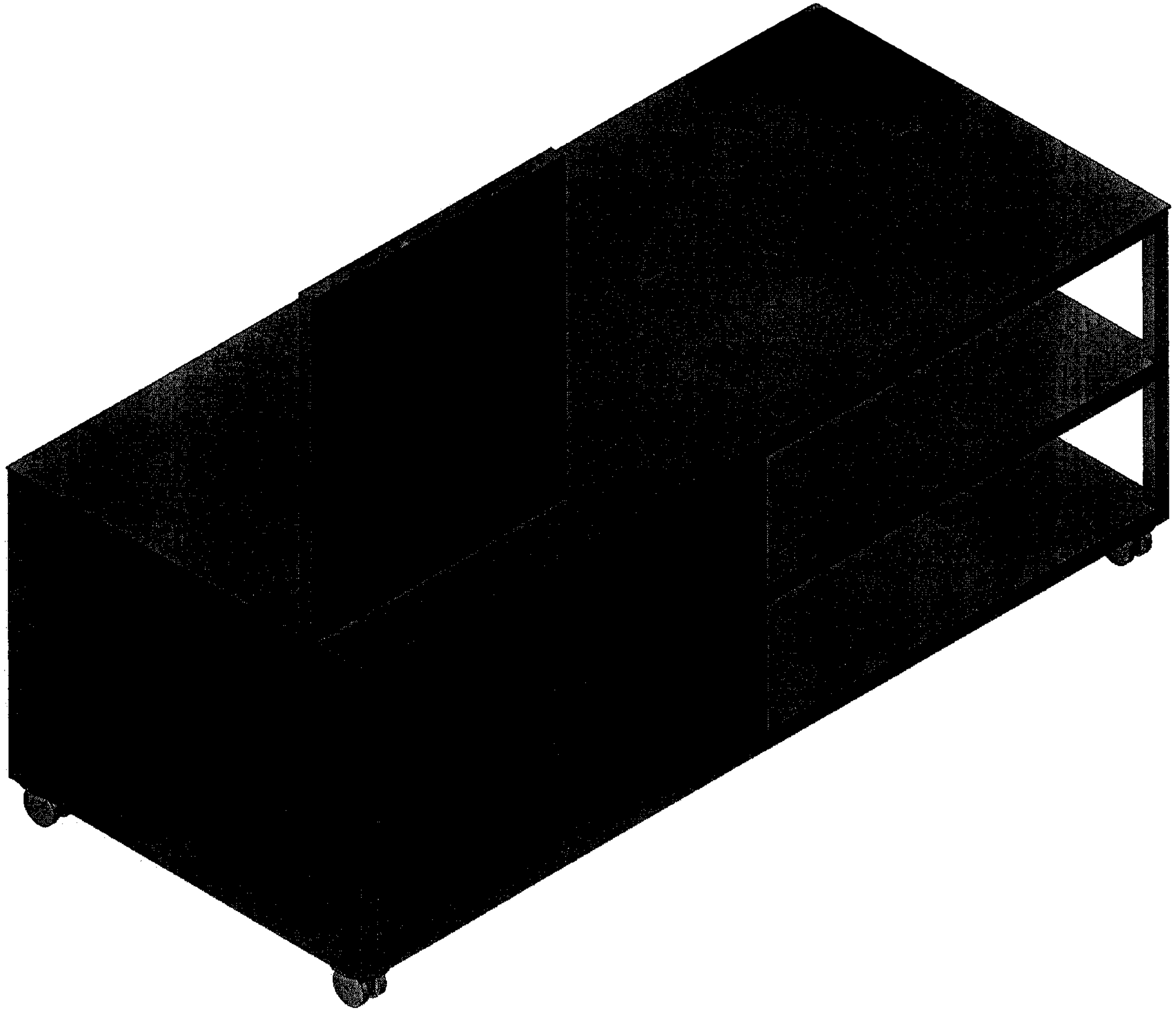
1. Safarudin Gazali Herawan, Farid Nasir Ani, Tan Jaan Soon, Miura, K. and Hayashi, J (2003). "Utilization of Oil Palm Shell by Converting into Carbon Molecular Sieve for Separation of Methane from Carbon Dioxide as a Waste Minimization". Environment 2003, Environmental Management and Sustainable Development for Better Future Growth, Pulau Penang, 18 – 19 February 2003.

2. Safarudin Gazali Herawan, Farid Nasir Ani, Tan Jaan Soon, Kouichi Miura, and Jun'ichi Hayashi (2003). "Carbon Molecular Sieves from Oil Palm Shell for Separation of Methane from Carbon Dioxide Gas Mixture". Engineering and Technology Conference 2003 (EnTech 2003), Kuching, 30 July – 1 August 2003.

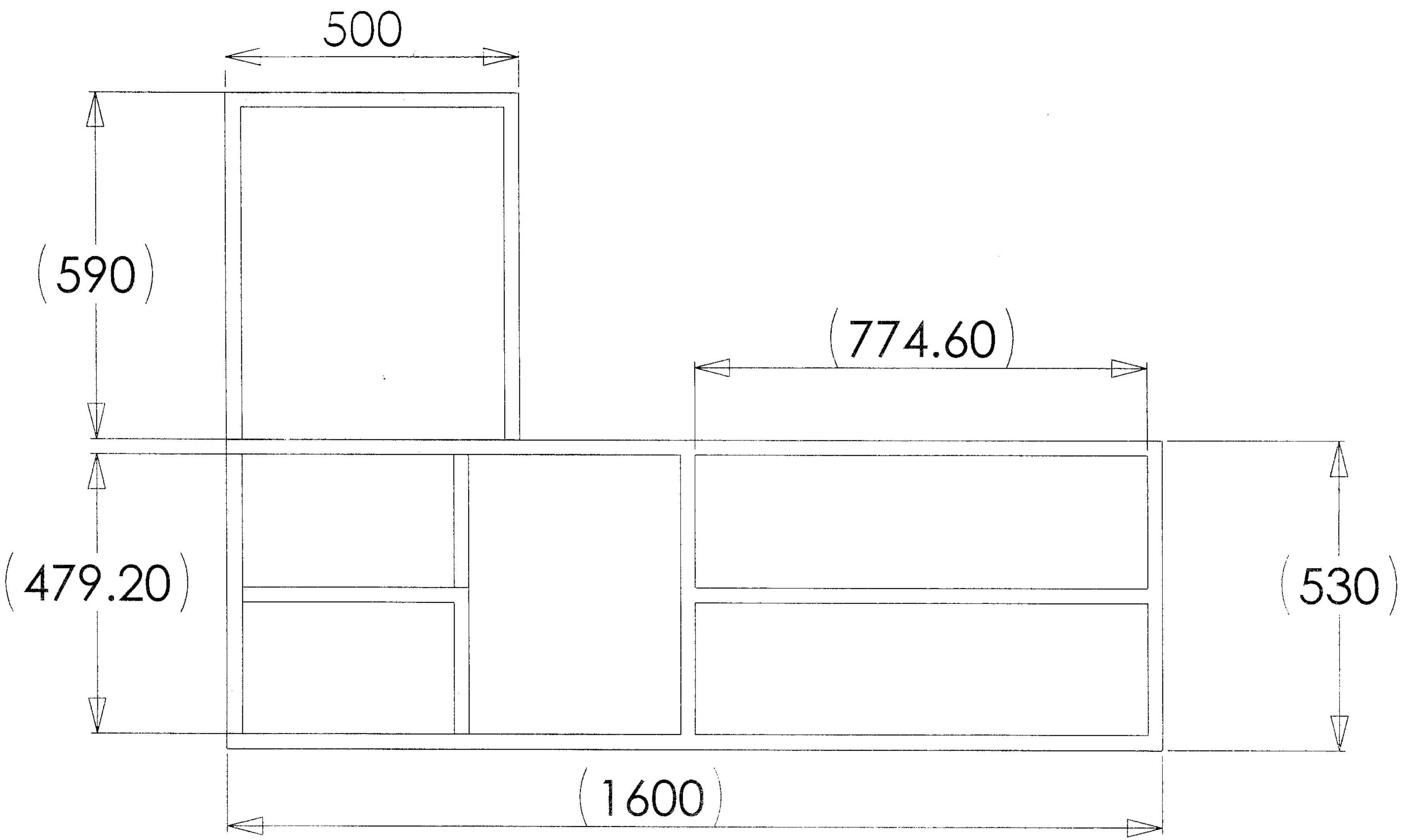
3. Safarudin Gazali Herawan and Farid Nasir Ani (2003). "Thermogravimetry Analysis for Determining the Adsorption Selectivity of Carbon Molecular Sieve from Oil Palm Shell between Oxygen and Nitrogen". The 3rd International Conference on Advances in Strategic Technologies, Kuala Lumpur, 12 – 14 August 2003.

APPENDIX

CARBON REACTOR DESK
DRAWING



		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME	DATE	Kolej Uni. Tek. Keb. M'sia
			DRAWN	A. Rahman		
			CHECKED	Safarudin		CARBON REACTOR DESK
			ENG APPR.			
			MFG APPR.			
		MATERIAL --	Q.A.			
			COMMENTS:			
NEXT ASSY	USED ON	FINISH --				SIZE A DWG. NO. PJP/2002/FKM(3)-01 REV.
APPLICATION		DO NOT SCALE DRAWING				SCALE:1:2 WEIGHT: SHEET 1 OF 1



DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME	DATE	Kolej Uni. Tek. Keb. M'sia
	DRAWN	M. Najib		
	CHECKED	Safarudin		CARBON REACTOR DESK FRAME -Front view-
	ENG APPR.			
	MFG APPR.			
MATERIAL: Mild Steel	Q.A.			
FINISH: Paint	COMMENTS:			

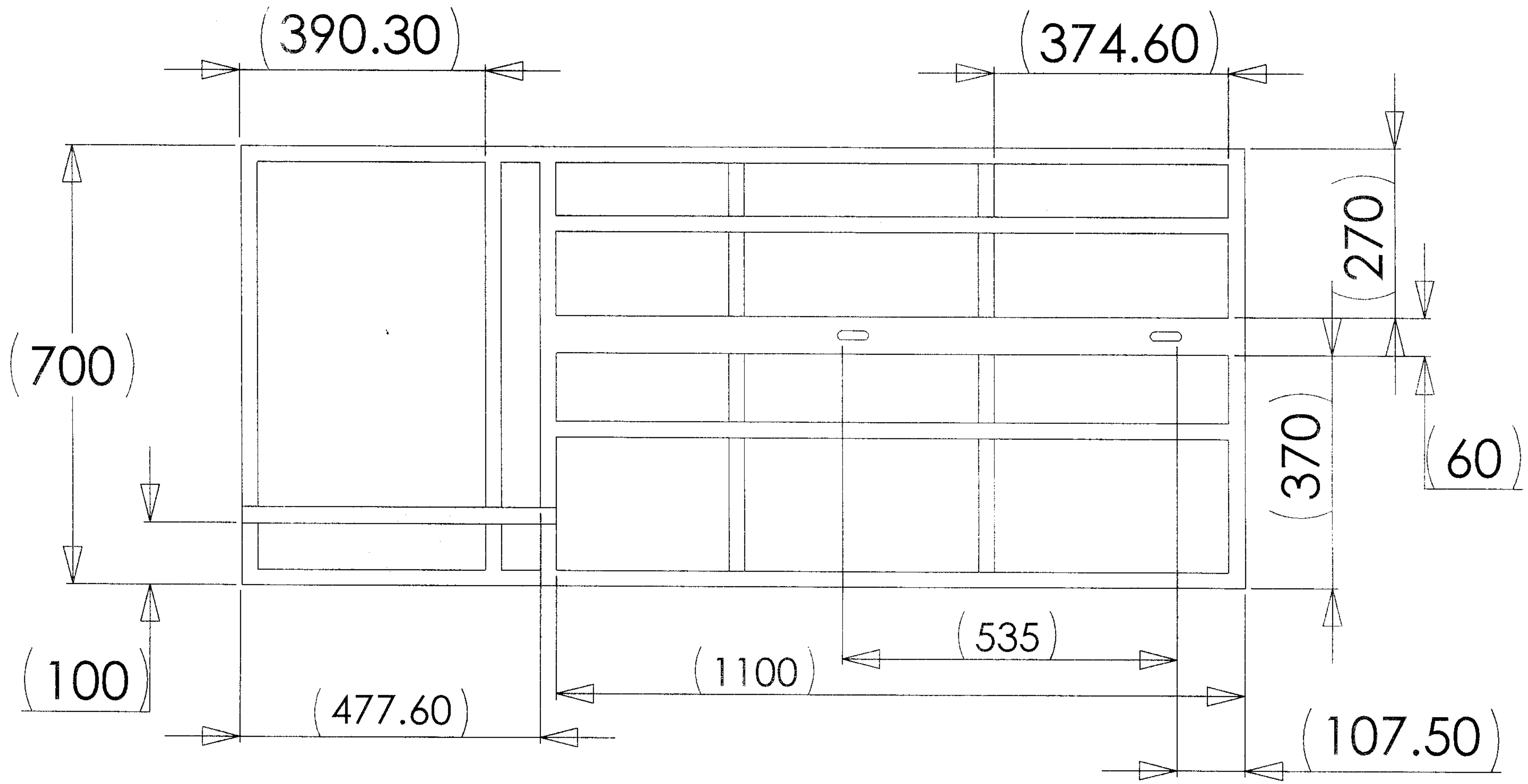
NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

SIZE	DWG. NO.	REV.
A	PJP/2002/FKM(3)-02	

SCALE:1:20 | WEIGHT: | SHEET 1 OF 1



DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

MATERIAL Mild Steel

FINISH Paint

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

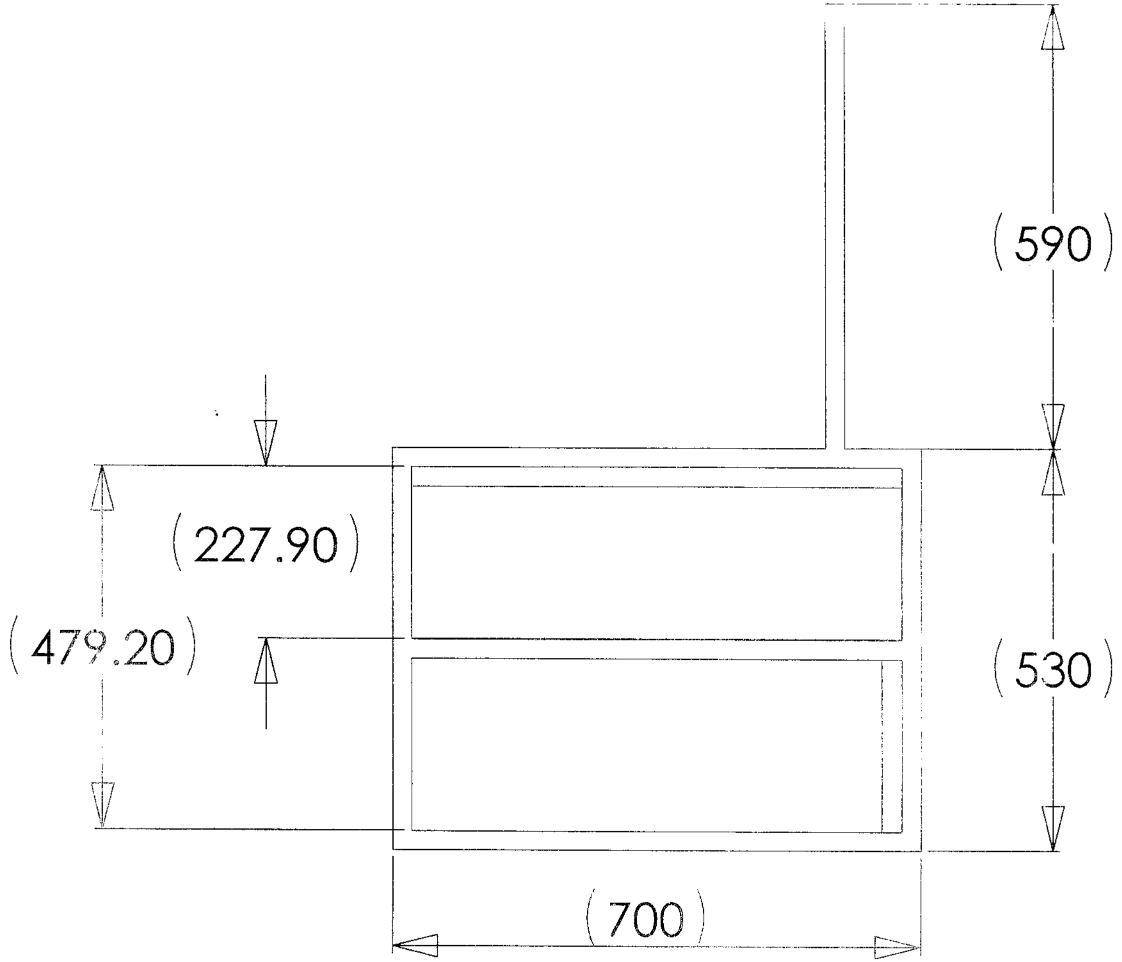
	NAME	DATE
DRAWN	A. Rahman	
CHECKED	Safarudin	
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

Kolej Uni. Tek. Keb. M'sia

CARBON REACTOR
DESK FRAME
-plan view-

SIZE A | DWG. NO. PJP/2002/FKM(3)-03 | REV.

SCALE:1:20 | WEIGHT: | SHEET 1 OF 1



		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME	DATE	Kolej Uni. Tek. Keb. M'sia
			DRAWN	M. Najib		
			CHECKED	Safarudin		CARBON REACTOR DESK FRAME -side view-
			ENG APPR.			
			MFG APPR.			
		MATERIAL: Mild Steel	Q.A.			
NEXT ASSY	USED ON	FINISH: Paint	COMMENTS:			SIZE: A / DWG. NO. PJP/2002/FKM(3)-04 / REV.
APPLICATION		DO NOT SCALE DRAWING				SCALE:1:20 / WEIGHT: / SHEET 1 OF 1

DATA COLLECTION FROM
CARBON ADSORBENT TEST BED

TIME TO REACH 0.30% GAS

SAMPLE	TYPE OF SAMPLE	TIME (s)
1	P-CHAR-600^{0}C	210
2	P-CHAR-700^{0}C	160
3	P-CHAR-800^{0}C	130
4	C-CHAR-600^{0}C	195
5	C-CHAR-700^{0}C	175
6	C-CHAR-800^{0}C	35
7	P-600-10--600CO_2-60+10%PB	50
8	P-700-10--700CO_2-60+10%PB	80
9	P-800-10--800CO_2-60+10%PB	35
10	C-600-10--600CO_2-60+10%PB	30
11	C-700-10--700CO_2-60+10%PB	180
12	C-800-10--800CO_2-60+10%PB	30
13	P-600-10--600CO_2-60	35
14	P-700-10--700CO_2-60	25
15	P-800-10--800CO_2-60	60
16	C-600-10--600CO_2-60	35
17	C-700-10--700CO_2-60	145
18	C-800-10--800CO_2-60	180