DEVELOPMENT OF SPRAYER NOZZLE OF THE UNPACKED SATURATOR FOR DISSOLVED AIR FLOTATION PROCESS

ASSOC.PROF.MOHD.NORDIN ADLAN

UNIVERSITI SAINS MALAYSIA
KAMPUS KEJURUTERAAN
2008

Laporan Akhir Projek Penyelidikan Jangka Pendek

Development of Sprayer Nozzle of the Unpacked Saturator for Dissolved Air Flotation Process

by
Assoc. Prof. Mohd. Nordin Adlan
Assoc. Prof. Hamidi Abdul Aziz

UNIVERSITI SAINS MALAYSIA

LAPORAN AKHIR PROJEK PENYELIDIKAN JANGKA *PENDEK*

FINAL REPORT OF SHORT TERM RESEARCH PROJECT

Sila kemukakan laporan akhir ini melalui Jawatankuasa Penyelidikan di Pusat Pengajian dan Dekan/Pengarah/Ketua Jabatan kepada Pejabat Pelantar Penyelidikan

1. **Nama Ketua Penyelidik:** Mohd. Nordin bin Adlan
Name of Research Leader

☑ Profesor Madya/ *Assoc. Prof.* ☐ Dr./ *Dr.* ☐ Encik/Puan/Cik *Mr/Mrs/Ms*

2. **Pusat Tanggungjawab (PTJ):** School of Civil Engineering
School/Department

3. **Nama Penyelidik Bersama:** Prof. Madya Hamidi Abdul Aziz
Name of Co-Researcher

4. **Tajuk Projek:** Development of Sprayer Nozzle of the Unpacked Saturator for Dissolved Air Flotation Process
Title of Project

5. **Ringkasan Penilaian/***Summary of Assessment:*	Tidak Mencukupi *Inadequate*		Boleh Diterima *Acceptable*	Sangat Baik *Very Good*	
	1	2	3	4	5
i) **Pencapaian objektif projek:** *Achievement of project objectives*	☐	☐	☐	√	☐
ii) **Kualiti output:** *Quality of outputs*	☐	☐	☐	√	☐
iii) **Kualiti impak:** *Quality of impacts*	☐	☐	√	☐	☐
iv) **Pemindahan teknologi/potensi pengkomersialan:** *Technology transfer/commercialization potential*	☐	☐	√	☐	☐
Kualiti dan usahasama: *Quality and intensity of collaboration*	☐	☐	☐	√	☐
nilaian kepentingan secara keseluruhan: *erall assessment of benefits*	☐	☐	☐	√	☐

6. Abstrak Penyelidikan

(Perlu disediakan di antara 100 - 200 perkataan di dalam **Bahasa Malaysia dan juga Bahasa Inggeris**. Abstrak ini akan dimuatkan dalam Laporan Tahunan Bahagian Penyelidikan & Inovasi sebagai satu cara untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti & masyarakat luar).

Abstract of Research

(An abstract of between 100 and 200 words must be prepared in Bahasa Malaysia and in English). This abstract will be included in the Annual Report of the Research and Innovation Section at a later date as a means of presenting the project findings of the researcher/s to the University and the community at large)

See Attachment A

7. Sila sediakan laporan teknikal lengkap yang menerangkan keseluruhan projek ini.
[Sila gunakan kertas berasingan]

Applicant are required to prepare a Comprehensive Technical Report explaning the project. (This report must be appended separately)

See Attachment B

Senaraikan kata kunci yang mencerminkan penyelidikan anda:
List the key words that reflects your research:

Bahasa Malaysia	*Bahasa Inggeris*
Pengapungan udara terlarut	Dissolved air flotation
Kecekapan penepu	Saturator efficiency
Muncung penyembur	Sprayer nozzle

8. Output dan Faedah Projek

Output and Benefits of Project

(a) * **Penerbitan Jurnal**

Publication of Journals

(Sila nyatakan jenis, tajuk, pengarang/editor, tahun terbitan dan di mana telah diterbit/diserahkan)

(State type, title, author/editor, publication year and where it has been published/submitted)

None so far, however in the preparation to publish in the Al-Azhar Engineering Journal.

(b) **Faedah-faedah lain seperti perkembangan produk, pengkomersialan produk/pendaftaran paten atau impak kepada dasar dan masyarakat.**
State other benefits such as product development, product commercialisation/patent registration or impact on source and society.

This research is beneficial to water treatment specifically for dissolved air flotation process. The developed nozzle can be used to improve the performance of the saturator.

* Sila berikan salinan/*Kindly provide copies*

(c) **Latihan Sumber Manusia**
Training in Human Resources

i) Pelajar Sarjana: Hasmarini binti Muhammad
Graduates Students
(Perincikan nama, ijazah dan status)
(Provide names, degrees and status)

Ijazah Sarjana Muda Kejuruteraan (Awam)

Postgraduate Student

ii) Lain-lain: Nor Azalina binti Rosli (Final Year Student)
Others
Tan Bey Yee (Final Year Student)

9. Peralatan yang Telah Dibeli:
Equipment that has been purchased

1. Dissolved Oxygen Meter (DO Meter)
2. Air compressor
3. Zero Oxygen Solution

Tandatangan Penyelidik
Signature of Researcher

13 March 2008

Tarikh
Date

Komen Jawatankuasa Penyelidikan Pusat Pengajian/Pusat
Comments by the Research Committees of Schools/Centres

- Kajian amat berguna & boleh terus memperbaiki & sistem ini yg boleh dikomersialkan.
- Dicadangkan sesuatu untuk paten atau dan jika sesuai, diterbitkan. dlm jurnal berwasit
- Pendelanyaan melebihi bajet. Perlu ditampung melalui projek lain

Prof. Madya Dr. Ahmad Farhan Mohd Sadullah
Dekan
Pusat Pengajian Kejuruteraan Awam
Kampus Kejuruteraan
Universiti Sains Malaysia

TANDATANGAN PENGERUSI JAWATANKUASA PENYELIDIKAN PUSAT PENGAJIAN/PUSAT
Signature of Chairman
[Research Committee of School/Centre]

2/3/08.

Tarikh
Date

ABSTRACT

Dissolved air flotation (DAF) process becomes prominent in water treatment technology all over the world. This process had been well-accepted as an alternative for sedimentation due to its potential to remove very small or light particles in a shorter period, simplicity of the design and only required less area. One important element in DAF system is the saturator efficiency, which is important to improve the performance on water treatment. The purposes of this research are to develop a new sprayer nozzle for the unpacked saturator and to evaluate its performance in terms of saturator efficiency. This is essential to enhance the operation of the dissolved air flotation process since the necessity to have more air to be dissolved in water is crucial to attain a better efficiency. The nozzles were tested at various conditions and the parameters obtained are later used together with Mathcad program, which was developed concurrently, to find out the saturator efficiency as well as air precipitation efficiency. The results show that the efficiency of Nozzle 3 is outperformed other nozzles at almost all experimental conditions. The best efficiency is occurred at a flowrate of 5 LPM and a saturator pressure of 400 kPa which is 91.47%.

ABSTRAK

Proses pengapungan udara terlarut semakin meluas dalam aspek rawatan air di seluruh negara. Proses ini semakin diterima dengan baik sebagai satu alternatif kepada proses pemendapan kerana potensinya dalam menyingkirkan partikel-partikel yang kecil serta ringan, rekabentuknya yang ringkas dan hanya memerlukan kawasan yang kecil. Salah satu elemen utama dalam sistem pengapungan udara terlarut adalah kecekapan penepunya yang sangat penting dalam meningkatkan keupayaan dalam merawat air. Tujuan utama kajian ini dijalankan adalah untuk membangunkan muncung penyembur untuk penepu tidak padat dan menilai prestasinya dari aspek kecekapan penepu. Ini perlu untuk meningkatkan operasi bagi sistem pengapungan udara terlarut memandangkan pentingnya mendapatkan lebih banyak udara terlarut di dalam air. Muncung-muncung penyembur diuji pada keadaan yang berbeza–beza dan parameter yang diperolehi dimasukkan ke dalam program Mathcad untuk mendapatkan kecekapan penepu dan juga kecekapan udara tersebar. Keputusan yang diperolehi menunjukkan Muncung 3 memberi kecekapan yang lebih baik berbanding yang lain pada hampir semua keadaan ujian. Kecekapan penepu paling baik terhasil pada kadar 5 LPM dan tekanan penepu 400 kPa dengan nilai 91.47%.

TECHNICAL REPORT

1.0 Introduction

In dissolved air flotation (DAF) process, saturator efficiency is important in benchmarking the performance of the saturator and the overall process of water treatment. Higher saturator performance will reduce the recycle rate of the saturator and eventually reducing the overall energy consumption for the recycle system of the dissolved air flotation. Previous study has indicated that unpacked sprayer nozzle (SN) saturator gave higher performance than unpacked plate distributor (PD) saturator. The unpacked SN saturator efficiency has given better performance which is up to 81% compare to 39% by unpacked PD saturator.

This research is emphasized the development of an appropriate sprayer nozzle to be used in unpacked saturator. This is very important because the need to have more air to be dissolved in the water body injected from the sprayer nozzle. The research was conducted in laboratory to evaluate the performance of the unpacked saturator in terms of saturator efficiency. The results obtained are later compared to the performance of the commercial nozzle.

2.0 Objectives

The main objectives of this research are:

1. To identify and develop an appropriate sprayer nozzle of the unpacked saturator for dissolved air flotation process.
2. To investigate the saturator and air precipitation efficiency.
3. To study the saturator performance using developed sprayer nozzle.

3.0 Methodology

The methodology of the research is divided into two experimental works. The first works are focused on the development of the dissolved air flotation system at laboratory scale, the setting up of the measuring unit for saturator efficiency

measurement and the development of Mathcad program. Before, the actual experiments were done, the performance of the system was checked by performing trial runs. The experiments were proceed after the system was satisfied.

The second works involved the development of the sprayer nozzle and laboratory works to obtain the required parameters to be used together with Mathcad program. The works later continued with the calculation procedures and the statistical analysis on the data.

The experiments were undertaken at different saturator pressures and flowrates. The saturator pressure varies from 400 kPa to 600 kPa and the flowrates were taken at 4 LPM, 5 LPM and 6 LPM. Therefore, each nozzle was tested for nine sets of experiments and each set is consisted 15 readings.

4. 0 Results and Discussion

The tables below give the results of the saturator efficiency and air precipitation efficiency for each nozzle. Nozzle 1 is the commercial nozzle. Nozzle 2 and Nozzle 3 are the developed nozzles as showed in Figure 1 and Figure 2. By referring to Table 1, the saturator efficiency for Nozzle 1 gives the highest result at 6 LPM and 400 kPa which is 78.39%. The air precipitation efficiencies vary from 78.62% to 91.33%.

Table 1: Results of the saturator efficiency and air precipitation efficiency for Nozzle 1

Saturator pressure (kPa)	Flowrate (LPM)	Saturator efficiency (%)	Air precipitation efficiency (%)
400	4	77.08	78.62
500	4	65.53	86.39
600	4	53.94	81.47
400	5	75.72	79.29
500	5	71.40	81.69
600	5	56.50	91.33
400	6	78.39	89.49
500	6	74.64	82.06
600	6	66.32	82.53

Table 2 gives the results of the saturator efficiency and air precipitation efficiency for Nozzle 2. The saturator efficiency is ranging from 54.66% to 91.56%. The highest value occurred at 4 LPM at 400 kPa. The air precipitation efficiency for each experiments set is not significantly different.

Table 2: Results of the saturator efficiency and air precipitation efficiency for Nozzle 2

Saturator pressure (kPa)	Flowrate (LPM)	Saturator efficiency (%)	Air precipitation efficiency (%)
400	4	91.56	86.46
500	4	79.67	86.23
600	4	67.82	88.44
400	5	80.88	88.69
500	5	73.53	89.41
600	5	56.98	85.15
400	6	74.32	88.64
500	6	83.81	82.95
600	6	54.66	89.27

Table 3 below gives the results for Nozzle 3. The highest saturator efficiency occurred at 5 LPM and 400 kPa which is 91.47%.

Table 3: Results of the saturator efficiency and air precipitation efficiency for Nozzle 3

Saturator pressure (kPa)	Flowrate (LPM)	Saturator efficiency (%)	Air precipitation efficiency (%)
400	4	91.03	90.65
500	4	81.63	90.83
600	4	69.61	90.42
400	5	91.47	88.97
500	5	76.12	90.21
600	5	65.28	88.66
400	6	81.13	90.38
500	6	68.71	89.98
600	6	57.68	90.94

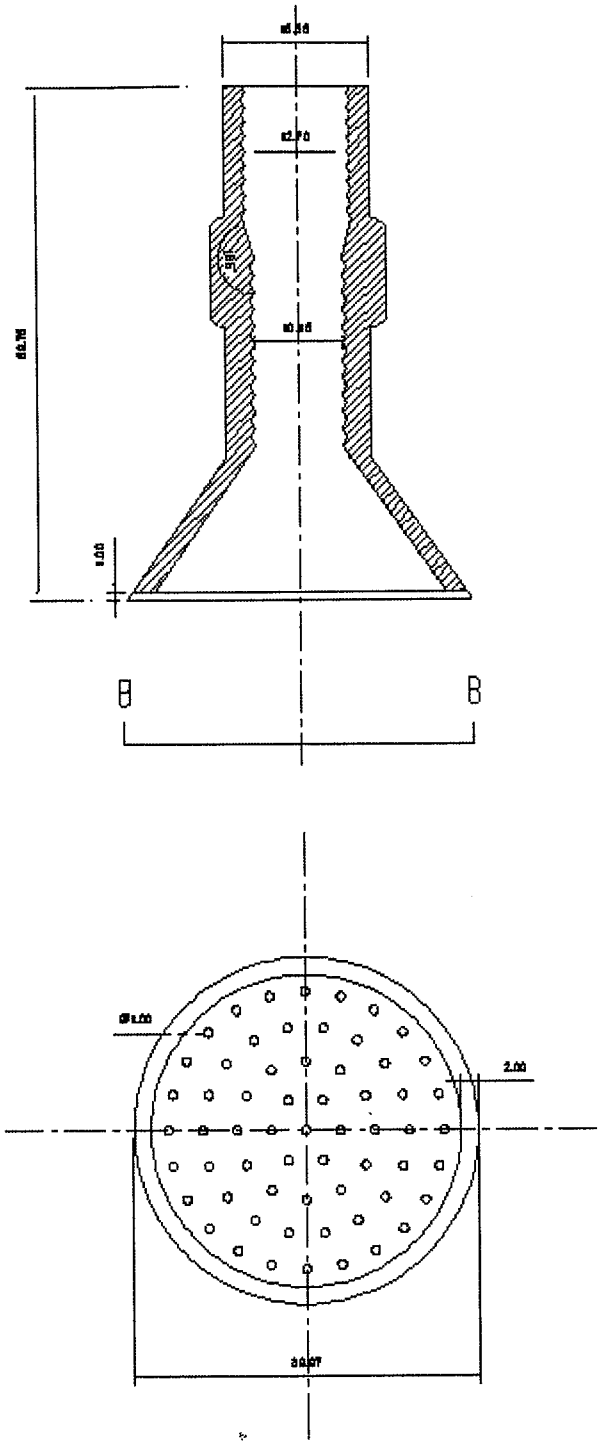


Figure 1: Schematic of nozzle 2

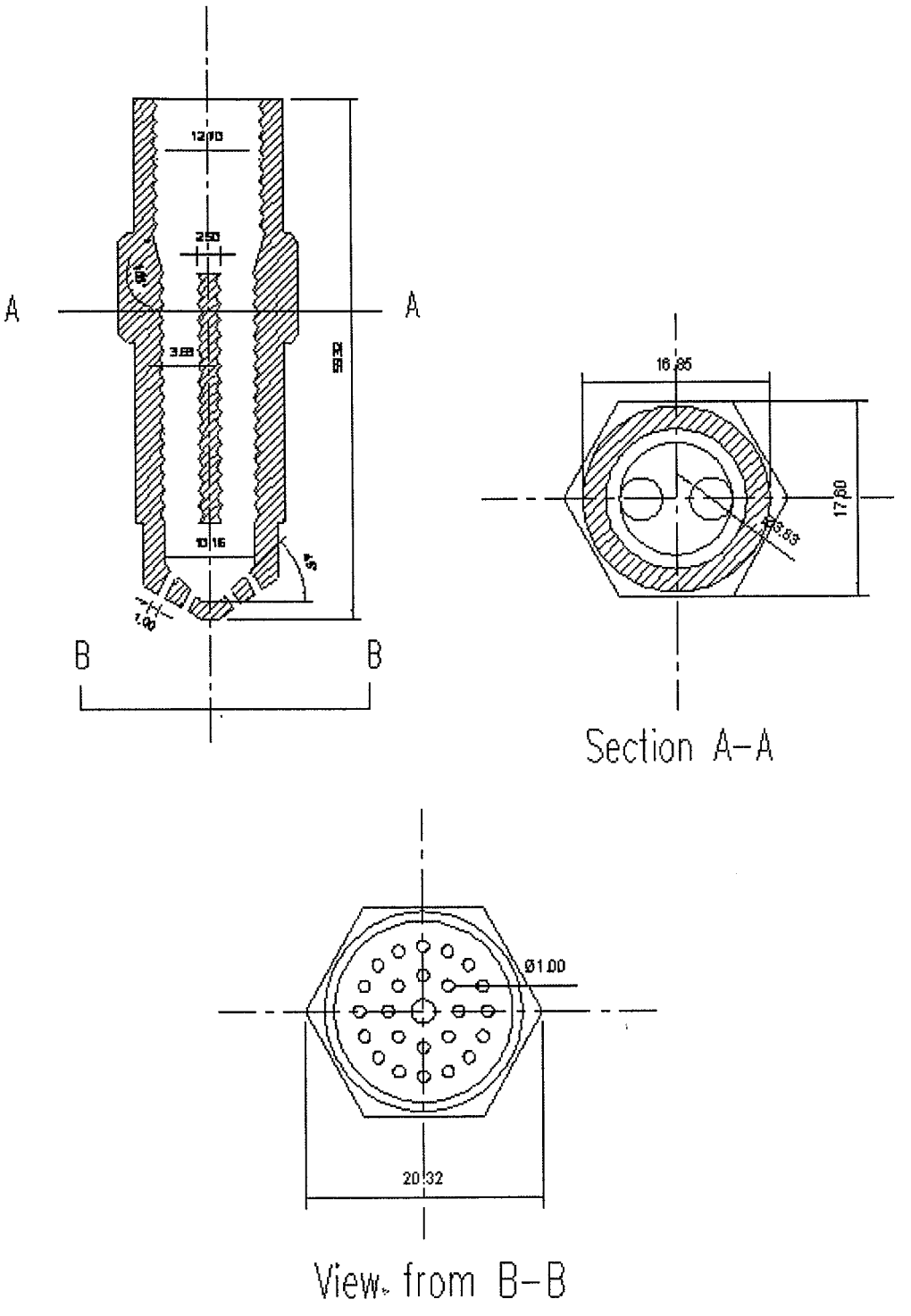
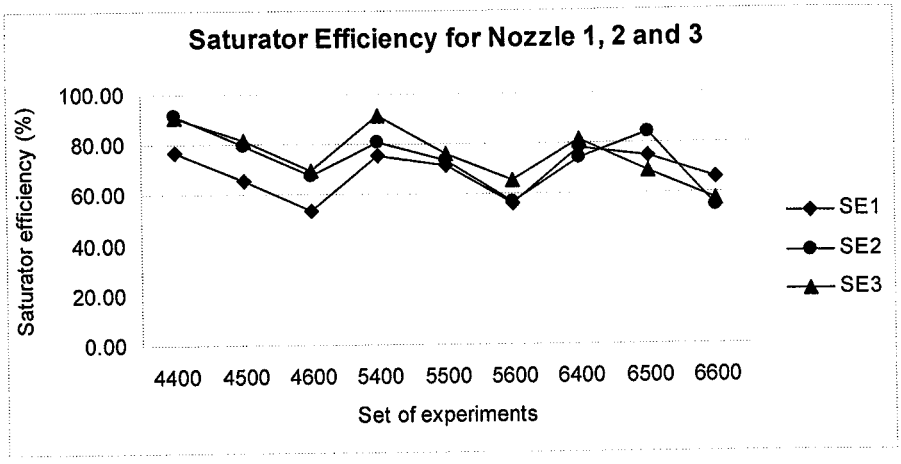


Figure 2: Schematic of nozzle 3

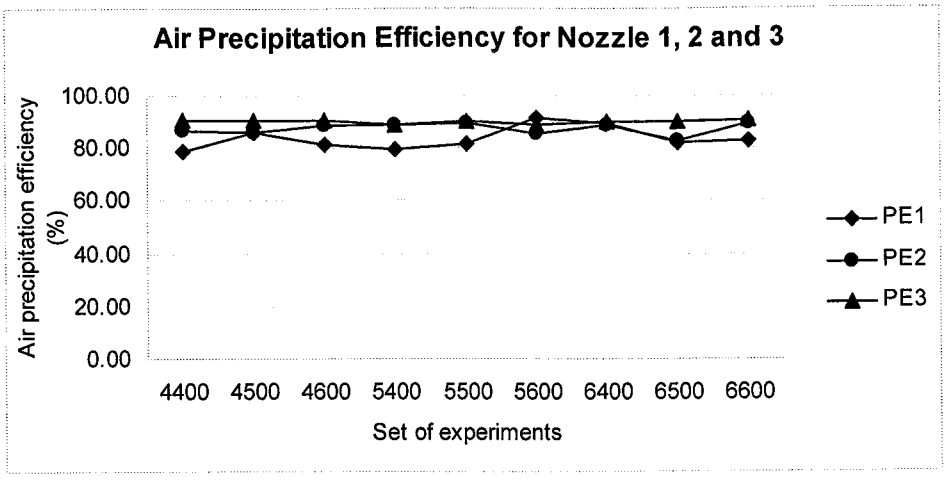
Figure 3 shows the graph for saturator efficiency of each nozzle. The graph indicates that the saturator efficiency is decreased when the saturator pressure is increased. This pattern is almost similar for every nozzle. Nozzle 3 gives better efficiency than other nozzles at almost all experimental conditions. Nozzle 1 only gives the higher efficiency at one condition which is at 6 LPM 500 kPa.



Note: For x-axis, 4400 = 4 LPM at 400 kPa
SE1 = saturator efficiency for Nozzle 1
SE2 = saturator efficiency for Nozzle 2
SE3 = saturator efficiency for Nozzle 3

Figure 3: Graph of the saturator efficiency for nozzle 1, 2 and 3.

On the other hand, the precipitation efficiency for each nozzle does not differ too much. The efficiency is approximately same for all conditions, however the air precipitation produced by Nozzle 3 slightly higher than other nozzles. Thus the results from this research conclude that the developed Nozzle 3 has outperformed commercial nozzle in terms of saturator efficiency as well as air precipitation efficiency.



Note: For x-axis, 4400 = 4 LPM at 400 kPa
PE1 = air precipitation efficiency for Nozzle 1
PE2 = air precipitation efficiency for Nozzle 2
PE3 = air precipitation efficiency for Nozzle 3

Figure 4: Graph of the air precipitation efficiency for nozzle 1, 2 and 3.

5.0 Conclusion

The results indicated that the saturator efficiency is higher when the applied saturator pressure is lower and the air precipitation efficiency for each nozzle does not differ too much. The saturator efficiency of Nozzle 3 gives better efficiency at almost all conditions compared to Nozzle 1 and 2. Nozzle 1 (commercial nozzle) appears to produce better efficiency than other nozzles at 6 LPM and 600kPa only, however higher pressure is no economical in terms of energy. Nozzle 2 outperformed Nozzle 3 at 4 LPM 400 kPa (saturator efficiency for Nozzle 2 and 3 are 91.56% and 91.03%) and 6 LPM 500 kPa (saturator efficiency for Nozzle 2 and 3 are 83.81% and 68.71%). However the difference in saturator efficiency between Nozzle 2 and 3 at 4 LPM and 400 kPa is not significant. Again for the rate of 6 LPM at 500 kPa the performance of Nozzle 2 could be considered not economical in terms of energy consumption.

It can be concluded that from the current research on nozzle development for the saturator, the utilization of the fund has achieved its objective. The nozzle may become a show case for the next exposition on technological innovative and development.

ORIGINAL PROJECT SCHEDULE

Activity	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Design of sprayer nozzles for the saturator												
2. Produce fabrication drawing and fabrication of sprayer nozzles												
3. Developed computer program using Mathcad to solve air mass transfer equations based on the work of Steinbach and Haarhoff (1997)												
4. Testing on the performance of different design of sprayer nozzles in the laboratory												
5. Data collection and data input to the developed program. This includes data analyses.												
6. Preparing of papers to be published												
7. Final report												

REVISED PROJECT SCHEDULE

ACTIVITY	MONTH (October 2005 to March 2008)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24	26	28	30
1. Literature reviews on dissolved air flotation																								
2. Setting up the equipments for saturator efficiency measurement																								
3. Developed computer program using Mathcad to solve air mass transfer equations based on the work of Steinbach and Haarhoff (1997)																								
4. Testing and checking the performance of saturator and measuring apparatus																								
5. Design of sprayer nozzles for the saturator																								
6. Produce fabrication drawing and fabrication of sprayer nozzles																								
7. Testing on the performance of different design of sprayer nozzles in the laboratory																								
8. Data collection and data input to the developed program. This includes data analyses.																								
9. Preparing of papers to be published																								
10. Final report																								

JUMLAH GERAN :- 18,400.00

NO PROJEK :-

PANEL :- J/PENDEK

PENAJA :- JANGKA PENDEK

PENYATA KUMPULAN WANG

TEMPOHBERAKHIR 29/02/2008

Tempoh Projek:01/10/2005 - 30/09/2007

DEVELOPMENT OF SPRAYER NOZZLE OF THE SATURATOR FOR DISSOLVED AIR FLOTATION PROCES

Vot	Peruntukan (a)	Perbelanjaan sehingga 31/12/2007 (b)	Tanggungan semasa 2008 (c)	Perbelanjaan Semasa 2008 (d)	Jumlah Perbelanjaan 2008 (c + d)	Jumlah Perbelanjaan Terkumpul (b+c+d)	Baki Peruntukan Semasa 2008 (a-(b+c+d)
11000: GAJI KAKITANGAN AWAM	8,580.00	6,723.88	0.00	1,219.65	1,219.65	7,943.53	636.47
21000: PERBELANJAAN PERJALANAN DAN SARAHI	1,920.00	2,049.40	0.00	0.00	0.00	2,049.40	(129.40)
23000: PERHUBUNGAN DAN UTILITI	300.00	21.95	0.00	0.00	0.00	21.95	278.05
24000: SEWAAN	1,700.00	0.00	0.00	0.00	0.00	0.00	1,700.00
26000: BAHAN MENTAH & BAHAN UNTUK PENYELE	1,500.00	1,542.90	0.00	0.00	0.00	1,542.90	(42.90)
27000: BEKALAN DAN ALAT PAKAI HABIS	0.00	6,178.70	0.00	229.90	229.90	6,408.60	(6,408.60)
28000: PENYELENGGARAAN & PEMBAIKAN KECIL	1,400.00	630.00	0.00	0.00	0.00	630.00	770.00
29000: PERKHIDMATAN IKTISAS & HOSPITALITI	3,000.00	935.10	0.00	37.70	37.70	972.80	2,027.20
35000: HARTA-HARTA MODAL LAIN	0.00	2,300.00	0.00	0.00	0.00	2,300.00	(2,300.00)
	18,400.00	20,381.93	0.00	1,487.25	1,487.25	21,869.18	(3,469.18)
Jumlah Besar	18,400.00	20,381.93	0.00	1,487.25	1,487.25	21,869.18	(3,469.18)