CUTC

Canadian
Universities
Technology
Consortium

THAI-CANADIAN HRD PROJECT
CUTC-SUT INSTITUTIONAL LINKAGE PROJECT
CIDA PROJECT # 906/14868

ANNUAL PROGRESS

AND

FINANCIAL REPORT

APRIL 1, 1996 to MARCH 31, 1997

Submitted to:
The ARA Consulting Group Inc.
April 1997

Prepared by:
Ryerson International

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INTERNATIONAL

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ANNUAL PROGRESS
Reporting Semi-Annually
AND

FINANCIAL REPORT

Linkage Project Title:	***Institutional Linkage Project***
Canadian Partners:	***Ryerson Polytechnic University (Canadian Lead Partner)***
	Guelph University
	University of Waterloo
	Technical University of Nova Scotia
Thai Partners:	***Suranaree University of Technology***
Project No.:	***906/14868***

Report

Covering the Period
April 1, 1996 to March 31, 1997

Submitted to ARA
April 1997

by

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PART 1

1.1 PROJECT SUMMARY

1. **Project Start:** July 15, 1993 **Finish:** March 31,1998

   CIDA Contribution: $ 995,484

2. **Summary of Project Management**

- Semi-Annual and Financial reports for the period April 1 to September 30, 1996 were produced and submitted to the ARA Consulting Group.

- Dr. Stalin Boctor, Technical Advisor to the Canadian Project Implementation Unit met with SUT academic administrators to discuss a number of issues related to the CUTC-SUT International Engineering and Applied Science program, as well as various project management matters in February, 1997. See Appendix , "SE Asia Deans of Engineering Conference and Mini-PRC (SUT/CUTC) February 10-14, 1997.

- Ryerson International (Dr. Sam Mikhail, Dr. Stalin Boctor) met with Roger Griffin, ARA, to discuss the implications of government funding cutbacks to SUT in terms of the planning, implementation and delivery of the remaining project activities. ARA acknowledged the challenges faced by other Thai universities, given government cutbacks. ARA, in principle, agreed that the project could cover key activities that could be implemented before March 31, 1998 which would support the goals of sustainability and mutual benefits.

- SUT advised CUTC at the Mini-PRC in February of government budget cutbacks of 15% for 1997 resulting in SUT's inability to financially support project activity. The remainder of the IUP program curriculum scheduled to be delivered in Thailand is now cancelled. (3rd Trimester, 4 teaching assignments) Curriculum for the Food Technology Program remains as planned for September 1997.

- The 4th Project Review Committee (PRC) meeting was held in Halifax at the Technical University of Nova Scotia (DalTech) on April 3 and 4, 1997. The 4th PRC determined specific activity which can be achieved through the support of project funds and consistent with the overall goals of sustainability.. A copy of the minutes is attached in Appendix .

- The 5th PRC meeting is scheduled for January 12-13, 1998 at SUT, Thailand.

3. Progress and Achievement to Date

a) Accomplishments
Through liaison with SUT, CUTC partners, and the ARA Consulting Group, the CUTC Project Implementation Unit has planned, implemented and evaluated the following activities in Program 2 and 3.

Program 2: International Academic Programs

Activity A2.11: Academic Program Planning

Dr. Stalin Boctor, Technical Advisory to the Canadian Project Implementation Unit met with SUT academic administrators for a Mini-Project Planning and Review Meeting February 12, 1997 to discuss a number of issues related to the CUTC-SUT International Engineering and Applied Science program. *(Appendix A)*

Details of these activities are provided in Part 2 of this report.

Program 3: University-Industry Linkage Program

Three seminar assignments for Canadian consultants were reconfirmed. SUT and the CUTC will be organizing the seminars during the 1997/98 final year of the project.
(See Appendix G: PRC meeting, Halifax, April 1997)

Program 4: Project Management

A4.32 Ten CUTC-SUT members participated in the Project Review Committee meeting held at TUNS on April 3 and 4, 1997. Dr. Tavee Lertpanyavit, Dr. Pongchan Na-Lampang, and Ms. Mantana Thammachoit participated from SUT. Dr. Bill Caley, Robert Eagle Feridun Hamdullahpur from Technical University of Nova Scotia and Dr. Gerry Schneider from University of Waterloo, and Dr. Jim Shute, University of Guelph, Dr. Stalin Boctor and Mary Jane Curtis were CUTC's official representatives at the meeting.

b) Schedules
Based on the decisions taken in April at the 4th PRC meeting in Halifax, SUT and CUTC partners, the Canadian Project Implementation Unit has decided to cancel the IUP Program based on budget restraints. Project funding has therefore been re-allocated to support new activities as follows: *(See Appendix E - Dr. S. Boctor letter to ARA, project status)*

A 2.4 Workshop on Postgraduate Engineering Prams and Quality Control
proposed for November 10-12, 1997, 7 Canadian consultants

A 2.5 Academic Research Exchange for Thai Faculty
5 Thai faculty to Canada, two-week programs
to be completed by December 1997

c) Expenditures
For the period October 1 to March 31, 1997 $128,658 was budgeted to support the implementation of proposed project activities. Funds expended totalled $ 95,085.

4. Progress Toward Achieving Project Objectives and Deliverables

a) Reached
The CUTC -SUT Institutional Linkage Project is currently in the 11th quarter of the project. As of March 31, 1996 the following deliverables have been completed:

- Activity A 2.11b — S.E. Asia Deans of Engineering, Feb 10-14, 1997 By 4 CUTC participants
- Activity A 2.21 — Ph.D. candidates and Advisors selected by Canadian Members
- Activity A 2.26 — 2 Thai Advisor visits to Canada
- Activity A 2.31a. — Work Placements in Canada, for 4 Thai Students
- Activity A4.21d — Canadian Management Team and Project Implementation Unit (Year 4)
- Activity A 4.32 — Project Review Committee meeting in Waterloo (October 1996) and in Halifax, Canada, April 1997.

b) Scheduled - *See Appendix F, Dr. Boctor's April 22 letter to ARA, for details*

- Activity A 2.23 — Ph.D Research, 1 assignment October 1997
- Activity A 2.25 — Post Doctoral Research Fellowships 1 additional fellow, May-June 1997
- Activity A 2.32b — Work Placements - Canada, 1 additional student, activity to be completed in September 1997
- Activity A 3.23 — Industrial Seminars by Canadian Consultants 3 industrial seminars to be completed by March 98

New Activities Proposed:

- Activity A 2.4 — Workshop for Postgraduate Engineering Programs Development and Quality Control, 7 Canadian consultants, November 1997.
- Activity A 2.5 — Academic Research Exchange for Thai Faculty, 5 Thai faculty members for 2 week visits to be completed by December 1997.

Can ARA Help?
No assistance from ARA is requested at this time.

PART 2

2.1 REPORT ON PROJECT MANAGEMENT

2.1.1 Project Managers

Canada: Professor Samih Mikhail, Director, Ryerson International, Ryerson Polytechnic University, Canada

Thailand: *Dr.Tavee Lertpanyawit, Vice Rector, Academic Affairs, Suranaree University of Technology, Thailand
** effective October 1, 1996*

2.1.2 Project Management Issues/Concerns/Problems and the Actual or Proposed Solutions

The Project Review Committee Meetings have provided the opportunity for the project partners to meet at SUT to review progress to date within the project, and facilitated discussions between the new SUT project management and implementation teams, and CUTC members.

2.1.3 Sustainable Institutional Relationship

CUTC and SUT have developed strategies within the project to support sustainable linkages once CIDA funding ends. Examples of this are the Joint PhD and Program Development for International Engineering and Applied Science programs. The important issue at this stage of the project is to ensure that the appropriate foundations are laid for the sustainability of these programs.

2.2 REPORT ON PROJECT DELIVERABLES

Deliverable No: A2.11 b **Deliverable Title: Academic Program Planning**

Narrative

Four Canadian CUTC representatives presented papers at the S.E. Asia Deans of Engineering Conference held at SUT February 11-14 1997. The CUTC representatives also attended the Mini-PRC meeting on February 12, 1997 which is referred to under Project Management (*Appendix A - Papers*)

Activity Planned Next Quarter

Activity completed. No activity scheduled for next quarter.

Anticipated Challenges

There are no major challenges anticipated.

Progress Toward Completion

This activity is now complete

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Deliverable No: A2.21 **Deliverable Title: Selection of Thai Supervisors and Ph.D. students by Canadian Faculty Members**

Narrative

At present, three SUT faculty members are Ph.D. candidates at TUNS, one in Industrial Engineering, one in Electrical Engineering and one in Chemical Engineering. Two more SUT faculty members have been chosen as Ph.D. candidates and are expected to arrive at TUNS by September 1997, one in electrical Engineering and one in Civil Engineering. Only the Ph.D. candidate in Chemical Engineering has co-supervisors at TUNS and at SUT. No further activities are expected this deliverable.

Progress Toward Completion

completed

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Deliverable No: A 2.26 **Deliverable Title: Thai Advisors visits to Canada**

Narrative
Dr. Kontorn Chammiprasart and Mr. Rawat Vipia .
University of Waterloo: November 4-8, 1996
Dr. Kontorn was given an overview of the faculties and laboratories in the Mechanical Engineering Department, including: wind tunnel, heat trans, fluid mechanics, robotics and library. Dr. Kontorn was provided with the undergraduate manual for the 3B academic term. Mr. Rawat meeting eith personnel from the Electrical and Computer Enginering Department. His key area of interest was in special constructions requirements for a high voltge lab for undergraduate and graduate study research. *(Appendix B, Reports)*

Activity Planned During Next Quarter
None

Anticipated Challenges
None

Progress Toward Completion
Activity completed

Changes in the Status in the Next Quarter
Not applicable

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Deliverable No: A 2.31a **Deliverable Title:** **Co-op 16-week Program for Thai Students in Canada**

Narrative
4 Student have completed their programs. 2 at the University of Guelph and 2 at TUNS

Podjana Chumkhunthod, and Piyachat Sintudeacha School of Food Technology, Institute of Agricultural Technology, SUT - assignment at University of Guelph, June-December 1996

Hathaikarn Nilawat, School of Technology of Resources, Chemical Engineering, September to December, 1996, TUNS. Program: Literature search, data analysis, presentation and experimental investigation of dynamic surface tension of industrial streams. Academic Supervisor: Dr. Al Taweel, TUNS,

Mr. Atit Koonsruisk, SUT, Co-operative Education: 4 month assignment, September to December 1996, Department of Mechanical Engineering, Supervised by Dr. Feridun Hamdullahpur in the Two-Phase Flow Research Laboratory at TUNS in the area of "Fluidization".

See Appendix C - four reports

Activity Planned During next Period
Activity A 2.31 b to be completed in December 1997

Anticipated Challenges
None

Progress Toward Completion
Activity completed

Changes in the Status in the Next Quarter
Not applicable

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Deliverable No: A 2.32 b) **Deliverable Title: Co-op Program in Thailand for Canadian students - 16 week program**

Narrative
Mr. John Soehl, Mechanical Engineering, Computer Applications, TUNS: Completed his Assignment at Babcock Hansa, Khorat, September - December, 1996.
One student from Food Science at Guelph is currently engaged in co-op placement in thailand, and one additional Food Science students from Guelph has an approved co-op assignment starting in May 1997.

Activity Planned During Next Quarter
Two additional students, 1 from Guelph and 1 from TUNS are scheduled for 16 week work placements in Thailand from May to August, 1997

Progress Toward Completion
Assignments will be completed by September 1997

Changes in the Status in the Next Quarter
One additional Canadian students was added to the budget. Total number of co-op placements in this deliverable has been changed from 4 to 5 assignments as agreed with the CUTC-SUT partners

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Deliverable No: A4.11 **Deliverable Title: Thai Project Implementation Unit**

Narrative
There has been a change in the project manager for the Thai management team. Dr. Tavee Lertpanyavit Vice Rector for Academic Affairs, SUT, has been appointed Project Manager. Dr. Tavee was able to participate in the April 1997 4th PRC meeting. He was involved in the early stages of the project and brings that knowledge to the position to provide continuity and direction.

SUT submitted a Semi-Annual Report for the period July-December 1997. *(See Appendix G*)

Activity Planned During Next Six-Months:
Joint planning with the Canadian management team to implement the project activities scheduled for the next six months.

Anticipated Challenges
No anticipated challenges at this time.

Progress Toward Completion
Ongoing for life of project.

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Deliverable No: A4.21d **Deliverable Title: Canadian Management Team and Project Implementation Unit**

Narrative
In consultation with CUTC institutions, SUT and ARA, the CUTC project implementation unit designed, implemented and evaluated the various project activities and deliverables.

On February 12, 1997 a Mini-PRC meeting was held at SUT and attended by 4 CUTC representatives to discuss the progress of the project. SUT indicated that the 15% government budget cutback for the current year would affect their ability to support the scheduled project activities, particularly with respect to the IUP Program. Four teaching assignments (Third Trimester/SUT) in Electrical Engineering scheduled from May-September were cancelled. A meeting was called by the Canadian CUTC partners on March 11, 1997 at Ryerson Polytechnic University, Ryerson International to discuss strategies and solutions. Dr. Sam Mikhail, Project Manager and Dr. Stalin Boctor, Program Manager, met with R. Griffin, ARA, to advise of the constraints faced by SUT and to determine what future activities could be supported by the remaining project funds.

The required Semi-Annual progress and financial reports were submitted to ARA.

Anticipated Challenges
None

Progress Toward Completion
On target according to the project plan

Changes in the Status in the Next Quarter
None.

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Deliverable No: A 4.32 **Deliverable Title: Project Review Committee, Canada**

Narrative
Ten CUTC-SUT members participated in the Project Review Committee meeting held at TUNS on April 3 and 4, 1997. Dr. Tavee Lertpanyavit, Dr. Pongchan Na-Lampang, and Ms. Mantana Thammachoit participated from SUT. Dr. Bill Caley, Robert Eagle Feridun Hamdullahpur from Technical University of Nova Scotia and Dr. Gerry Schneider from University of Waterloo, and Dr. Jim Shute, University of Guelph, Dr. Stalin Boctor and Mary Jane Curtis were CUTC's official representatives at the meeting. (See Appendix G - PRC minutes)

Activity Planned During Next Quarter
None

Progress Toward Completion
Completed according to the project plan

Changes in the Status in the Next Quarter
5th PRC meeting schedule at SUT, January 12, 13, 1998, under deliverable A 4.311

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2.3 FINANCIAL REPORTS

2.3.1 FINANCIAL REPORTS

FOR

CIDA FUNDED EXPENDITURES

THAI CANADIAN HRD PROJECT
Linkage - CUTC & SUT
Project #L3004-91063
CIDA #906-14868

CIDA FUNDED EXPENDITURES
Contract Summary
As at March 31, 1997

	1993/94 Actual	1994/95 Actual	1995/96 Actual	1996/97 Actual	1997/98 Budget	Total Actual/Budget	Contract Value	Variance
Program 1								
Fees	22,190	27,540	23,532	45,380		118,642	118,642	0
Travel	34,921	24,815	42,580	19,300		121,616	121,616	0
Other	0					0	0	0
Subtotal	**57,111**	**52,355**	**66,112**	**64,680**	**0**	**240,258**	**240,258**	**0**
Program 2								
Fees		3,600	5,400	25,320	39,600	73,920	73,920	0
Travel		3,662	11,187	103,553	138,926	257,328	257,328	0
Other		0		4,640	7,222	11,862	11,862	0
Subtotal	**0**	**7,262**	**16,587**	**133,513**	**185,748**	**343,110**	**343,110**	**0**
Program 3								
Fees		0	2,700	12,600	4,500	19,800	19,800	0
Travel		0	4,534	28,175	15,100	47,809	47,809	0
Other		0				0	0	0
Subtotal	**0**	**0**	**7,234**	**40,775**	**19,600**	**67,609**	**67,609**	**0**
Program 4								
Fees	34,320	35,759	37,561	34,416	45,202	187,258	187,258	0
Travel	2,488	11,895	19,597	38,144	63,899	136,023	136,023	0
Other	746	1,672	914	4,121	13,773	21,226	21,226	0
Subtotal	**37,554**	**49,326**	**58,072**	**76,681**	**122,874**	**344,507**	**344,507**	**0**
Total	**94,665**	**108,943**	**148,005**	**315,649**	**328,222**	**995,484**	**995,484**	**0**

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THAI CANADIAN HRD PROJECT
Linkage - CUTC and SUT
Project #L3004-91063
CIDA #906-14868

CIDA FUNDED EXPENDITURES
Deliverable Status
As at March 31, 1997

Deliverable	Current Half Year Actual Oct-Mar/97	Current Half Year Budget Exp. Oct-Mar/97	Current Half Year Variance	Project to Date Actual Exp. to Mar 31/97	Project to Date Budget Exp. to Mar 31/97	Project to Date Variance	Estimated Expenditures to Completion	Delivery Completed
1. Institutional Capacity Building Program								
A1.11a) Training Academic Administrators (4)	0	0	0	36,789	36,789	0	0	Mar/95
A1.11b) Training Academic Administrators (1)	0	0	0	5,276	5,276	0	0	May/95
A1.21 Training Faculty Members	0	0	0	50,524	50,524	0	0	May/95
A1.31 Training Support Personnel	0	0	0	81,557	93,164	11,607	0	Oct/96
A1.32 Institutional Support Services	0	0	0	8,936	14,949	6,013	0	Oct/96
A1.41 Evaluate ESL Needs	0	0	0	9,095	9,095	0	0	Dec/93
A1.42 Study Tour ESL	0	0	0	16,581	16,581	0	0	Feb/94
A1.5 CUTC Additional Mgt Activities	0	0	0	31,500	31,500	31,500	0	Apr/96
Program 1 Sub-total	**0**	**0**	**0**	**240,258**	**257,878**	**49,120**	**0**	
2. International Academic Program								
A2.11a) Academic Program Planning	0	0	0	24,172	37,512	13,340	0	Oct/96
A2.11b) Academic Program Planning	16,709	0	(16,709)	16,709	0	(16,709)	0	Apr/97
A2.11c) Academic Program Planning	0	0	0	0	0	0	21,681	
A2.12a) Curriculum Implementation	0	19,200	19,200	21,840	25,600	3,760	0	Oct/96
A2.12b) Curriculum Implementation	0	0	0	0	19,200	19,200	0	Cancelled
A2.12c) Curriculum Implementation	1,695	0	(1,695)	1,695	0	(1,695)	3,005	
A2.12d) Curriculum Implementation	0	0	0	0	0	0	12,800	
A2.21 Selection Supervisors/PHD	4,600	0	(4,600)	15,835	10,637	(5,198)	0	Apr/97
A2.23 Ph.D Research	0	0	0	0	0	0	6,900	
A2.25 Post Doct. Research Fellowships	8,338	20,000	11,662	25,038	20,000	(5,038)	34,762	
A2.26 Thai Advisors visit to Canada	8,073	5,000	(3,073)	8,073	5,000	(3,073)	0	Apr/97
A2.27 Collaboration co-supervisors		5,670	5,670		7,560	7,560	0	Cancelled
A2.31a) Work Placements - Canada	8,000	8,000	0	16,000	8,000	(8,000)	0	Apr/97
A2.31b) Work Placements - Canada	4,000	0	(4,000)	4,000	8,000	4,000	12,000	
A2.32a) Work Placements - Thailand	0	16,000	16,000	16,000	16,000	0	0	Oct/96
A2.32b) Work Placements - Thailand	8,000	0	(8,000)	8,000	16,000	8,000	12,000	
A2.4 Workshop-Post-grad. Eng Prog/Control	0	0	0	0	0	0	51,100	New
A2.5 Academic Research Ex. Thai Faculty	0	0	0	0	0	0	31,500	New
Program 2 Sub-total	**59,415**	**73,870**	**14,455**	**157,362**	**173,509**	**16,147**	**185,748**	
3. University-Industry Linkage Program								
A3.11 Training Co-op Program	0	0	0	7,234	7,234	0	0	May/95
A3.21 Industrial Training Framework	0	0	0	3,775	3,400	(375)	0	Oct/96
A3.22 Training Seminars by Canadian Consult.	0	0	0	33,225	31,350	(1,875)	0	Oct/96
A3.23 Additional Ind. Seminars in Thailand	0	0	0	0	0	0	19,600	
A3.31 Monitor Co-op Students	0	3,400	3,400	3,775	3,400	(375)	0	Oct/96
Program 3 Sub-total	**0**	**3,400**	**3,400**	**48,009**	**45,384**	**(2,625)**	**19,600**	
4. Project Management								
A4.21a) Canadian Management Team -yr 1	0	0	0	34,320	34,320	0	0	Mar/95
A4.21b) Canadian Management Team -yr 2	0	0	0	35,759	35,759	0	0	Mar/95
A4.21c) Canadian Management Team -yr 3	0	0	0	32,881	32,881	0	0	Mar/96
A4.21d) Canadian Management Team -yr 4	16,848	18,105	1,257	34,416	36,210	1,794	0	Mar/97
A4.21e) Canadian Management Team -yr 5	0	0	0	0	0	0	38,002	
A4.31 Project Review Committee - Thai	0	0	0	22,298	22,298	0	0	Dec /95
A4.311 Project Review Committee - Thai	0	0	0	0	0	0	25,560	
A4.32 Project Review Committee- Can	10,225	14,100	3,875	24,491	28,200	3,709	0	Apr/97
A4.33a) Project Management	0	0	0	24,144	26,957	2,813	0	Oct/96
A4.33b) Project Management	5,873	14,435	8,562	5,873	14,435	8,562	20,539	
A4.33c) Project Management	0	0	0	0	0	0	25,000	
A4.41 Communication/Support	2,724	4,748	2,024	7,451	12,827	5,376	13,773	
Program 4 Sub-total	**35,670**	**51,388**	**15,718**	**221,633**	**243,887**	**22,254**	**122,874**	
Total	**95,085**	**128,658**	**33,573**	**667,262**	**720,658**	**84,896**	**328,222**	

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THAI CANADIAN HRD PROJECT
PROJECT #L3004-91063
CIDA#906-14868

CIDA FUNDED EXPENDITURES
Forecast of Expenditures
As at March 31,1997

	Actual 1993/97	Budgeted 1997/98			Forecast 1998/99	Total Actual/ Budgeted	Total Contract	Variance
		1st Half Apr-Sept97	2nd Half Oct-Mar98	Total Apr-Mar98				
Program 1								
Fees	118,642			0		118,642	118,642	0
Travel	121,616			0		121,616	121,616	0
Other				0		0		0
Subtotal	240,258	0	0	0	0	240,258	240,258	0
Program 2								
Fees	34,320	14,700	24,900	39,600		73,920	73,920	0
Travel	118,402	56,611	82,315	138,926		257,328	257,328	0
Other	4,640	4,360	2,862	7,222		11,862	11,862	0
Subtotal	157,362	75,671	110,077	185,748	0	343,110	343,110	0
Program 3								
Fees	15,300	3,000	1,500	4,500		19,800	19,800	0
Travel	32,709	10,067	5,033	15,100		47,809	47,809	0
Other				0		0	0	0
Subtotal	48,009	13,067	6,533	19,600	0	67,609	67,609	0
Program 4								
Fees	142,056	22,601	22,601	45,202		187,258	187,258	0
Travel	72,125	31,949	31,950	63,899		136,024	136,024	0
Other	7,452	6,887	6,886	13,773		21,225	21,225	0
Subtotal	221,633	61,437	61,437	122,874	0	344,507	344,507	0
Total	667,262	150,175	178,047	328,222	0	995,484	995,484	0

04/22/97

Table 1(b)

THAI CANADIAN HRD PROJECT

PROJECT IMPLEMENTATION SCHEDULE

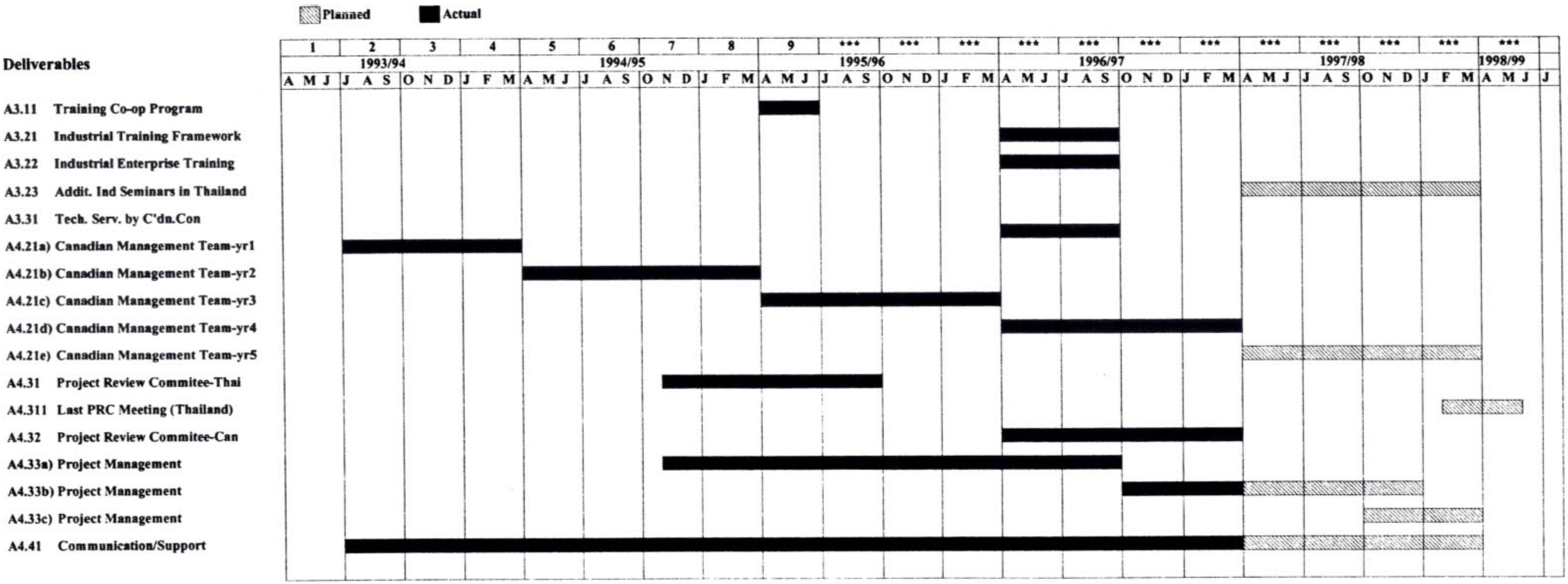
LINKAGE -CUTC & SUT
PROJECT NUMBER - L3004
START: JULY 15/93 fINISH : MARCH 31/98

PRIMSCH1.WK4

THAI CANADIAN HRD PROJECT

PROJECT IMPLEMENTATION SCHEDULE

LINKAGE -CUTC & SUT
PROJECT NUMBER - L3004
START: JULY 15/93 fINISH : MARCH 31/98



2.3.2 FINANCIAL REPORT

FOR

CONSOLIDATED PROJECT EXPENDITURES

THAI CANADIAN HRD PROJECT
Linkage - CUTC & SUT
Project #L3004-91063
CIDA #906-14868

CONSOLIDATED PROJECT EXPENDITURES
Contract Summary
As at March 31, 1997

	1993/94 Actual	1994/95 Actual	1995/96 Actual	1996/97 Actual	1997/98 Budget	Total Actual/Budget	Contract Value	Variance
Program 1								
Fees	59,962	74,914	77,597	54,633		267,106	267,106	0
Travel	58,939	31,522	53,099	36,319		179,879	179,879	0
Other	0					0	0	0
Subtotal	**118,901**	**106,436**	**130,696**	**90,952**	**0**	**446,985**	**446,985**	**0**
Program 2								
Fees		6,000	9,000	746,190	263,644	1,024,834	1,024,834	0
Travel		10,663	29,365	252,620	641,867	934,515	934,515	0
Other		0		216,029	202,875	418,904	418,904	0
Subtotal	**0**	**16,663**	**38,365**	**1,214,839**	**1,108,386**	**2,378,253**	**2,378,253**	**0**
Program 3								
Fees		0	8,242	28,800	8,100	45,142	45,142	0
Travel		0	5,585	46,075	15,100	66,760	66,760	0
Other		0		80,000		80,000	80,000	0
Subtotal	**0**	**0**	**13,827**	**154,875**	**23,200**	**191,902**	**191,902**	**0**
Program 4								
Fees	77,900	80,298	83,302	88,446	127,087	457,033	457,033	0
Travel	2,833	11,896	27,170	45,849	71,479	159,227	159,227	0
Other	1,408	3,457	1,891	3,331	25,194	35,281	35,281	0
Subtotal	**82,141**	**95,651**	**112,363**	**137,626**	**223,760**	**651,541**	**651,541**	**0**
Total	**201,042**	**218,750**	**295,251**	**1,598,292**	**1,355,346**	**3,668,681**	**3,668,681**	**0**

Method of statement preparation: We are unable to accurately calculate the in-kind contribution of CUTC and SUT partners. Therefore, we have apportioned each partner's contribution based upon CIDA's contribution and the partner's budgeted in-kind contribution.

THAI CANADIAN HRD PROJECT
Linkage - CUTC and SUT
Project #L3004-91063
CIDA #906-14868

CONSOLIDATED PROJECT EXPENDITURES
Deliverable Status
As at March 31, 1997

Deliverable	Current Year - Apr 96-Mar/97 Actual	Original Budget	Variance	Project to Date Actual Exp. to March/97	Budget Exp. to March/97	Variance	Estimated Expenditures to Completion
1. Institutional Capacity Building Program							
A1.11a) Training Academic Administrators	0	0	0	83,118	83,118	0	0
A1.11b) Training Academic Administrators	0	0	0	7,917	7,917	0	0
A1.21 Training Faculty Members	0	0	0	102,716	102,716	0	0
A1.31 Training Support Personnel	44,622	65,600	20,978	156,210	177,188	20,978	0
A1.32 Institutional Support Services	14,830	25,800	10,970	16,756	27,726	10,970	0
A1.41 Evaluate ESL Needs	0	0	0	17,578	17,578	0	0
A1.42 Study Tour ESL	0	0	0	31,188	31,188	0	0
A1.43 ESL Course Thailand	0	0	0	0	0	0	0
A1.5 Additional Management Activities	31,500	31,500	0	31,500	31,500	0	0
Program 1 Sub-total	**90,952**	**122,900**	**31,948**	**446,983**	**478,931**	**31,948**	**0**
2. International Academic Program							
A2.11 Academic Program Planning	28,949	32,814	3,865	73,596	77,461	3,865	27,559
A2.12 Curriculum Implementation	822,381	1,454,462	632,081	822,381	1,454,462	632,081	690,720
A2.21 Selection Supervisors/PHD	16,597	8,858	(7,739)	26,978	19,239	(7,739)	0
A2.22 PHD Courses Provided	100,000	600,000	500,000	100,000	600,000	500,000	100,000
A2.23 PHD Research	0	0	0	0	0	0	30,285
A2.25 Post Doct. Research Fellowships	75,725	58,400	(17,325)	75,725	58,400	(17,325)	106,022
A2.26 Advisors Monitor PH.D	11,687	7,400	(4,287)	11,687	7,400	(4,287)	0
A2.27 Collaboration Co-Supervisors	0	19,560	19,560	0	19,560	19,560	0
A2.31 Work Placements - Canada	75,500	19,200	(56,300)	75,500	19,200	(56,300)	45,300
A2.32 Work Placements - Thailand	84,000	112,000	28,000	84,000	112,000	28,000	17,500
A2.4 Workshop-Post grad Eng Prog./Control			0			0	59,500
A2.5 Academic Research Ex-Thai Faculty			0			0	31,500
Program 2 Sub-total	**1,214,839**	**2,312,694**	**1,097,855**	**1,269,867**	**2,367,722**	**1,097,855**	**1,108,386**
3. University-Industry Linkage Program							
A3.11 Training Co-op Program	0	0	0	13,827	13,827	0	0
A3.21 Industrial Training Framework	13,275	12,900	(375)	13,275	12,900	(375)	0
A3.22 Industrial Enterprise Training	128,325	126,450	(1,875)	128,325	126,450	(1,875)	0
A3.23 Additional Ind Seminars in Thailand			0			0	23,200
A3.31 Monitor Co-op Students	13,275	12,900	(375)	13,275	12,900	(375)	0
Program 3 Sub-total	**154,875**	**152,250**	**(2,625)**	**168,702**	**166,077**	**(2,625)**	**23,200**
4. Project Management							
A4.11 ThaiProject Implem. Unit	25,875	23,288	(2,587)	87,975	85,388	(2,587)	51,750
A4.21a) Canadian Management Team	0	0	0	57,200	57,200	0	0
A4.21b) Canadian Management Team	0	0	0	59,598	59,598	0	0
A4.21c) Canadian Management Team	0	0	0	54,802	54,802	0	0
A4.21d) Canadian Management Team	57,360	60,350	2,990	57,360	60,350	2,990	0
A4.21e) Canadian Management Team	0	0	0	0	0	0	63,337
A4.31 Project Review Committee - Thai	0	0	0	28,394	28,394	0	32,360
A4.32 Project Review Committee- Can	31,124	35,400	4,276	31,124	35,400	4,276	0
A4.33 Project Management	14,936	28,511	13,575	36,242	49,817	13,575	51,119
A4.41 Communication/Support	8,331	17,229	8,898	15,088	23,986	8,898	25,194
Program 4 Sub-total	**137,626**	**164,778**	**27,152**	**427,783**	**454,935**	**27,152**	**223,760**
Total	**1,598,292**	**2,752,622**	**1,154,330**	**2,313,335**	**3,467,665**	**1,154,330**	**1,355,346**

Method of statement preparation: We are unable to accurately calculate the in-kind contribution of CUTC and SUT partners. Therefore, we have apportioned each partner's contribution based upon CIDA's contribution and the partner's budgeted in-kind contribution.

Ref:condel

APPENDIX A

ACTIVITY A 2.11 S.E. ASIA DEANS ENGINEERING CONFERENCE
FEBRUARY 10-14, 1997
4 PAPERS

The Challenges of Co-operative Engineering Education

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Introduction

The challenges of the co-operative system of Engineering education will be discussed. Our concern will be with the usefulness of the system with respect to the purposes of education, although some mention of organizational, administrative, and financial issues will be included.

Co-operative education has been widely praised as a highly effective system of education, particularly by those institutions that have adopted the system. However, there is no system that cannot be improved in some way and the claimed advantages of the system do not come without some associated cost. A true measure of cost-effectiveness has yet to be realized; thus, much of this article will necessarily be qualitative in nature.

Co-operative education has been remarkably successful at the University of Waterloo. It is largely responsible for raising the institution to be a major force in Canadian (North American) higher education within the short span (in university measures) of 40 years. Waterloo employs the conventional, alternating work and academic terms, co-operative program that is mandatory for the 3600 undergraduates enrolled in the Faculty of Engineering at Waterloo.

In the following pages, some background for the co-operative Engineering program at Waterloo will be provided followed by some of the issues and challenges affecting this system of study in an Engineering education environment.

Background

Co-operative education was introduced into Canada with the organization of the University of Waterloo in 1957. Seventy-five (75) students were enrolled in that year in a mandatory co-operative Engineering program in Chemical Engineering. The program expanded rapidly in enrolment and into disciplines other than Engineering. At present the co-operative enrolment is approximately 9,000 students comprising about 60% of the total undergraduate enrolment. Of these, 3600 are enrolled in Engineering making Waterloo the largest Engineering school in Canada. The co-operative program at the University of Waterloo is the second largest in North America.

Waterloo uses the conventional system of alternating periods of on-campus academic study interspersed with practical work experience at employer organizations. There are eight academic terms and six co-operative work terms. Engineering students enrol in the co-operative program in September and complete their first academic term on campus. The freshman intake is about 750 students per year. Beginning in the following January, approximately one-half of the students begin their first four-month work term in a business, industry, or government setting while the remaining students continue on-campus to complete their first year of studies. In the following May, the two groups of students exchange the nature of their activity and this establishes the alternating academic/work term sequence on a year-round basis. This alternating schedule is maintained until the fourth year of academic studies. The fourth year students entering 4A (the first academic term of fourth year) in the fall term continue for eight months in their academic studies. All students are again on campus for their 4B (final) term of academic studies.

Students must successfully complete a minimum of five (of the possible six) successful work terms in order to graduate. Employers complete a performance evaluation for the student(s) they employ, discuss the evaluation with the student(s), and submit the evaluation form(s) to the University for entry on the students' co-operative record file. In addition to the requirement for five successful work terms, students must submit at least four work-term reports that are graded satisfactory or better. These work-term reports must report in detail on some technical aspect of their work term and are judged for analysis and design as well as for communication skills including layout, organization, grammar, spelling, and clarity of presentation.

The administration of the work terms at the University of Waterloo is performed by the Department of Co-operative Education and Career Services (CECS). Although faculty members are not directly involved in this aspect of the program, close ties are maintained between CECS and the Faculty on a personal level and via committees within the Faculty on which CECS has contributing and voting members. Examples of such committees include Engineering Faculty Council, Engineering Faculty Undergraduate Studies Committee, and Engineering Examinations and Promotions Committee. Much of the formal communication between the Faculty and CECS has traditionally been undertaken through the Associate Dean of Engineering for Undergraduate Studies; however, recently a Director for Liaison with CECS and the PEO (Professional Engineers of Ontario) has been appointed who reports to the Associate Dean. Close contact and liaison between the Faculty and CECS is deemed to be sufficiently important to warrant such a dedicated position, albeit not a full-time one.

At Waterloo, assignment of students to jobs takes place during the on-campus academic term immediately prior to the work term at hand. It is expected that a student will return to his/her employer for at least a second term if a job is available. Each term, approximately 1500 engineering students require co-operative employment, including those that will be returning to their employer for a second (or third, etc) work term. Traditionally, 85-90 % of the students obtain jobs in the private sector with the balance being employed in various federal, provincial, or municipal agencies, governments, or organizations. Of approximately 2,500 potential employers of Engineering students contacted each term, about 450-500 actually hire students. While there are about 12 employers who hire more than 20 students each term, the majority hire fewer than three students and about 60 % of employers hire only one student. In the Canadian (North American) economic climate, the trend is to have increasingly more employers each of which is hiring, on average, increasingly fewer students.

The Challenges

In the following, some of the challenges facing co-operative Engineering education will be presented. These will be presented in brief form, with the issues identified and succinctly described. In some cases, the issues will be culturally dependent as to their importance; some issues related to local economy and culture may have been missed entirely. A discussion of all of the challenges of co-operative Engineering education is highly perspective dependent. Nevertheless, some of the important challenges are presented below.

Industrial Linkage

It is crucial to form strong links with industrial and government concerns. The nature of this linkage must reflect a commitment from the industry to the continued participation in the co-operative program. There are responsibilities that the industry must fulfill including student performance evaluation, job description preparation, interview participation, and co-ordinator interview participation. This commitment must in turn reflect the recognition by the industrial 'partner' that this is **not** a student aid or training program; the industrial partner must be convinced of the actual benefits that accrue to it through the program. The remuneration package must be an appropriate full-time rate for a student Engineer. In some countries this will represent a cultural barrier that must be overcome.

Institution Commitment

The University must demonstrate commitment to the concept of co-operative education. This requires a significant infrastructure within the University, some of this being physical and much of this being human resource in nature. The 'co-ordinators' are required to interact with the students both on campus and on the job. Job development personnel are required to continuously develop (secure) jobs from partner industries and government offices. Internal record-keeping is required for promotion, evaluation, communication and discipline purposes.

Meaningful Jobs

The jobs that ore offered as part of the co-operative Engineering education program must be meaningful and appropriate for the student and for the employer. A co-operative job is **not** just a job! The job must provide a meaningful learning, employment, and contributing environment for the student yet it must also provide a return on investment for the employer. The employer should want to participate because it recognizes the benefit to itself.

Responsible Students

The admissions process must develop a student population that has a strong work ethic, understands the co-operative education process, and understands the students' responsibility in this process. The student must be willing to accept that not all jobs will meet his/her expectation but that this is part of the process. The student must act responsibly on the job and contribute to the goals of the employer. The student must understand that the purpose of the co-operative work term from the his/her perspective is to produce a superior Engineer on graduation and not to simply finance his/her education. Here again, there may be some cultural barriers to overcome.

Faculty Commitment

Individual faculty members must be committed to the concept of co-operative Engineering education. They will be involved in marking work reports, their classes will be disrupted by students coming from and going to job interviews, some students will want special arrangements for job-related matters, etc. Where faculty members do not appreciate the benefits of the co-operative education environment, they will become resentful and impose barriers to the smooth and cooperative implementation of the program.

Government Commitment

There are additional expenses involved in running a co-operative education program in excess of those required for a 'regular' program. These expenses are not insignificant and place an additional financial burden on the University. Where government funding is used to operate the University, it would be very useful if the University grants recognized these additional burdens in a tangible way. Unfortunately, the government recognition generally does not come in the form of additional financial support.

Graduate Student Population

Engineering graduates from a co-operative Engineering program generally are far better prepared to enter the work force and begin contributing in a meaningful way than are the graduates from the 'regular' programs of conventional Universities. Industry is generally eager to acquire these graduates, offering them very attractive salaries. As a result, graduates move directly into industry under the temptation of high salaries and do not consider graduate school as an option. It can be argued that we lose some of our best students to industry in this manner.

Academic Term Dynamics

The nature of a co-operative program of study is one of constant interchange between the work term and the academic term. Students must frequently travel significant distances in making the transition, and when they arrive on campus, because of their short term time, there is no time to spare. Students and instructors must move into high gear immediately. Exams must occur every four month term, and as a result the 'teaching time' is further reduced so that the time on campus must be used very effectively.

University Identification

Normally, a four year residence at a university builds identification and loyalty. The residency is not only an important learning experience for the student but is an important bridge for the University to alumni support. Co-operative students, with their frequently interrupted attendance, are often unable to live on campus. Even when they do, the lack of continuity and of long periods at the University considerably hinders their ability to identify with the University. A strong group identity does develop in the co-operative program but it is restricted to the group or stream with whom students make their way through the program. A lesser identification occurs with the program as a whole, and an even lesser identification occurs with the University.

Social Isolation

A problem analogous to the one above is that of developing contacts with students in other disciplines besides Engineering. Movement between the work term job and the campus and frequent changes in housing arrangements hinders the building of long term friendships based on a living group, on clubs, or on other student activities. In many cases clubs and student government offer students invaluable training in leadership and administration but the intermittent presence of the students on campus makes it difficult for co-operative students to take on officer positions. University athletics poses a similar problem.

Closure

The foregoing presents some of the challenges facing the implementation of a co-operative Engineering education program. As can be seen, they are many so the task is not an easy one. However, the benefits are great. Benefits to the student and to the University include the following: increased learning through the experiences that the students bring to the classroom; increased learning through the interactions of students with each other; research ideas and challenges that come to the University from the students' work experiences; increased student maturity through the work-term experience; increased student maturity through the requirement to change venue every four months; research funding and opportunities through the employer-student identification of potential need/expertise alignment; innovation that results from the non-conservative co-operative environment; in situ sensors of change in the workplace in the form of students; and, soon to be realized in Ontario, reduced experience requirements for professional registration as a result of the work experience gained on co-operative work terms. As noted in the introduction, however, a true measure of cost-effectiveness has yet to be realized.

At Waterloo we are firmly convinced that the benefits of co-operative Engineering education far outweigh the costs of implementation.

Thai-Canadian Collaboration in Human Resource Development

The SUT/CUTC Project

Dr. S.A. Boctor, Ryerson Polytechnic University
Dr. W. Caley and Dr. F. Hamdullahpur, Technical University of Nova Scotia

INTRODUCTION

In 1991, CIDA decided to provide $10M to support ten HRD collaboration projects between Canadian universities and corporations and their Thai counterparts, intended to enhance the development of human resources in Thailand, particularly the Engineering, Business and Technology related disciplines, and encourage long term collaboration between the Canadian and Thai partners in these fields. Dr. Wichit Sris-an and the Ministry of University Affairs were the projects' main driving force in Thailand, and through their excellent coordination and planning the ten projects were launched in 1993.

THE SUT/CUTC PROJECT

One of the first projects to be launched was the SUT/CUTC project, with a total budget of about $6.0 M, of which CIDA's contribution is about $1.0 M. The Thai partner is the newly established Suranaree University of Technology, and the Canadian partner, the "Canadian Universities Technology Consortium," consists of four institutions: Ryerson Polytechnic University, University of Waterloo, Technical University of Nova Scotia and the University of Guelph. Over the five year duration of this linkage project, the approved activities and deliverables are designed to provide mutual benefits and ultimately result in sustainable and enduring institutional relationships, particularly in the field of Human Resource Development.

<u>The Project Activities and Deliverables</u>

To achieve the goals of this novel institutional linkage and technical cooperation project, three specific programs were designed to provide the project deliverables.

I) Institutional Capacity Building Program

To support the institutional development and capacity building of SUT, four major activities were implemented:

1. <u>*Development of Academic, Administrative and Management Framework at SUT*</u>

   Customized programs were designed for five SUT academic administrators in the areas of academic planning, policy development, system of governance, curriculum planning and development, research administration, academic standards and promotion, and admissions procedures. The exposure of the SUT personnel to these areas of academic activities at the CUTC institutions provided them with various ideas to assess the benefits of implementing similar or modified management procedures at SUT.

2. *Development of Academic Programs and Curricula at SUT:*
Seven academic chairs and coordinators visited the CUTC partner institutions on customized programs to assess the curriculum development and planning activities, laboratories, equipment, computer facilities, and research programs in various areas of applied science and engineering disciplines.

3. *Development of Institutional Support Services*
Customized training programs were designed for 10 SUT personnel in the areas of library automation, computerized management and information systems, and maintenance of scientific equipment, at the various campuses of the CUTC partner institutions. Also, Canadian consultants visited SUT to assess and provide recommendations about library automation, management information systems (MIS) and computer support systems.

4. *Establishment of ESL Centre at SUT*
Two SUT professors in ESL visited various ESL centres in Canada, and a Canadian consultant assessed and provided planning and curriculum related recommendations about the establishment of the ESL centre at SUT. This centre has now been in operation for about three years and provides valuable language proficiency services to all of SUT's students.

II) International Academic Program

Three major areas of activities constitute the novel components of this program:

1. *International Applied Science and Engineering Programs (IUP):*
Curriculum planning and implementation activities were undertaken by CUTC professors in collaboration with SUT professors to design and deliver four international undergraduate engineering and applied science programs in the fields of Mechanical, Electrical and Chemical engineering and Food Technology. These programs anticipated serving international students from South East Asian countries in those critical engineering areas which are essential in support of the expansion of industrial developments in SE Asia. The language of instruction in all of the curriculum course material is English. The curriculum design takes into

account the opportunities available to the undergraduate students in these programs to transfer to the CUTC partner universities to complete their degree requirements, either after the first or the second year(s) of their undergraduate programs. Hence the curriculum for at least the first two years were mostly transplanted from the partner Canadian universities. This also implied that those transfer students could then earn Canadian bachelor degrees and become eligible to be licensed as Professional Engineers in Canada.

This is the second year of implementation of these IUPs. As many as twelve Canadian professors have been assigned to SUT to help in the delivery and curriculum development of the different course material. Thai students in Mechanical Engineering have already transferred to Canadian universities, and another group of Electrical Engineering students are expected to transfer this year.

We expect that these programs once they overcome the growing pains, will have long-term impact on the human resource development in Thailand and the SE Asian countries. This is also an area of enduring and sustainable relationships.

2. *Joint Research and Ph.D. Program*
Junior faculty members at SUT, with the support of scholarships for the Thai Ministry of University Affairs, are given the opportunity to pursue their graduate studies to obtain their Ph.D. degrees at the CUTC partner universities. At present, three such doctoral candidates are enrolled at TUNS and it is anticipated that another three candidates will take part in this aspect of the project. To strengthen the collaborative nature of these activities and its long-term sustainability, the Canadian graduate supervisors will visit SUT to discuss and explore the long-term continuation of such research activities with their Thai counterparts. Further, four postdoctoral scholarships were provided to SUT faculty members, to renew and expand their research activities at the CUTC partner universities. We expect that such postdoctoral research opportunities will also lead to on-going sustainable research collaboration in the future. Also, three senior professors from the CUTC partner universities will provide consultancies to SUT to support, and collaboratively plan the development of postgraduate engineering programs at SUT.

3. *Co-op Student Exchange Program*
Through this program 8 Thai and 8 Canadian students will be assisted by the project in securing co-op placements in Canada and in Thailand

respectively. The objective of this activity is to provide seed funding to convince industrial and governmental institutions of the viability and benefits of cross-cultural and cross-technological exposure of undergraduate students in both countries to the international development occurring in their fields. To date, seven Canadian students and four Thai students have completed their co-op assignments.

III) University-Industry Linkage Program

SUT, through its newly established Technopolis and its Centre for International Affairs, has established many university-industry linkages, particularly in the areas of continuing education and specialized industrial seminar series and conferences. Canadian professors from the CUTC partner universities and industrial consultants have contributed to these activities and provided seminars and lectures in such fields as University-Industry linkage projects, water resource management, environmental management issues, Internationalization of Higher Education, Computer Integrated Manufacturing, etc. This is another area that promises sustainable and mutually beneficial long-term collaboration.

Project Management and Project Review Committee (PRC)

An important aspect of the project was the unique management structure adopted in the early stages of the project design. Each of the partners, SUT and the CUTC, established a steering sub-committee. Frequent dialogue and on-going communications between these sub-committees, together with the annual meeting of the whole PRC (in Canada and in Thailand) helped overcome perceived and anticipated difficulties even before they arose. Through these PRC meetings, review and assessments of completed activities were discussed, and planning for implementation and/or minor changes in the project deliverables and activities took place in a collegial and friendly atmosphere. This open and frank dialogue helped immensely in steering the project towards its successful completion.

CONCLUSION

The authors wish to express their pride in taking part in this exciting, stimulating and gratifying project, and also wish to express their sincere thanks to CIDA, SUT and the Thai Ministry of University Affairs for making this project a reality. The achievements of this project and its goal of mutual benefits and sustainable institutional relationships provide an excellent viable example for international cooperation and collaboration. We hope to see many such linkage projects established in the near future, ushering in a new century of open markets, global exchanges and communications and maybe one day a borderless world.

QUALITY ASSURANCE IN ENGINEERING EDUCATION
ENGINEERING ACCREDITATION IN CANADA

Dr. S. A. Boctor, Ryerson Polytechnic University
Dr. W. Caley and Dr. F. Hamdullahpur, Technical University of Nova Scotia

Introduction

The practice of the engineering profession in Canada is governed by legislation at the provincial level. Like most professional fields of endeavours that involve public liability issues, society needs to be assured of the quality, qualifications and ethical conduct of those people practising the profession. Each of the ten provinces in Canada has its own Professional Engineering licencing body. In order for a graduate engineer to be able to practice his/her profession, he/she must be a member of and licenced by the provincial body where he/she expects to be employed.

Instead of a system involving provincial licence examinations in each of the engineering disciplines, as is the case in the United States, the Canadian provincial engineering associations formed the Canadian Council of Professional Engineers (CCPE). One of the four standing boards of the CCPE is the Canadian Engineering Accreditation Board (CEAB). The main objective of the CEAB is to conduct cyclical assessments of the 33 colleges of engineering, at the various Canadian universities and undertake a thorough review of each of the engineering programs offered at the various Faculties. The successful evaluation by the CEAB of the engineering programs at a specific university provides an indication to all of the provincial licencing bodies that the graduates of these "accredited" programs are eligible for licencing, after an internship period (three to four years) and after successfully completing the "Professional Practice and Ethics " examination. A new engineering program is usually assessed for the first time while the final year of the program is being implemented, i.e. just before the graduation of the first class of graduants. The quality assurance assessment conducted by the CEAB and the exhaustive parameters used for these evaluations are of prime importance to all of the Faculties of Engineering at the various Canadian universities; particularly in the design of the undergraduate engineering curricula and in the establishment of the engineering educational environment.

This paper will briefly discuss the evaluation parameters and the procedure used to assess the quality of engineering programs in Canada.

Accreditation Criteria

These criteria, which fall under three categories, are formulated to ensure that the graduates of a specific program are provided with an academic education that meets or exceeds the professional registration requirements, placing special emphasis on the quality of the graduates, the academic and support staff and the educational facilities (such as laboratories, library, computer centre, etc.).

I - General Criteria

- The engineering undergraduate program must develop an individual's ability to use appropriate knowledge and information to convert, utilize and manage resources optimally through effective analysis, interpretation and decision making (i.e. the design process).

- Overspecialization in curricula is discouraged, exposure to fundamental knowledge of other branches of engineering and innovative educational development are encouraged.

- The graduate must be adaptive, creative, resourceful and responsive to changes in society, technology and career demands. The graduate must also be aware of the role and responsibilities of the professional engineer in society and must be able to communicate effectively within society at large.

II - Curriculum Content

Judgement is applied to both the qualitative and quantitative aspects of each of the criteria used to assess a specific program's curricular content.

An accreditation unit (AU) is used to assess quantitatively the various components of the curriculum. One AU is 1 lecture hour, or two tutorial or laboratory hours. For example, a three-hours lecture/two-hours laboratory per week, in a course offered over a 13-week semester, would be equivalent to 52 AU. An activity that is not properly described by specific contact hours, like Thesis Projects and Design Assignments, can be evaluated by multiplying the credit units assigned by the university to such activity by a mathematically derived proportionality factor, to arrive at the equivalent AU units. The minimum content of each curricular category is defined as follows:

Mathematics: 195 AU, including algebra, differential and integral calculus, differential equations, probability and statistics and numerical analysis.
Basic Science: 225 AU, including elements of physics, chemistry, life and earth sciences. These subjects are intended to impart an understanding of natural phenomena and relationships.
Engineering Science and Engineering Design: 900 AU of the combined subject matter, but no less than 225 AU in each category. The remaining 450 AU could be any combination of Engineering Science and Design as deemed desirable by the specific program and institution. Engineering Science subjects have their roots in basic science and mathematics but carry the knowledge further towards creative applications, like modelling and numerical techniques, simulation procedures, materials, fluid mechanics, thermodynamics, electrical and electronic circuits, computer science, soil mechanics, control systems, aerodynamics,

transport phenomena, environmental studies, etc.
Engineering design integrates mathematics, basic and engineering science and complementary studies to develop systems, elements, processes to meet specific needs. Such activity is characterized by its creative, interactive and often open-ended nature.
Appropriate content requiring the application of computers must be included in this component of the curriculum.
Complementary Studies: 225 AU, covering studies in humanities, social sciences, literature, management, economics and communications, that complement the technical content of the curriculum. Considerable latitude is provided in the choice of suitable courses, but this category must include studies in engineering economics, the impact of technology on society and must develop the students' capability to communicate effectively.

The remaining 235 AU can be assigned to any category as deemed appropriate and desirable by the program. The entire program must include a minimum of 1800 AU. Laboratory experience must be an integral component of the engineering curriculum. The total instructional AU content of a given course does not include final examination and can be split between different categories (normally two).

III - Program Environment

The emphasis here is placed on the qualitative evaluation of the program's environment, including:

- Quality of students, faculty, support staff, teaching assistants, administration of the program, the laboratories and computing facilities, library resources and other supporting facilities.

- The moral, commitment, experience and engineering competence of the faculty members. The majority of the faculty must be full-time to assure adequate levels of student-faculty interaction, curricular counselling and development and control of the curriculum.

- Faculty teaching workload should allow time for adequate participation in research and professional development activities.

- Faculty members teaching the engineering science and engineering design component of the curriculum are expected to have a high level of competence and dedication to the engineering profession. This criteria is assessed through faculty qualifications, experience, level of scholarly activities, participation in professional and learned societies and registration as professional engineers.

- The Deans and Chairs of engineering programs are expected to provide effective leadership and to have achieved a high standing in the engineering community. They are expected to be professional engineers.

- The Engineering Faculty Council, or equivalent, must have effective control of the engineering programs and their curricula.

- The academic admissions, promotion and graduation policies adopted by the Engineering Faculty must verify that the students have demonstrated competence in the courses taken. The definition of competence should be acceptable to the CEAB.

Accreditation Procedures

The CEAB reassesses all of the,accredited programs (about 210) at intervals not exceeding six years. At the invitation of an institution to the CEAB, by January 1 of the year in which the visit is to take place, the CEAB sends documentation to the institution, including structured questionnaires, documents required by the visiting team, schedule of events and procedures to be followed before, during and after the accreditation visit. A visiting team chair, usually a board member of the CEAB is selected, and the chair selects his team, which normally includes a vice chair and a program visitor specialist for every program to be assessed at the specific institution. One of the team members is specified by the Professional Engineering Licencing Association in the province of the assessed institution. All members of the visiting team must be professional engineers. At least six weeks before the date of the visit (usually in October or November), each member of the team must receive the appropriate documents requested from the institution.

The Accreditation Visit

The accreditation visit normally takes two days. The team members assess qualitative factors such as environment, morale, professional attitudes, quality of students, staff and faculty; and may request clarifications regarding certain issues raised through the questionnaire submitted by the institution. The activities undertaken by the visiting team include:

a) interviews with the President, the Vice President (Provost), the Dean of Engineering and the Chairs of the engineering programs being assessed;
b) interviews with faculty members, staff members and students;
c) tour of the facilities such as labs, computing facilities, libraries, etc;
d) review of recent examination papers, laboratory manuals, student transcripts, sample student work, reports and projects, course outlines (management sheets) and textbooks used in the various courses of the programs' curriculum;
c) before the end of the visit, an exit interview is conducted between the team members and the Dean and Chairs of Engineering, to review the perceived strengths and weaknesses of the programs and to indicate areas of concern.

Reports and Decision

Six to eight weeks after the accreditation visit, the chair of the visiting team sends a written report, including the individual findings of the team members, to the CEAB and then to the Dean of Engineering at the institution. The Dean and the Chairs could respond to the team's report and may advise on improvements being implemented in the current academic year.

The CEAB board meets normally in June, to assess the institution's dossier, including the original submission, the visiting team's report and the institution's response to the report. The Dean is invited to respond to any questions from the (13) board members and may make a presentation to the board if he/she wishes. The accreditation decision is then made at the conclusion of the board meeting, regarding each of the programs being assessed.

If the CEAB board has no concerns, the program is deemed to meet the accreditation criteria and is granted the maximum six-year accreditation term. Accreditation for a term less than six years, normally three, is granted to programs when the board feels that certain concerns need to be overcome. A reassessment visit may then takes place near the end of the accreditation term. Depending on the nature of the concerns, the board may require a report (instead of a visit) to be submitted to the CEAB at the end of the three-year term and upon favourable review, the board may extend the accreditation term for another three years before the revisit occurs.

If the CEAB judges that significant weaknesses currently exist in the program being assessed, either a limited term termination notice or denial of the accreditation decision is made. Before the end of the term termination notice, an institution may write a report to the CEAB explaining the major improvements made to the program(s). The CEAB, upon reviewing such a report, may then re-initiate a new cycle of assessment visit, or may decide to terminate the accreditation on the end date of the termination notice.

The accreditation decision is conveyed by letter to the Dean and the President of the institution whose programs are being assessed. The Dean could then convey the CEAB's decision to the faculty, staff and students.

Conclusion

For over 30 years, the experience of the Canadian universities with the engineering education quality assurance process provided by the CEAB accreditation procedure, has been favourable. At times, some institutions may have confronted some difficulties. However, through feedback and discussions, the process has been fine-tuned over time and does indeed provide a very valuable service to the profession.

UNIVERSITY-INDUSTRY LINKAGES IN ENVIRONMENTAL ENGINEERING

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for presentation at

Regional Colloquium on Engineering and Technology Education
for the 21st Century
Surasammanakhan Suranaree University of Technology
Nakhon Ratchasima, Thailand
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SUMMARY

Linkages between university and industry in environmental engineering is presented in terms of educational programs and research activities. The current state of the environmental industry and the driving forces for the demand of environmental products and services are also reviewed. Government is found to play the most important role in creating the demand and also provides most of the research funding for environmental research, which is becoming increasingly a multi-disciplinary effort.

1. INTRODUCTION

Before considering environmental engineering linkages between university and industry in Canada, it is useful to look at the environmental industry itself. It is important to realize that the environmental industry is only about ten years old even though environmental issues have been addressed in different industries for many decades. It should also be understood that environmental engineering as a discipline is relatively new and much of the environmental activities are still found in traditional engineering disciplines, such as civil and chemical engineering. They deal mainly with the environmental aspects of the pulp and paper industry, petrochemical and related industries, mining industry, manufacturing industry, and the municipal sector. Although the evolving environmental engineering discipline and industry cover the same areas, they are interested in a broader spectrum of environmental concerns, including the remediation of past mistakes and the introduction of new environmental management process and technology. For this reason environmental engineering has a significant multi-disciplinary component.

Environmental attention of many product manufacturers, such as the consumer product industry, has shifted from production processes to the product itself. Today, product R&D has to take into account a large amount of government regulations and market requirements, such as the recycling and re-use of packaging, energy efficiency and emissions standards in use, and take-back guarantees at the end of service life. An excellent example is the disposable diaper industry which has been forced to redesign the product to make it more environmentally acceptable. The industry has spent millions of dollars on life-cycle analyses to determine the cradle-to-grave impact of the diapers and on the development and promotion of recycling methods, such as composting.

2. ENVIRONMENTAL INDUSTRY

The Canadian environmental industry consists of about 5000 companies which provide technologies, processes, products and services. Although there are some large multinational corporations, the majority of companies are small to medium-sized, employing less than 50 people. However, like many growing industries with a large number of small companies, the environmental industry is undergoing restructuring and consolidation as smaller companies are being bought up by larger ones. The total employment is probably in excess of 150,000 engineers, scientists, technologists and technicians.

Canada's domestic market for environmental goods and services in 1994 was about $11 billion and is expected to increase at a rate of 10% per year to $22 billion by the year 2000. About 70% of environmental companies sell services, such as waste handling and facility operation, consulting services, environmental pollution and related field services, environmental research, natural resource conservation and protection. Waste handling and environmental facility operations is the largest component of the service sector, accounting for 65% of the total service sector income of $5 billion in 1994. Consulting services and construction contribute about 20% and 10%, respectively.

The other 30% of the companies represent the environmental manufacturing sector with yearly revenues of $6 billion. Equipment for water pollution control accounts for 40% of the equipment manufacturing income, followed by air pollution control equipment (25%) and solid waste management/recycling equipment (25%). The remaining 10% includes the production of monitoring, chemicals (especially chlorine for water treatment plants), laboratory equipment, noise control equipment, and equipment for natural resource conservation.

Canada's share of the world market for environmental products and services was 3.5% in 1994 but is growing rapidly. The primary market for Canadian exports is the United States. In general, the total world market for the environmental industry is expected to reach $600 billion by the year 2000, with the U.S. market alone being $200 billion. However, the fastest growing markets (perhaps an average of 15% per year) during the next few years are expected to be the industrialized nations of central and eastern Europe, Latin America, The Pacific Rim and Southeast Asia.

3. DRIVING FORCES

The driving forces for the demand of environmental goods and services can be summarized as follows:

1. Compliance with ever increasing federal, provincial and municipal legislation and policies.

2. Economic growth, which creates the need for environmental goods and services at new industrial plants to meet environmental standards.
3. Population growth, which generates the demand for water and waste water treatment, and solid waste management facilities.
4. The increasing demand by consumers for environmentally-friendly "green" products.
5. Increased corporate environmental consciousness resulting from a public relations need to show a strong environmental record.
6. The general acceptance of the concept of sustainable development which forces governments and industry to consider long term environmental implications of economic and social growth. (Brundtland, 1987)
7. Improved competition, such as resulting from ISO 14000.
8. Increased profits due to minimization of waste and waste treatment, recycling, reduction in packaging, energy savings, etc.

Currently, compliance with legislation and policies is probably to most significant reason for the growth of the environmental industry. The manufacturing sector will benefit from legislation regarding air pollution control, such reduction of NO_x and VOC's, control of green house gases, SO_2 emissions from major point sources, and other toxic emissions. Water pollution control will require equipment and technologies for the implementation of "closed loop" systems, water separation technologies, water filtration, mobile pretreatment of water before final disposal, run-off from parking lots, on-site solvent reclamation in case of spills, UV treatment of water as an alternative to chlorine, water treatment services and membrane separation. Integrated solid waste management will require equipment and technologies for soil remediation, material recovery facilities, composting facilities, and recycling plants. Additional needs will be for computer software and hardware, incineration equipment, solid waste collection, handling and disposal equipment and systems.

Of course the service sector will grow accordingly. Consulting services are expected to grow significantly, especially in the areas of environmental audits, impact assessment, integrated solid waste management master plan development, public consultations and education, emergency response systems, geographic information systems, software development, energy conservation, site remediation studies, and project management.

4. EDUCATIONAL UNIVERSITY-INDUSTRY LINKAGE IN ENVIRONMENTAL ENGINEERING

Education and training programs to serve the environmental industry have increased considerably in the past decade but are still in a developmental stage. Depending on the requirements, the education and training can be obtained at universities, colleges and technical institutes, contract training, and in-house training programs.

4.1 Undergraduate Education

At the undergraduate university level there are four types of programs where environmental expertise can be obtained; namely, civil and chemical engineering programs, environmental engineering programs, environmental science programs, and course electives found in engineering, physical or biological science programs.

Most traditional civil and chemical engineering programs have environmental options. Civil engineering mostly covered the areas of municipal wastewater treatment, sediment transport, landfill design, and urban water supply. Chemical engineering generally addressed industrial environmental problems, such as air pollution control and industrial wastewater treatment using chemical processes. Many such programs have introduced new environmental electives and minors to broaden the scope of environmental training.

However, in the past few years engineering faculties at the Universities of Guelph, Regina and Windsor developed new environmental engineering programs accredited by the Canadian Engineering Accreditation Board (CEAB). The enrolment at these three institutions in 1995 was 243, 127 and 75, respectively (CCPE, 1996). The objective of these programs is to develop engineers with a scientific appreciation of the ecosystem and a broad understanding of the social-legal-economic environmental framework. In addition to the usual prerequisite courses in mathematics, physical and engineering sciences required by all accredited engineering programs. environmental engineering students are provided with a background in environmental sciences such as biology, microbiology, analytical and/or organic chemistry. In subsequent courses the students concentrate on the conceptualization, model development, and application of engineering solutions to environmental problems. The courses cover such topics as water resource engineering, contaminant and pollution transport in the environment, hazardous waste management, solid waste management, wastewater treatment, hydrogeology and ground water flow management, and municipal engineering. Broader perspectives of environmental management is obtained through courses in environmental impact assessment, environmental law, environmental planning, ecology, ecotoxicology, and environmental resource management.

4.2 Coop and Internship Programs

An important direct educational link with industry is through the placement of students enrolled in Cooperative Educational programs or a variety of Internships. The Coop students spend four to six work terms in engineering jobs, depending on the university's Coop program. A 1993 survey showed that about 20% of the environmental companies participated in cooperative educational programs. Both the Guelph and Regina environmental engineering programs have Cooperative opportunities.

Internship programs work on a similar principle except that the student may we be on a work assignment for a summer semester or a full year.

4.3 Graduate Programs

Because the environmental industry is growing rapidly the demand for new employees with new skills is outstripping the supply of people on the short term. Several engineering programs have responded by developing graduate level environmental programs. In addition to the research-based programs which normally lead to a M.Sc. or Ph.D. in Engineering, there are programs based on coursework which often result in M.Eng. degrees. These programs are particularly popular with practicing engineers and scientists because they allow them to upgrade their environmental engineering knowledge and skills on a part-time basis. The School of Engineering of the University of Guelph has both thesis-based and coursework degrees in environmental engineering.

In many instances the graduate programs are offered in cooperation with university centres or institutes. For example, the Waterloo Centre for Groundwater Research accepts a limited number of students with scientific and engineering background. During their studies they learn to apply hydrogeological principles to the management of groundwater systems.

Another well-known non-thesis graduate program with specialization in environmental engineering is the M.Eng. Pulp and Paper Program offered at the University of British Columbia and McGill University in association with the Pulp and Paper Research Institute of Canada. The institute represents Canada's largest resource-based industry.

4.4 Special Short-Courses and Training Programs

Companies with interest in environmental issues have several other avenues of satisfying their specific training needs, such as association training, on-the-job training, outside trainers, industry seminars and conferences, internally-developed training programs, and equipment supplier/vendor training programs.

Industry associations often offer courses to their members. For example, The Air and Waste Management Association has a Training Institute in Calgary to provide some 32 courses on a broad variety of environmental topics. Similarly, the Environmental Services Association of Alberta has a program to retrain technically-skilled workers from the oil and gas industry for work in the environment.

University engineering and science faculty with special knowledge often contribute as teachers in the associations' initiatives, as outside-trainers or as seminar speakers. They normally provide these services as consultants. An important spin-off of these involvements is that they frequently lead to research projects funded by member companies.

It is expected that distance education through video conferencing or similar methods will play an increasingly important role in making university courses available to industry for on-site training.

5. ENVIRONMENTAL RESEARCH

In considering research linkages between universities and industry it should be kept in mind that the research is often done in traditional engineering programs as well as in the newer environmental engineering program, and increasingly involves interdisciplinary groups. This is particularly true for the environmental research at the University of Guelph where most of the focus is on nonindustrial areas, with the exception of the food processing industry. For example, a one-year pilot project involving composting of source-separated organic waste from 15,000 Metro Toronto households involved environmental engineering, soil science, and microbiology faculty and staff.

The actual linkages between environmental research at universities and industry can be summarized as being either direct or indirect. In direct cases individual companies provide funding though grants or contracts to individual faculty or group of faculty. Usually this type of involvement is due to the specific expertise of the researcher or the need of a company to find a solution to a specific problem.

In indirect instances a number of companies fund research of general interest to all of them through an association, research institute, Centre, or similar industrial organization. Again, the grant or contract may be with individual faculty or group of faculty. It is also possible for the industrial organization to provide funding to a University Research Centre or Institute. These will in turn fund the work of individual faculty or groups of faculty.

Another indirect linkage is developed through the funding of Research Chairs by, usually with additional funding from government sources. The Chair is usually for a limited duration, normally five years, during which time research is conducted on behalf of the industry. The Natural Science and Engineering Research Council normally funds 50% of industrial chairs.

Figure 1 shows the structure of one industry/university organization - Environmental Science and Technology Alliance Canada (ESTAC). In 1995 ESTAC consisted of the member companies shown, each contributing an annual membership fee ranging from $25,000 to $100,000 based on Canadian-Made Sales or Total Sales in Canada, and universities, each contributing $10,000 per year. Additional funding in the amount of $5 million over 5 years is provide by Industry Canada to carry out environmental research & development. It is expected that ESTAC will grow to 50 companies and 20 universities by 1999. Research projects are conducted through interactive networks of company personnel and university faculty.

The MEND program (see Table 1) is a cooperative effort financed and administered by the Canadian mining industry, the Canadian government through Energy, Mines and Resources Canada (CANMET), Environment Canada, and Indian and Northern Affairs Canada, and the governments of British Columbia, Manitoba, Ontario, Quebec and New Brunswick. MEND's objective is to develop knowledge and technology that will substantially reduce the concerns and the environmental problems related to acid mine drainage caused by bacterial oxidation and acidification of sulphide minerals contained in copper, nickel, gold and uranium orebodies and tailings. In Ontario alone some 20 out of a possible 2000 sites have been documented to contain 55,000,000 tonnes of reactive sulphide tailings over a surface area of 830 hectares. The cost of stabilizing some sites have been estimated to be as high as $400,000 per hectare, while the average cost is expected to be $200,000 per hectare.

In the past two years there has been a significant shift in funding of environmental research. In the past almost all of the environmental engineering research at universities was funded by grants or contracts from federal, provincial and municipal governments. However, governments have either significantly reduced or completely eliminated their direct grant programs. The present situations is

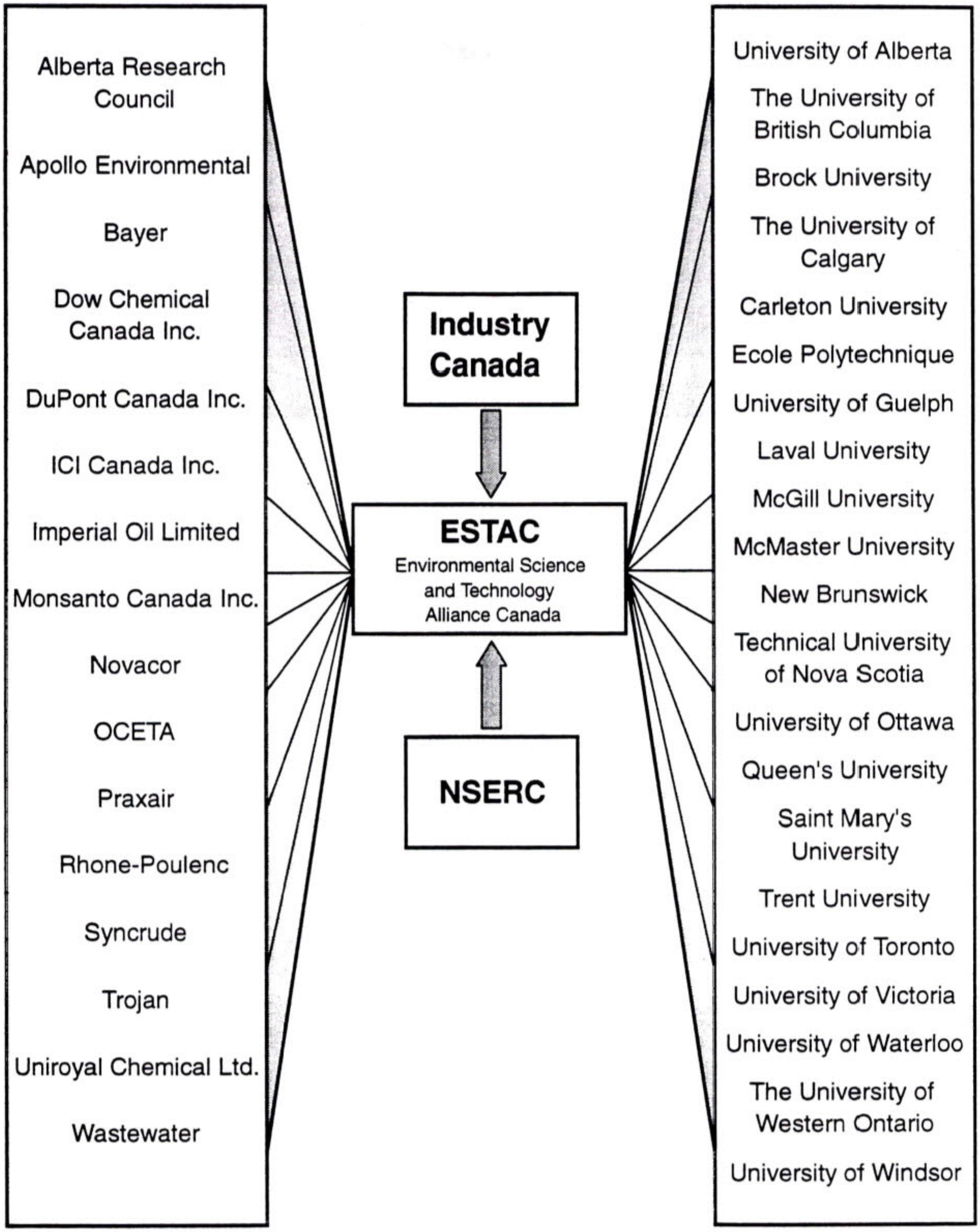

Figure 1. Environmental Science and Technology Alliance Canada

that researchers must have industrial or commercial sponsors before they can apply for matching governments funding. In most cases this still means that government provides most of the funding but the research tends to be more applied and problem oriented. NSERC has a number of special programs, including co-operative research grants, shared equipment and facilities, industrial research chairs, senior and visiting industrial fellowships to promote research.

Table 1. Examples of Industrial Research Funding

INDUSTRIAL RESEARCH FUNDING GROUPS	TYPICAL RESEARCH PROJECTS
Associations	
Canadian Chemical Producers' Association	hazardous waste; air & water pollution; bioremediation
Petroleum Association for the Conservation of the Conservation of the Canadian Environment (PACE)	plant decommissioning; soil remediation, air & water pollution; hazardous waste, environmental impact of explorations
North American Recycled Rubber Association (NARRA)	recycling tires; incineration; reclamation; reprocessing;
Alliance of Manufacturers and Exporters of Canada	packaging
Ontario Restaurant Association	organic waste disposal: land application, composting
Institutes	
Environmental and Plastics Institute of Canada	hazardous waste; packaging; toxicity; recycling; waste disposal; life-cycle analysis; solvent substitution
Pulp and Paper Institute of Canada (PAPRICAN)	wastewater treatment; biological treatment; sludge management; biodegradation; deinking; recycling; bioconversion; oxygen bleaching; closed cycle technologies
Other	
Soft Drink Manufacturers	recycling, packaging; life-cycle analysis
Food and Consumer Products Manufacturers of Canada (FCPMC)	packaging, recycling, waste management; life-cycle analysis
Mine Environment Neutral Drainage (MEND)	land reclamation, acid mine drainage control, groundwater and surface water pollution

The Canadian Pulp & Paper Industry has recently launched a $88-million closed cycle research drive The objective of the five-year program is to shift the emphasis from pollution treatment to prevention, while boosting the industry's global competitiveness. The program is a follow up of the $5-billion investment in new bleaching technology and secondary treatment facilities from 1988-1995, which effectively eliminated dioxins and furans and sharply reduced pollutants in effluent streams. The new research effort is expected to contribute significantly to the various university pulp and paper centres and other environmental engineering efforts.

Table 2. Examples of University Centres with Environmental Research Interest

UNIVERSITY CENTRES	RESEARCH EFFORTS
Pulp and Paper Centres: University of British Columbia University of Toronto McGill University École Polytechnique McMaster University	deinking, chlorine dioxide production, anaerobic fermentation, composting, biodegradation of resin acids, monitoring of contaminants in pulp mill discharges, treatment of newsprint mill whitewater; dour removal and control, bioprocessing of solid waste residue, wastewater sludge management.
Waterloo Centre for Groundwater Research	groundwater quality; soil remediation; risk assessment; environmental impact assessment

5. EXAMPLES OF RESEARCH LINKAGES

As mentioned before, the scope of environmental research is considerable and involves traditional engineering fields, environmental sciences, chemical and biological sciences, toxicology, sociology, mathematics, computer science, etc. Table 3 was constructed to provide some specific examples of the types of projects funded directly or indirectly by industry in the last few years at the School of Engineering. It does not show the research funded directly by different levels of government, which still accounts for at least 80% of all environmental engineering research funding for the School because of its roots and connections with the agricultural and food sciences.

It is interesting to note that several of the projects involve biological treatment of contaminated sites and waste streams. Biofiltration and composting of organic wastes are major areas of research, only a fraction of which is funded by industry. Nevertheless, industry has provided some $300,000 for these projects in the past few years.

6. CONCLUSIONS

These has been a rapid growth in the environmental industry, both in equipment production and services sectors, in response to a number of driving forces. The most important one being the need to comply with new environmental laws and standards. Most engineering faculties have responded by either increasing the number of environmental options available to the students or, in a few cases, by introducing accredited environmental engineering programs. A variety of graduate programs have also

Research linkages in environmental engineering between universities and industry are less common than government sponsored research. Furthermore, most projects that are funded by industry also has significant contribution of government funds. It is however expected that industry will play a greater role in research funding as governments are more and more cutting back to reduce their enormous deficits.

Table 3. Examples of Industry Funded Environmental Engineering Research Project at Guelph (1994-1996)

PROJECT TITLE [SPONSOR]
Formation of chlorinated organic compounds by commercial bleach discharges to sewers [Chlorox]
Quality of storm water runoff. [Gamsby and Mannerow Ltd]
Enhanced biofiltration of waste off-gas streams. [Canadian Petroleum Products Institute]
Biofiltration pilot study for CGT's dry laminator emissions. [Canadian General Tower Limited]
Composting of source-separated municipal solid waste. [Procter & Gamble Inc.]
Fate of disposable diapers in composting systems. [Procter & Gamble Inc.]
Biological degradation of slaugtherhouse waste. [J.M. Schneider Limited]
Soil remediation using supercritical extraction. [GASRep]
Chemical spill behaviour. [Imperial Oil]
Stripping and volatilization in wastewater facilities. [Water Pollution Control Federation Institute]
VOC emissions from industrial drops and drains. [Dupont Chemicals]
Gasoline volatilization from wet soil. [Imperial Oil]
Biological remediation of diesel fuel contaminated soil. [Bell Canada]
Hydrocarbon flux measurement: method development and application. [Bell Canada]
Infiltration into permeable concrete block pavement. [Unilock Ltd.]
Thermal enrichment of stormwater runoff by paving. [Unilock Ld.]

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APPENDIX B

ACTIVITY A 2.26 STUDY TOURS REPORTS

A 2.26 57387
REPORTS - FINAL

Mary Jane Curtis
Supervisor, Administration
Ryerson International
Ryerson Polytechnic University
350 Victoria Street
Toronto, Ontario.
M5B 2K3

November 8, 1996

RE: Study Tours for Kontorn Chamniprasart and Rawat Vipia
November 4 - November 8, 1996

Mary Jane;

Kontorn and Rawat arrived on Saturday, November 2, 1996. I contacted them on Sunday to arrange for pick-up and transportation ot UW on Monday Morning. Since the missions of theses two individuals was somewhat different from each other, there was not a great deal of 'common time' with the two individuals except for lunches, dinners, and some specific activities of mutual interest. Specific individual reports from Dr. Kontorn and Mr. Rawat are attached to this communication.

Kontorn was primarily interested in the laboratory setup and equipment in the Mechanical Engineering department. As such, he was given an overview tour of the facilities and laboratories in Mechanical Engineering on his first day. On subsequent days he explored specific areas of particular interest to him; these included the wind tunnel laboratory, the heat transfer and fluid mechanics laboratory, the robotics laboratory, and the library. He was also provided with an undergraduate laboratory manual for the 3B academic term.

Rawat spent the majority of his formal study time with personnel in the Electrical and Computer Engineering department. His primary interest was in the construction and special considerations needed for a high voltage laboratory, for both undergraduate and graduate study and for research. He had extensive meetings with Prof. J.D. Cross (internationally respected for his research in this area), Prof. Shesha Jayaram, and the technician for the High Voltage Laboratory, Terry Weldon. In addition, he met with the Associate Chair for Graduate Studies and Research for the Department, Prof. A. Vanelli, and with the Chair of the Department, Prof. S. Chaudhuri.

I believe that both individuals enjoyed their stay at Waterloo and that their study tour was successful in achieving the objectives for their respective tours.

Respectfully submitted,

G.E. Schneider

G.E. Schneider
Associate Dean of Engineering
Undergraduate Studies
GES:1251

Attention:
Mary Jane Curtis
Supervisor-Administration
Ryerson International

The Summary Report:
Visiting University of Waterloo Mechanical Engineering Laboratory
By Dr. Kontorn Chamniprasart

We, me and Mr. Rawat, arrived at Toronto International Airport on Saturday, November, 2, 1996 at 6:30 p.m.. We got into hotel in Kittener that night. I received a phone call from Dr. Scheider on Sunday and making arrangements for Monday.

Monday morning Dr. Scheider kindly picked us up at the hotel and brought us to University of Waterloo. Dr. Scheider kindly arrange mechanical engineering laboratory tour for me and I did visit all undergraduate laboratories that I like to see, such as Fluid Mechanics Lab., Heat Transfer Lab., Materials Lab., Wind Tunnel, Machine Shop, etc.

I found out that the Heat Transfer Lab. was very interesting,so on Wednesday Dr. Schneider explained how the apparatus was builded and how to conduct the experiments. He also gave me the experiment direction sheets, which very useful for me.

The Wind Tunnel at University of Waterloo is also very impressive. I had a change to meet Dr. Ewart Brundrett, the designer of this wind tunnel. We had a long meeting and he kindly explained every thing about this Flexible Wall Wind Tunnel. He also gave me all documents and papers related to how to build the wind tunnel and how to conduct experiments in the wind tunnel.

We also have a change to visit the engineering library which is very interesting placed. Most engineering related books, references, journal can be find in this library. Finally, Friday afternoon, we have change to visit graduate and research laboratory.

I find my time at University of Waterloo very interesting and rewarding. I would like to thank all faculties at University of Waterloo for their time and a warm welcome. I also like to thank all staff of SUT-CUTC project for arrange such a convenient trip. Special thank to Dr. Scheider for his time and warmest hospitality.

Nov, 8, 96

Dr. Kontorn Chamniprasart
Lecturer, Mechanical Engineering School
Institute of Industrial Technology
Suranaree University of Technology

University of Waterloo
November 8,1996

About: A summary report of visit the High Voltage Lab at the University of Waterloo from November 1-11,1996

Dear Project Coordinator
Thailand-HRD CUTC-SUT

I have already visited the HV lab,discussed about detialed equipments needed,required grounding and other safety issues, posible research collaboration with Prof.Dr.J.D Cross, Assistant prof Dr.Shesha Jayaram and Mr.N Terry Weldon

And I have a good opportunity to discuss with Prof.Dr.Ewart Brundret,Prof.Dr.Antrony Vannelli and Prof.Dr.Sujeet K Chaudnuri.

Thank you very much for the staff that treat me and Dr.Kontorn very kindly and warmly,especially Prof.Dr. G.E Schneider that take care us everyday.

Your Sincerely

Rawat Vipia

(Rawat Vipia)
Instructor
School of Electrical Engineering
Suranaree University of Technology
THAILAND

APPENDIX C

ACTIVITY A 2.31A CO-OP PROGRAM
THAI STUDENTS IN CANADA
REPORTS

Co-op Work Term Report

" Whey protein isolates as an emulsifier in ice cream mixes "

A Report
Presented to Dr. Douglas H. Goff

Department of Food Science Ontario Agricultural College
University of Guelph

By

Piyachat Sintudeacha

School of Food Technology Institute of Agricultural Technology
Suranaree University of Technology
November 29, 1996

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1.Introduction

1.1 The definition of ice cream

The term " ice cream " is a family of whipped dairy products that are manufactured by freezing and are consumed in the frozen state, including ice cream that consists of either dairy or non-dairy fats, premium, higher fat versions, light, lower, fat versions, ice milk, sherbet, frozen yogurt, etc. The ice cream industry is a large consumer of fat. Fat not only provides flavor to ice cream and related products, but is also produces the smooth-eating texture that is both desired by and expected from the donsumers. The manufacturing process for ice cream and related products is similar and involves the preparation of a liquid mix, whipping and freezing this mix with high shear to a semi-frozen slurry, adding flavoring ingredients to this partially frozen mix, packaging and storage of the products (Goff,H.D. 1996).

1.2 The composition of and ingredients in ice cream

Ice cream has the following composition : a) greater than 10% milkfat by legal definition, and usually between 10%-16% fat; b) between 9-12% milk solids-not-fat, the component which contains the proteins (caseins and whey proteins)
and carbohydrates (lactose) found in milk; c) 12%-16% sweeteners, usually a combination of sucrose and glucose-based corn syrup sweeteners; and d) 0.2%-0.5% added stabilizers and emulsifiers, depending on each type of products. The balance, usually 55% to 64%, is water which comes from the milk (Goff,H.D. 1996).

The ingredients used to supply this composition include : a) a concentrated source of the milkfat, usually cream or butter ; b) a concentrated source of the milk solids-not-fat component, usually evaporated milk or milk powder; c) sugars including sucrose and glucose solids, a product derived from the partial hydrolysis of the cron starch component in cron syrup; and d) milk

The butter (fat) increases the richness of flavor in ice cream, produces a characteristic smooth texture by lubricating the palate, helps to give body to the ice cream, and aids in good melting properties.

The serum solids or milk solids-not-fat improve the texture of ice cream, help to give body and chew resistance to the finished product, are capable of allowing a higher overrun without the characteristic snowy or flaky textures associated with high overrun, and may be a cheap source of total solids.

The sweeteners improve the texture and palatability of the ice cream, enhance flavors, and are usually the cheapest source of total solids.

The stabilizers are a group of compounds, usually polysaccharides, that are responsible for adding viscosity to the unfrozen portion of the water and thus holding this water so that it can not migrate within the product. This results in an ice cream that is firmer to the chew. Without the stabilizers, the ice cream would become coarse and icy very quickly due to the migration of this free water and growth of existing ice crystals.

Emulsifiers have been used in ice cream mix manufacture for many years. They aid in the production for improvement of the whipping quality of the mix; production of a drier ice cream necessary for molding, fancy extrusion, and sandwich manufacture; smoother body and texture in the finished product; superior drawing qualities at the freezer producing a product with good stand-up properties and melt resistance; and more exact control of the product during the freezing and packaging operations (Goff,H.D.

1988).The emulsifying agents commonly used in the ice cream industry are the mono- and di-glycerides, and Polysorbate 80, polyoxyethylene sorbitan monooleate. Emulsifiers are surface active agents which move instantly to an interface where fat and water meet. Since each molecule of an emulsifier contains a hypophilic phase, they act to reduce the interfacial tension or the force which exists between the two phases of the emulsion.

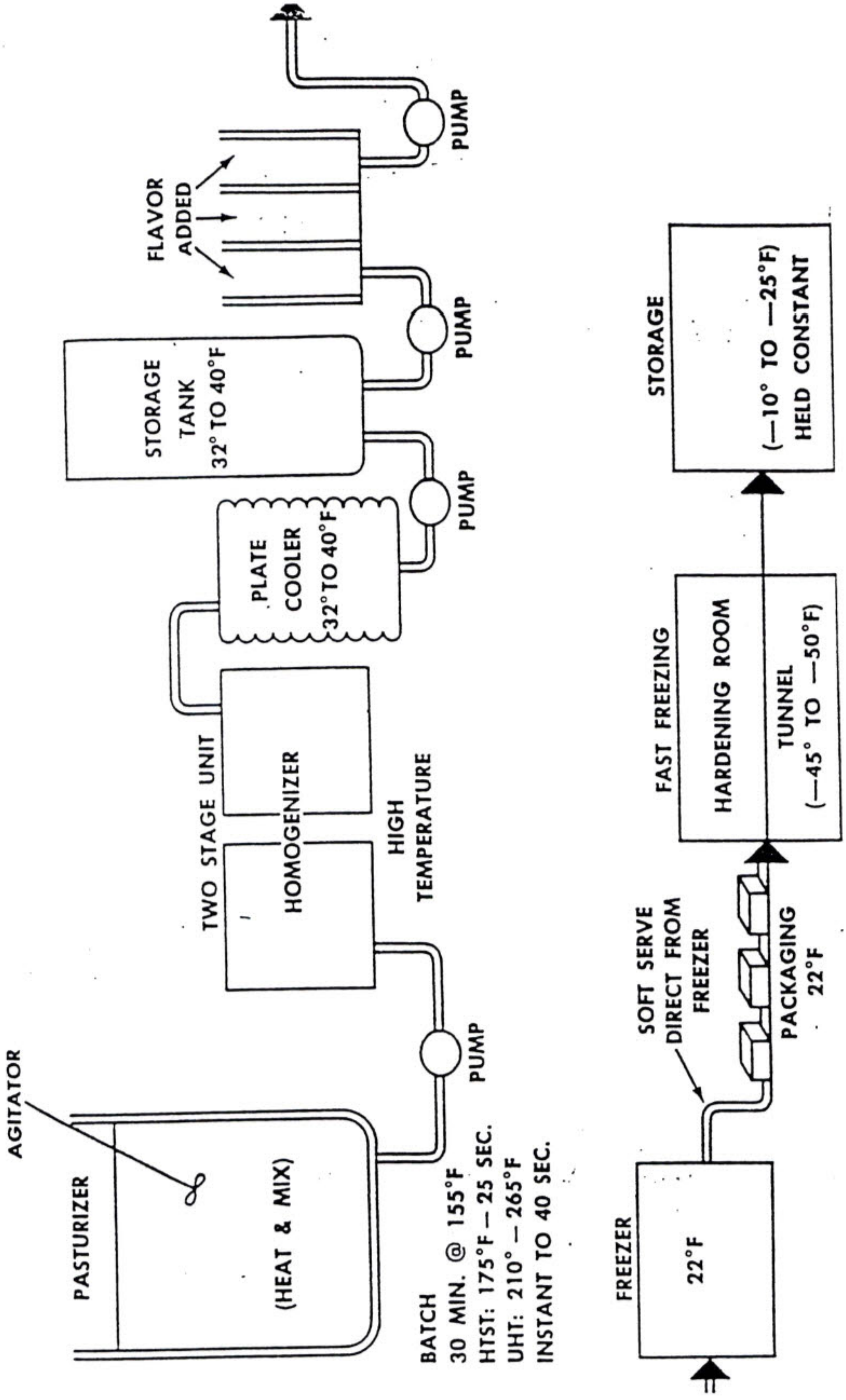
1.3 The manufacturing process of ice cream

Ingredients are chosen by the manufacturer on the basis of desired quality, availability and cost. The components are blended together and produce the ice cream mix. The first step of mix manufacture is pasteurization process which is designed to kill all of the possible pathogens that may be present. Organisms such as *Mycobacterium tuberculosis*, *Salmonella*, *Staphylococcus*, *Listeria*, and others that cause human disease can be found associated with farm animals and thus raw milk products must be pasteurized. Pasteurization also reduces the number of spoilage organisms such as psychrotrophs. the mix is also homogenized which forms the fat emulsion by breaking down or reducing the size of the fat globules found in milk or cream to less than 1μm. Homogenization helps to produce a smooth product when frozen. The mix is then aged for at least four hours and usually overnight (at 2-4°C). This allows time for the fat to cool down and crystallize, and for the proteins and polysaccharides to fully hydrate (Goff,H.D. 1996).

Following mix processing, the mix is drawn into a flavor tank where any liquid flavours, fruit purees, or colours are added. The mix then enters the freezing process which both freezes a portion of the water and whips air into the frozen mix. The barrel freezer is a scraped-surface, tubular heat exchanger, which is jacketed with a boiling refrigerant such as ammonia or freon. Mix is pumped through this freezer and is drawn off the other end in a matter of 30 seconds, (or 10-15 minutes in the case of batch freezers) with about 50% of its water frozen. There are rotating blades inside the barrel that keep the ice scraped off the surface of the freezer and also dashers inside the machine which help to whip the mix and incorporate air. Ice cream contains a considerable quantity of air, up to half of its volume. This gives the product its characteristic lightness. Without air, ice cream would be similar to a frozen ice cube.

As the ice cream is drawn with about half of its water frozen, particulate matter such as fruits, nuts, candy, cookies, or whatever you like, is added to the semi-frozen slurry which has a consistency similar to soft-serve ice cream. In fact, almost the only thing which differentiates hard frozen ice cream from soft-serve, is the fact that soft serve is drawn into cones at this point in the process rather than into packages for subsequent hardening. After the particulates have been added, the ice cream is packaged and is placed into a blast freezer at -30° to -40°C where most of the remainder of the water is frozen. Below about -25°C, ice cream is stable for indefinite periods without danger of ice crystal growth; however, above this temperature, ice crystal growth is possible and the rate of crystal growth is dependant upon the temperature of storage. This limits the shelf life of the ice cream (Goff,H.D. 1996). The manufacture of ice cream that described above are shown in figure 1.

Figure 1: The manufacture of ice cream.



(From : Lampert, 1970.)

1.4 Whey protein isolates processing

Whey is a dilute liquid containing lactose, proteins, minerals and traces of fat. Most whey is a result of cheese manufacture but some is a byproduct of casein production. Recovery of the proteins from whey can be accomplished using a variety of methods. The protein content of the final product is dependent upon the isolation method chosen. A comparison of ion exchange protein isolates with those produced by other techniques is summarized in Table 1. The table shows that samples isolated by ion exchange are substantially lower in ash, fat and lactose and usually higher in protein (Ross,N. 1989).

Table 1 : Composition of Whey Protein Isolated by Different Methods.

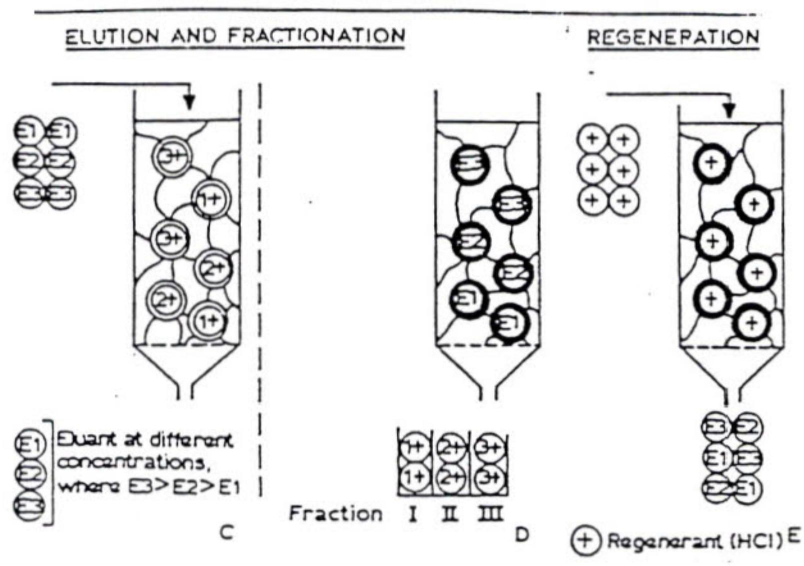
Process	Protein	Lactose	Minerals	fat
Electrodialysis	13-17	82-86	1-2	1
Metaphosphate complex	55-60	18-22	10-18	6-9
Gel Filtration (GF)	54-68	18-25	3-14	2-5
Ultrafiltration (UF)	30-70	20-25	35	45
Demineralisation (IE)	15	78	1	1
GF&UF	81	12	2	3
UF&IE	76	16	2	3
Ion Exchange (CM-C)	88	0.4	1.5	0.3

(From : Kanekanian and Lewis, 1986.)

The ion exchange phenomenon as applied to the manufacturer of whey protein products relies on the amphoteric nature of protein. This ability to act as either an acid or a base permits their adsorption onto a matrix that has a surface layer of charged groups. Recovery of the protein by elution from the matrix can be accomplished by a variety of techniques that act by causing a lowering of the charge-charge attraction between the protein molecules and the ion exchanger (Ross,N. 1989).

Ion exchangers consist of an insoluble matrix to which ionizable groups have been covalently bound. These charged groups (active groups) are associated with exchangeable counter-ions through the formation of electrostatic bonds. These counter-ions are oppositely charged to the active groups on the matrix and can be reversibly exchanged with other ions of the same charge without altering the matrix (Ross,N. 1989).

The term used to name an ion exchanger is dependent on its status of carrying either a positive or negative charge. An anionic exchanger refers to a positively charged material with anionic (negative) counter-ions. Conversely, a negatively charged material with cationic (positive) counter-ions is termed a cationic exchanger (Ross,N. 1989).



(From : Ross, 1989.)

In 2A, the ion exchanger is in the positively charged counter ion form. The molecules in the treated solution also bear a positive charge due to reduction of solution pH to below their isoelectric point. Thus in the adsorption stage (2B) the proteins compete with the counter-ions for the ionizable sites of the ion exchanger. Upon completion of adsorption the ion exchanger is first washed with either water or buffer followed by an elution step to recover the adsorbed protein. This can be done by altering the pH, by increasing the ionic strength or a combination of both. The choice of eluant is dependent upon the type of material adsorbed, the effect of eluant on it and the purity required in the final product (Ross,N. 1989).

Altering the pH away from the optimum for adsorption can effect elution in two ways. In a cation exchanger, a pH lower than the optimum value causes elution through competition of the H^+ with protein molecules for the ionizablesites or if it is a weak cationic exchanger a low pH will suppress ionisation. If the pH is raised above the optimum than elution is effected due to a neutralization of the charge on the adsorbed molecules which weakens the attraction forces between protein and the exchanger.

In 2C, elution is effected by the use of an eluant which increases the ionic strength. The salt ions compete with the protein for the active sites and thus the protein is released. The eluted protein may be collected in bulk or in successive fractions (2D) which comprise proteins having different affinities toward the ion exchanger.

The final stage (2E) involves regeneration of the ion exchanger. In this stage all contaminating ions are removed and the ion exchanger is replenished with positively charged counter-ions.

Optimum performance of an ion exchanger is dependent upon two fundamental properties, selectivity and capacity. The selectivity must be such that there is complete adsorption of the desired ion and efficient use of the desorbing reagent during the elution step. Capacity refers to the number of ions bound per gram (or ml) of ion exchanger. An ion exchanger that allows the treatment of a large volume of liquid per unit volume of resin is desireable (Ross,N. 1989).

And the stages involved in protein isolation and fractionation by ion exchange is outlined in figure 3.

Figure 3 : Stages involved in protein isolation and fractionation by ion exchange.

Raw Material
(whey protein in dilute solution)
↓
Pre-Treatment Procedure
- to increase ion exchange capacity
- pH adjustment by demineralization
↓
Treatment with suitable ion exchanger

↓ Cation
↓
weak strong
Normally under acidic conditions
↓
Column system
for bulk adsorption fractionation
↓

↓ Anion
↓
weak strong
Normally under alkaline conditions
↓
Stirred tank system
mainly for bulk adsorption
↓

Draining then washing with
water or buffer
↓
Elution
- alter the pH using HCL, NaOH, etc.
- increase the ionic strength using NaCl
↓
Protein Recovery From the Eluate
Eluate, containing low concentration of protein
concentration, using, e.g. ultrafiltration,
freeze or spray drying
↓
Protein Isolate
contains about 90% protein

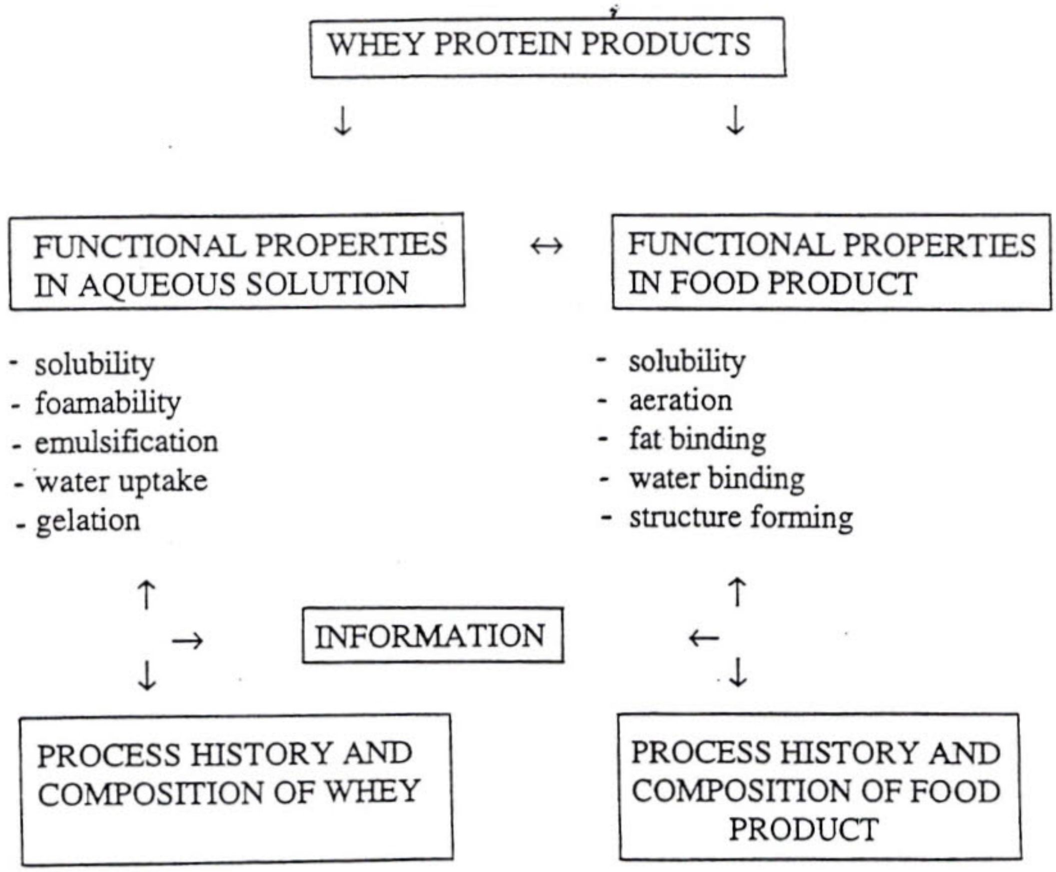
(From : Ross, 1989.)

1.5 Functional Properties of Whey Proteins

Whey protein isolates (WPI) are a group of proteins (88%w/w), consisting mainly of β-lactoglobulins and α-lactalbumins and it has 0.4%(w/w) lactose, 1.5%(w/w) minerals and only 0.3%(w/w) fat (Ross,N. 1989). They are used in the food and beverage industries for production of frozen desserts, ice creams, salad dressings, sport supplements or for replacing higher quantities of caseinates, soy protein, egg whites. They are also emulsifying agent or enhance functional properties and/or nutritional values of foods. The ability of proteins to give emulsifying properties of foods, such as texture, water holding capacity, etc. (Labropoulos,A.E. and Hsu,S.-H. 1996).

The term " Functional properties " generally is used in relation to physicochemical parameters of proteins in aqueous solutions or in simple model systems. Functional properties primarily reveal information on the processing history and composition of the whey protein product. The usefulness of these parameters in predicting corresponding functional characteristics in food products is limited, mainly because of the complex behavior of whey proteins with other ingredients of any food product during food processing. Differences are noted between functional properties in aqueous solution and food products are shown in Figure 4.

Figure 4 : Functional characteristics of whey protein products.



(From : Dewit,1990.)

The solubility of whey protein in aqueous solution may differ widely from their solubility in a pasteurized fruit drink as a consequence of interactions with fruit colloids in this beverage. Similar discrepancies may be observed between foaming properties (of whey proteins in water) and aeration (of food products), between emulsifying properties and fat binding, between gelation properties and structure forming. To predict the functional performance of whey proteins in many food products, these proteins must be in the undenatured state before food processing (Dewit,J.N. 1990).

Commercial milk protein products such as whey protein isolates intended for use in food products must possess reasonably good flavor, texture and color. Because one of the functional properties of whey protein isolates were emulsifying agent, they may be divided into three main groups : 1) those that reduce surface tension at o/w interfaces and promote emulsification and formation of phase equilibria between o/w emulsifier at the interface which stabilizes the emulsion, 2) those that interact with starch and protein components in food that modify texture and rheological properties and 3) those that modify the crystalization of fat and oils. Because food emulsifiers have a wide variety of diverse properties, there are many factors that will be used for selecting the type of emulsifier for a particular food product (Charalambous,G. and Doxastakis,G. 1989).

Cheese whey was once concidered a waste protein, but today whey protein isolates have high prices because of their excellent nutritional and functional properties. Whey protein isolates suffer from variations in composition, which influences their functional properties considerably. Most food emulsions are oil-in-water (o/w) systems. Emulsifier must be used in processing to reduce surface tension between fat and water phase that enhance their properties in many ways such as texture and structure of the products. The manufacture of food emulsions is a highly energetic and dynamic process in which successively fresh oil/water interfaces are created, protected by adsorption of surfactants and partially lost again by recoalescence of those emulsion. Stability of o/w emulsions seems to be seriously affected by the pH, temperature, the presence of salts during the emulsification process and the ionic strength of the aqueous phase (Fox,P.E. 1982).

1.6 The Use of Whey Protein Products

Whey proteins are often used to improve food products because of their high nutritional quality and their versatile functional properties. However, the behavior of whey proteins during food processing is very complex and is governed by their heat sensitivity. Many attempts have been made to predict desired functional characteristics in food products on the basis of functional properties of whey proteins (Dewit,J.N. 1990).

A systematic approach for the functional evaluation of whey protein products in a number of food systems has been outlined elsewhere. This procedure, which is shown schematically in Table 3 will be followed in the discussion of the various food product groups. The main product groups mentioned in column 1 of this table are detailed in a number of related model products in column 2, which in turn result in the functional demands on whey proteins summarized in column 3. Most of these demands are related to the functional properties of whey proteins.

Table 3 : Applications of, and functional demands made on, whey protein isolates in food products.

Food products	Related model products	Functional demands
Beverages	Chocolate drink (pH 6.5) Soft drink (pH ~ 3.0)	Colloidal stability Solubility
Confectionery	Frappe Meringue	High whipping powder Foam stability at high temperature
Desserts/dressings	Whipped topping Salad dressing Ice cream	Whipping ability with fat Emulsifying ability at pH 4.0 Emulsifying ability
New dairy products	Cheese-like product Spreadable product	Heat setting Emulsification and water-binding
Meat products	Ham Frankfurter	Water solubility at low viscosity water- and fat-binding
Bakery products	Bread Cake	Dough formation Fat-binding/heat setting

(From : Fox, 1982.)

1.6.7 Bakery Products

For both nutritional and organoleptic reasons, there is continuous interest in fortifying or substituting wheat flour by milk solids in bakery products. It is well established that gluten, the major wheat protein complex, is the important determinant of the visco-elastic properties of dough in the breadmaking process. Moreover, the whey protein fraction appears to contain a loaf volume depressant, which is tentatively identified as proteose peptone component.Characteristic parameters in the breadmaking process are the water absorption of the mix, the rheological behaviour of the dough and the volume and crumb of the bread. The lipid fraction in whey is very important for the baking properties of WPI in bread. The use of WPI as a nutritious supplement in bread is an area with considerable potential. The removal of loaf volume depressants and the accumulation of whey lipids, will hopefully improve the functional quality of whey proteins for breadmaking. A quite different situation exists in cake where, mainly for economic reasons, eggs are replaced by cheaper protein products. The main functions for egg proteins in a cake are encapsulation of the fat droplets during the mixing process, stabilization of the aqueous foam in the intermediate bakery stage and coagulation of the egg proteins during the heat-setting stage of the cake batter that replaced by WPI.

1.7 Functional Role of Proteins and Emulsifiers in ice cream

Ice cream is a complex system, composed of fat globules, air bubbles, ice crystals and an unfrozen serum phase. The fat globlues (coated with a protein / emulsifier layer) are linked together in a partially coalesced structure around the air bubbles to form a matrix which holds the foam structure together with the ice crytals. The unfrozen serum phase is composed of the sugars and high molecular weight polysaccharides in a freeze concentrated form (Goff, H.D. and Jordan, W.K. 1989).

Emulsifiers and stabilizers are used quite extensively in the manufacture of ice cream, they both play an important role in the formation of the structure of ice cream. Stabilizers are added to increase smoothness in body, texture and reduce or protecting crystal growth during storage and temperature fluctuation, and to improve melt down properties (Goff, H.D. and Caldwell, K.B. 1991).

Emulsifiers (surface active agents) are used to improve the whipping quality, create a drier ice cream with smoother body and texture and increase the standing properties and melt resistance. Emulsifiers act during homogenization. Homogenization increases the number of fat globules by greatly reducing them in size. This reduction in size causes an increase in total surface area exposed which results in an increase in total free energy in the emulsion. The newly formed globules are devoid of protective membrane, and readily absorb material form the environment to lower this total free energy. The material that can lower the interfacial tension the most more readily adsorbs at the interface. Emulsifier can lower the interfacial tension much more than the natural material present in the milk serum (casein, undenatured whey protein, phospholipid, lipoprotein molecules, and components of the original milk fat globule membrane), thus are preferably adsorbed at the interface. Emulsifiers reduce the stability of the fat globules to partial coalescence during whipping / freezing stage (which also produces a lot of air bubbles in the system) which leads to the desirable structure of the ice cream. (Goff, H.D. and Jordan, W.K. 1989). Fat destabilization results from a lower interfacial tension between fat globules and air bubbles than interfacial tension between air bubbles and water, or fat globules and water. So when the ice cream mix was frozen the fat globlues partly or completely cover the air bubbles. Thus, these fat globules surround air bubbles by partial coalescence. This is how the air bubbles are stabilized in the ice cream structure.

2.Material , Methods and Results

Emulsion (40% of mix)
Composition : butter, water, WPI
↓
Pasteurization (heat 65°C, 30 min)
↓
Homogenization
(2 stages : 2500 psi and 500 psi)
↓
Cooling in cold water
Fridge 4°C
↓
Storage overnight 4°C (Aging)

Thickening Solution (60% of mix)
Composition : water, SMP, sugar, CSS, WPI
↓
Pasteurization (heat 80°C & 75°C and 10 & 20 min)
↓
Cooling in cold water
Fridge 4°C
↓
Storage overnight 4°C (Aging)

Viscosity (Brookfield)
at 4°C

Creaming (Babcock)
(Storage 2 days)

↘ ↙

Mixing
↓ → Viscosity (Brookfield) at 4°C

Freezing
2 L mix
22°F (-5°C) 15 min

Fat destabilization → Storage over night → Absorbance λ = 540 nm
samples every 2.5 min / Fridge 4°C / with Spectronic 88
from 0 - 15 min

Figure 5 : The process of ice cream making ; WPI = whey protein isolates, SMP = skim milk powder, CSS = corn syrup solids.

Objective

- To study the effect of heating conditions and levels of whey protein isolates added in ice cream mixes. These proteins are intended to replace other emulsifying agents, as well as being a protein source for the mix.

Variables

1. % WPI in Emulsion
2. % WPI in Thickening Solution
3. Heatihg temperature of Thickening Solution
4. Heating time of Thickening Solution

Measurements

1. Stability of Emulsion (Top/Bottom)
2. Size distribution of Emulsion
3. Viscosity of Mixes
4. Viscosity of Thickening Solution
5. Overrun of Ice Cream
6. Fat destabilization in Ice Cream
7. Size distribution of Ice Cream

2.1 Preparation of the ice cream mix

The standard formulation was used for all preparation consisting of 10% fat, 10% sugar, 5% glucose solids, 11% milk solid non-fat (MSNF), and 64% water added. The mix prepared with butter, skim milk powder, sucrose, corn syrup solids and whey protein isolates.

The initial study was performed to determine the appropriate range of WPI concentration required in the mix to act as an emulsifier and stabilizer. To facilitate the experiment the mix was prepared as two separate solution : an emulsion composed of water, fat and WPI and a solution of high viscosity composed of skim milk powder, sugar, glucose solids, water and WPI.The sugar and corn syrup solids were added to the thickening solution to restore the standard formulation of ice cream mixes when added to the emulsion.

The emulsion was prepared by melting the butter in tap water (at ~ 45°C) using a double jacked steam pot. Once the butter was melted, the selected concentration of WPI (see Table 4) was added and mixed in to solution using a mechanical stirrer. The emulsion was homogenized immediately after pasteurization using a two stage super homogenizer. The first stage was set at 2500 psi and the second at 500 psi. The homogenized emulsion was then placed in a cool water bath for 20 minutes followed by storage at 4°C for 24 hours. Samples for creaming (emulsion stability) analysis(100 ml in a 100 ml graduated cylinders) and a sample for particle size distribution analyses (40 ml) were taken before the homogenized emulsion was placed in the cooling bath and then stored at refrigeration temperatures until used (24 hrs).

The thickening solution was prepared in a double bottom steam pot by dispersing the dry ingredients in tap water (~ 45 °C) and heat treated according to the conditions outlined in Table 4. The WPI was blended with the sugar prior and then the dry ingredients where mixed into solution using a mechanical stirrer and followed to aging at 4°C for 24 hrs.

Table 4 : Shown the combination performed during preparation of the ice cream mix.

Type	% WPI	Heating temperature	Heating time
Emulsion	0.15%	65°C	30 min
	0.275%	65°C	30 min
	0.40%	65°C	30 min
Thickening Solution	15% replacement of SMP with WPI	75°C	10 min
			20 min
		80°C	10 min
			20 min
	20% replacement of SMP with WPI	75°C	10 min
			20 min
		80°C	10 min
			20 min

2.2 Freezing of the mixes

The emulsion and thickening solution were blended together after aging overnight at 4°C in the ratio 1:1.5, obtained from figure 5. In the situation where a gel formed, a Black & Deker household 3 speed mixer was used to disperse the structure. Once blended together, the solution was mixed using a mechanical mixer for about 1 min. A flavoring vanilla-vanillin extract was added at a concentration of 1.5 ml/kg to all mixes after aging. Mixes were frozen in a Tayor batch freezer until the mix temperature reached -5°C (22°F). Once the correct temperature was reached, the refrigeration was turned off and the mix whipping continuted. Aliqots (40ml) of frozen mix were removed from the barrel of the batch freezer every 2.5 min starting at time zero and analysed for fat destabilization by Spectronic 88. The overrun was measured at time 15 min for each ice cream by compared weight of ice cream (at 15 min) in the cup measured with overrun table for Batch Freezer that is shown in Table 5.

2.4 Viscosity measurement

Samples of the thickening solution and mixes were measured for apparent viscosity the same day the mixes were made (i.e. after aging for 24 hrs). In this experiment, the rheology of the mixes were tested using the Brookfield; synchro-electric viscometer model LVT. The spindles were used depending on sample. Full 400 ml beaker of sample and spindles were allowed for equilibrium at 4°C (~ 1 hr) before measurement.

Results

Table 7 : Viscosity of the mix prepared with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently.

% wpi in emulsion	% wpi replacement	T(C)/time	Viscosity (mPa.s)
0.15	15%	75/10	20
		75/20	19.3
		80/10	356.4
		80/20	536.7
	20%	75/10	19.2
		75/20	19.3
		80/10	462.8
		80/20	2438.4
0.275	15%	75/10	18.68
		75/20	18.78
		80/10	151.25
		80/20	257.25
	20%	75/10	15.8
		75/20	17.4
		80/10	183.5
		80/20	379.1
0.4	15%	75/10	15.2
		75/20	18.6
		80/10	31.8
		80/20	312
	20%	75/10	14.5
		75/20	18.6
		80/10	178.7
		80/20	299.1

2.5 Particle size distribution analysis

Particle size measurement of the emulsion and mixes were performed using a Mastersizer X (Malvern Instruments) by optical parameters of a presentation code 0303. In the case of the emulsion, the sample was tested after 24 hours of storage so they could be tested at the same time as the samples of the ice cream. Samples of ice cream were tested the same day they were prepared. The particle size is expressed as the $D_{(3,2)}$ value and the area of fat surface of particle size is presented in Sp.A.S.(m^2 /g) of the solution.

Results

Table 8 : Particle size distribution of the mix prepared and % overrun with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently.

Mix no.	rep	% wpi E	% wpi TS	H-temp	H-time	visc @ 30 rpm	over run	Size distribution of parilces		
									1 peak	2 peak
1	1	0.15	15	75	10	19	45	normal	0.68	
2	2	0.15	15	75	10	22.4	60	normal	0.7	
3	1	0.275	15	75	10	22	70	binomial	0.69	75
4	2	0.275	15	75	10	15.2	73.8	normal	0.75	
5	1	0.4	15	75	10	14.5	75	binomial	0.88	75
6	2	0.4	15	75	10	15	67.5	binomial	0.78	70
7	1	0.15	20	75	10	21.8	57.5	normal	0.83	
8	2	0.15	20	75	10	16	55	binomial	0.93	100
9	1	0.275	20	75	10	14.8	72.5	normal	0.58	
10	2	0.275	20	75	10	16.5	71.3	normal	0.63	
11	1	0.4	20	75	10	15	70	binomial	0.55	77.5
12	2	0.4	20	75	10	13	75	binomial	0.56	80
13	1	0.15	15	75	20	17	60	normal	0.61	
14	2	0.15	15	75	20	19.2	80	normal	0.65	
15	1	0.275	15	75	20	20	62.5	normal	0.65	
16	2	0.275	15	75	20	12	67.5	binomial	0.71	
17	1	0.4	15	75	20	16	67.5	binomial	0.84	68
18	2	0.4	15	75	20	21	65	binomial	0.88	80
19	1	0.15	20	75	20	20	57.5	binomial	1.2	100
20	2	0.15	20	75	20	17	60	normal	0.95	33
21	1	0.275	20	75	20	14.5	72.8	normal	0.7	
22	2	0.275	20	75	20	20	71.3	normal	0.64	
23	1	0.4	20	75	20	17.6	62.5	binomial	0.64	80
24	2	0.4	20	75	20	18.5	73.8	normal	0.69	
25	1	0.15	15	80	10	445	80	binomial	0.85	75
26	2	0.15	15	80	10	37.4	58.8	binomial	0.82	80
27	1	0.275	15	80	10	180	62.5	binomial	1.11	73
28	2	0.275	15	80	10	111	66.3	binomial	0.8	68
29	1	0.4	15	80	10	35	67.5	binomial	0.83	73
30	2	0.4	15	80	10	30	62.5	normal	0.79	
31	1	0.15	20	80	10	522.5	57.5	binomial	1	74
32	2	0.15	20	80	10	297.5	58.75	binomial	0.98	75
33	1	0.275	20	80	10	186.2	58.8	binomial	0.98	65
34	2	0.275	20	80	10	157	65	binomial	0.9	77
35	1	0.4	20	80	10	155	57.5	binomial	0.85	74
36	2	0.4	20	80	10	158	73.8	binomial	0.78	70
37	1	0.15	15	80	20	785	57.5	binomial	0.78	70
38	2	0.15	15	80	20	84	56.3	binomial	0.9	70
39	1	0.275	15	80	20	150.5	57.5	binomial	0.95	60
40	2	0.275	15	80	20	307.5	67.5	normal	0.85	
41	1	0.4	15	80	20	417.5	58.8	binomial	0.84	57
42	2	0.4	15	80	20	151.4	70	binomial	0.81	63
43	1	0.15	20	80	20	204.8	56.3	binomial	0.88	73
44	2	0.15	20	80	20	2000	55	binomial	0.8	70
45	1	0.275	20	80	20	365	73.8	normal	0.94	
46	2	0.275	20	80	20	336.25	70	normal	0.81	
47	1	0.4	20	80	20	252	57.5	binomial	0.7	70
[illegible]	[illegible]	[illegible]	[illegible]	80	20	[illegible]	[illegible]	binomial	0.75	70

2.6 Fat destabilization analysis

Samples for fat destabilization were thawed overnight in the fridge and 40 ml gently mixed before analyses. Three grams of thawed mix was weighed into a 50 ml erlenmeyer flask and diluted with 27 ml of dionized water at room temperature. One ml of this solution was removed into a 50 ml volumetric flask and added with dionized water at room temperature (1: 50 dilution) and measured for absorbance at 540 nm using the Spectronic 88 Spectrophotometer. Percent fat destabilized was calculated as :

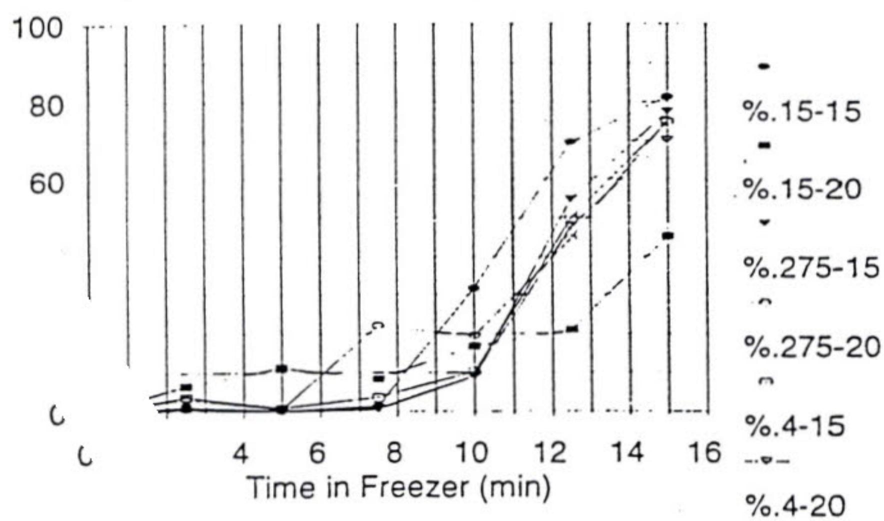
$$\frac{A_{\text{unfrozen mix}} - A_{\text{sample}}}{A_{\text{unfrozen mix}}} \times 100\ \%$$

A = Absorbance

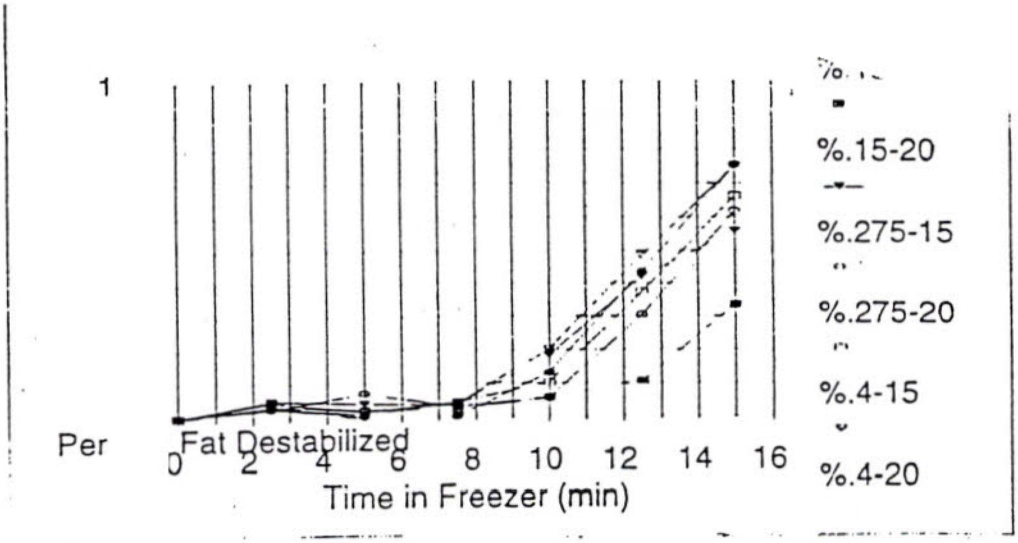
Dionized water was used as blank. The percent of fat destabilized was then plotted against time in the barrel freezer (Goff,H.D. and Jordan,W.K. 1989).

Results

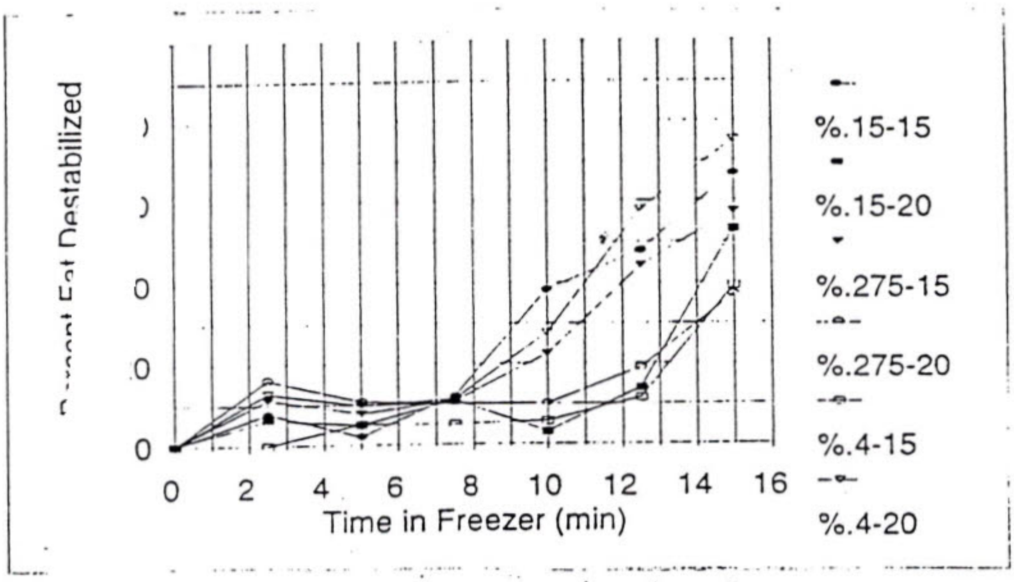
Figure 7 : Fat destabilization exhibited by mixes prepared with different ntration of WPI in the emulsion and thickening solution. The 1st and 2 nd number e: the % WPI in the emulsion and thickening solution respectively.



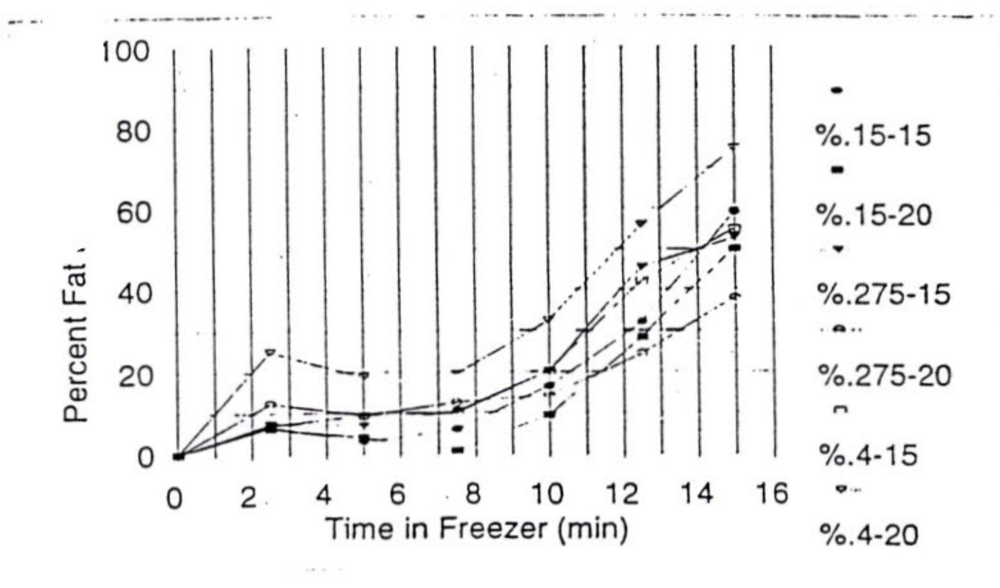
a) H ated at 75C for 10 min



b) Heat treated at 75C for 20 min



c) Heat treated at 80C for 10 min



d) Heat treated at 80C for 20 min

Table 9 : Tests of Significance for VIS@30 using UNIQUE sums of squares.

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design 1 * * * *

Tests of Significance for VISC@30 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	2017525.97	24	84063.58		
HTEMP2	1094161.12	1	1094161.1	13.02	.001
HTIME2	192970.58	1	192970.58	2.30	.143
WPITS2	99722.66	1	99722.66	1.19	.287
WPIE2	318277.97	2	159138.99	1.89	.172
HTEMP2 BY HTIME2	191047.88	1	191047.88	2.27	.145
HTEMP2 BY WPITS2	101296.78	1	101296.78	1.21	.283
HTEMP2 BY WPIE2	309190.25	2	154595.12	1.84	.181
HTIME2 BY WPITS2	18183.81	1	18183.81	.22	.646
HTIME2 BY WPIE2	54544.64	2	27272.32	.32	.726
WPITS2 BY WPIE2	83209.38	2	41604.69	.49	.616
HTEMP2 BY HTIME2 BY WPITS2	17155.53	1	17155.53	.20	.656
HTEMP2 BY HTIME2 BY WPIE2	56503.31	2	28251.65	.34	.718
HTEMP2 BY WPITS2 BY WPIE2	83194.33	2	41597.16	.49	.616
HTIME2 BY WPITS2 BY WPIE2	51610.18	2	25805.09	.31	.739
HTEMP2 BY HTIME2 BY WPITS2 BY WPIE2	51179.50	2	25589.75	.30	.740
(Model)	2722247.91	23	118358.60	1.41	.205
(Total)	4739773.88	47	100846.25		

R-Squared = .574
Adjusted R-Squared = .166

Table 10 : Tests of Significance for OVERRUN using UNIQUE sums of squares.

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design 1 * * * *

Tests of Significance for OVERRUN using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	3134.50	72	43.53		
HTEMP2	128.34	1	128.34	2.95	.090
HTIME2	52.51	1	52.51	1.21	.276
WPIE2	1658.64	2	829.32	19.05	.000
WPITS2	3.76	1	3.76	.09	.770
HTEMP2 BY HTIME2	2.67	1	2.67	.06	.805
HTEMP2 BY WPIE2	355.05	2	177.52	4.08	.021
HTEMP2 BY WPITS2	60.17	1	60.17	1.38	.244
HTIME2 BY WPIE2	33.69	2	16.85	.39	.681
HTIME2 BY WPITS2	73.50	1	73.50	1.69	.198
WPIE2 BY WPITS2	120.88	2	60.44	1.39	.256
HTEMP2 BY HTIME2 BY WPIE2	435.10	2	217.55	5.00	.009
HTEMP2 BY HTIME2 BY WPITS2	49.59	1	49.59	1.14	.289
HTEMP2 BY WPIE2 BY WPITS2	58.22	2	29.11	.67	.516
HTIME2 BY WPIE2 BY WPITS2	81.77	2	40.88	.94	.396
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	74.73	2	37.37	.86	.428
(Model)	3188.63	23	138.64	3.18	.000
(Total)	6323.13	95	66.56		

R-Squared = .504
Adjusted R-Squared = .346

Table 11 : Tests of Significance for D32 using UNIQUE sums of squares.

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * *

Tests of Significance for D32 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	2.62	72	.04		
HTEMP2	1.60	1	1.60	43.87	.000
HTIME2	.08	1	.08	2.26	.137
WPIE2	.06	2	.03	.83	.438
WPITS2	.05	1	.05	1.32	.254
HTEMP2 BY HTIME2	.01	1	.01	.27	.602
HTEMP2 BY WPIE2	.13	2	.07	1.82	.170
HTEMP2 BY WPITS2	.04	1	.04	1.03	.313
HTIME2 BY WPIE2	.05	2	.02	.63	.537
HTIME2 BY WPITS2	.08	1	.08	2.15	.147
WPIE2 BY WPITS2	.46	2	.23	6.25	.003
HTEMP2 BY HTIME2 BY WPIE2	.11	2	.05	1.44	.243
HTEMP2 BY HTIME2 BY WPITS2	.20	1	.20	5.46	.022
HTEMP2 BY WPIE2 BY WPITS2	.18	2	.09	2.49	.090
HTIME2 BY WPIE2 BY WPITS2	.05	2	.02	.62	.541
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	.02	2	.01	.22	.804
(Model)	3.10	23	.13	3.69	.000
(Total)	5.72	95	.06		

R-Squared = .541
Adjusted R-Squared = .395

Table 12 : Tests of Significance for FD@12.5 using UNIQUE sums of squares.

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * *

Tests of Significance for FD@12.5 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	34278.24	72	476.09		
HTEMP2	440.50	1	440.50	.93	.339
HTIME2	638.91	1	638.91	1.34	.251
WPIE2	3360.39	2	1680.19	3.53	.035
WPITS2	3399.59	1	3399.59	7.14	.009
HTEMP2 BY HTIME2	948.28	1	948.28	1.99	.162
HTEMP2 BY WPIE2	585.54	2	292.77	.61	.543
HTEMP2 BY WPITS2	275.20	1	275.20	.58	.450
HTIME2 BY WPIE2	166.03	2	83.02	.17	.840
HTIME2 BY WPITS2	516.90	1	516.90	1.09	.301
WPIE2 BY WPITS2	6972.64	2	3486.32	7.32	.001
HTEMP2 BY HTIME2 BY WPIE2	170.81	2	85.41	.18	.836
HTEMP2 BY HTIME2 BY WPITS2	1.80	1	1.80	.00	.951
HTEMP2 BY WPIE2 BY W PITS2	1223.50	2	611.75	1.28	.283
HTIME2 BY WPIE2 BY W PITS2	435.56	2	217.78	.46	.635
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	393.41	2	196.70	.41	.663
(Model)	19529.07	23	849.09	1.78	.033
(Total)	53807.30	95	566.39		

R-Squared = .363
Adjusted R-Squared = .159

3. Discussion

The objective of this study was to investigate the potential use of WPI as an emulsifier and stabilizer in the manufacture of ice cream, through the process of selective homogenization. Whey protein isolate (WPI) is manufactured from whey which is a by-product of cheese making, therefore is widely available. It has some properties (emulsifying and gelling) which indicates that it could be used as an emulsifier and stabilizer replacer as well as a source of protein in ice cream. Other materials present in milk have a better affinity for the interface than WPI, and if present they will be preferably adsorbed rather than WPI. The adsorption of WPI onto the oil water interface can be done by controlling the material present at homogenization. This was achieved by selective homogenization, which consisted of homogenizing separately an emulsion composed of a fat source, water and small amount of WPI. The rest of the ingredients were prepared as a separate solution with WPI to act as a stabilizer.

The ice cream mix used had the following composition: 10% milk fat, 10% sugar (sucrose), 5% glucose solids(corn syrup solids) and 11% milk solids-not-fat (MSNF). The mix was prepared as two solutions: an emulsion containing the fat, WPI (0.15, 0.275 and 0.4%) and water to create a 25% fat emulsion. This emulsion was pasteurized at 65°C for 30 minutes in a double jacket steam pot followed by homogenization (2500/500 psi) in a two stage homogenizer and cooled at 4°C. The thickening solutions were comprised of the rest of the ingredients (skim milk powder, sucrose, corn syrup solids and WPI) and the remainder of the water to make up the correct composition of the final mix. The thickening solution was pasteurized at 75 or 80°C for 10-20 min depending on the treatment required in a double jacket steam pot, and was cooled directly after pasteurization. The two solutions were aged separately at 4°C for 24 hours. They were then mixed to form a 6 kg ice cream mix (40% emulsion, 60% thickening solution). Then, the ice cream mix was passed through the batch freezer untill the correct temperature reached -5°C. The finished product was measured to study the properties of ice cream.

In stability of emulsion test, the emulsion was put into a 100 ml cylinder right after homogenization and stored for two days at 5°C. The percentage of fat was measured in the top and bottom 9 grams of the emulsion using the Pennsylvania Method of the Babcock test. It was shown that increasing the total percentage of protein in the mix maintained the stability but it was separated between fat and oil phases when reducing the total percentage of protein. The emulsions containing 0.275% and 0.4% WPI showed good stability, with the latter being slighly more stable (less creaming and smaller mean size distribution of the fat globules; Table 6). The emulsion containing 0.15% WPI was unstable; significant flocculation was observed after 48 hrs.

A two-litre aliquot of the ice cream mix was frozen in a batch freezer to -5°C and held in the freezer for a total of 15 min of agitation. Samples (40 ml) were removed from the barrel every 2.5 min and analyzed for the percentage of fat destabilization. Samples were diluted 1:500 with deionized water and absorbance was measured at 540 nm. Percent fat destabilized was calculated as $[(A_{mix}-A_{ice\ cream})/ A_{mix}] \times 100$ %. Table 12 shows a significant difference in fat destabilization with different values of WPI in emulsion and in thickening solution. The highest degree of fat destabilization was observed in the mix heated at 75°C for 10 min with the emulsion composed of 0.275% and 0.4% WPI, and either the thickening solution containing 15% or 20% WPI. The increase in heating time of the thickening solution at 75°C from 10 to 20 min seemed to cause a decrease in fat destabilization in all the mixes (0.15%, 0.275% and 0.4% WPI in emulsion). The same effect was observed with the increase of WPI replacement in the thickening solution from 15-20%. Increasing the temperature or increasing the percent of WPI in the thickening solution both caused an increase in viscosity which seems to have the effect of slowing down the rate of coalescence or preventing coalescence to a certain degree. This is supported by the mean size distribution analyses of the ice cream (taken at 15 min).

Aliquots (40 ml) of ice cream were taken after freezing and were thawed overnight at 5°C. A few drops were put into the Mastersizer X for particle size analysis. The values obtained were the average diameter ($D_{(3,2)}$) and the specific surface area Sp.A.S.,m^2/g) of the particles. A decrease in mean size distrition by an increase of WPI replacement from 15 to 20 % was shown. However, there was no significant variation when the heating time was increased from 10 to 20 min (Table 11). Heating the thickening solution at 80°C caused a dramatic increase in viscosity. The thickening solution with 15 % WPI formed a gel when heated at 80°C for 20 min, and the thickening solution with 20 % WPI gelled when heated at 10 and 20 min. Samples (500 ml) of the thickening solution and ice cream mix were sampled after aging for viscosity. The viscosity was measured with a Brookfield synchro-electric viscometer model LVT. Ideal range of viscosity was 30-180 mPa.s which was used a standard (medium viscosity); it gave a characteristic of ice cream mix that can flow and not melt too rapidly. Table 9 shows the test of significance for viscosity using Unique sums of squares that presents a significant difference in viscosity with different heating time of thickening solution.

The highest degree of overrun was observed in the ice cream made with thickening solution heated at 75°C for 10 min (~71% overrun for 0.275% and 0.4% WPI emulsion; Table 8). The increase in heating time and temperature caused a decrease in overrun, but there was no significant difference in overrun when the % WPI replacement was increased in the thickening solution. From these basic sensory analysis, it was shown that the ice cream made with 0.275% WPI in the emulsion, 20% WPI replaced, heated at 75°C for 10 min, showed good meltdown properties, good body and chew resistance and was smooth and creamy. The ice cream made with 0.4% WPI in the emulsion showed similar properties but not as much.

4. Conclusion

An increase in the total percentage of protein in the mixture maintained the stability in a standard formulation; whereas a reduction in percentage of protein caused the separation of water and oil phases. The protein is acting as an emulsifying agent. The mixture was composed of two solutions: emulsion and thickening solution. Selective homogenization proved to be advantageous to allow the whey protein to act at the interface. It was observed that at a certain concentration, WPI can act as an emulsifier; it showed good emulsion stability after 48 hrs, good partial coalescence of the fat measured by fat destabilization and good overrun. A concentration of 0.275% WPI in the emulsion showed the best properties. Replacing a portion of the milk solids by WPI proved to be beneficial on the structure of the ice cream: 20% replacement showed less partial coalescence than 15% and showed improved texture, body, chew resistance and melt down properties. The heating time and temperature affected the viscosity of the thickening solution but did not affect significantly the characteristics of the ice cream. This study suggests that WPI is a potential replacer of stabilizers and emulsifiers currently in use.

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CO-OPERATIVE WORKTERMS REPORT

PRESENTED

BY

PODJANA CHUMKHUNTHOD

B3650172

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Preface

This report were created during the author was doing training in food science department, University of Guelph, Ontario, Canada in the area of Food Microbiology , Co-operative student program during June 3 to Dec 20, 1996. Most of informations involve about job description, organization of department, the results of work term co-operative, they include experience which the author got during that period. The author think that it will be useful for someone who is interested in Modern technology in Food Microbiology and for the co-operative students of the next generation to gain ideas about the co-operative program.

Thank you The HRD SUT-CUTC Project (co-operative education student exchange program) so much for giving me a good chance to come to Canada.

Podjana Chumkhunthod
Dec 20,1996

Contents

1. The organization of Food Science Deparment University of Guelph, Ontario, Canada.

Chair--Marc LeMaguer
Graduate co-ordinator-Rickey Y.Yada
Graduate secretary--Margaret Walmsley

Graduate Faculty:
Shai Barbut--Associatate Professor
Douglas G. Dalgleish--Professor and Ontario Dairy Council and Industrial Reseach Chair in Dairy Technology
H. Douglas Goff--Associate Professor
Mansel W.Griffiths--Professor and Ontario Milk Marketing Board and Industrial Reseach Chair in Dairy Microbiology
Schraft Heidi--Associate Professor
Linda J,Harris--Associate Professor
Arthur R.Hillnd--Associate Professer
Yukio Kakuda--Associate Professor
Marc LeMaguer--Professor
Robert W.J.Lencki--Assistant Professor
Alejandro G.Marangoni--Assistant Professor
Ronald E.Subden--Professor
Howard J.Swatland--Professor
Marvin A.Tung--Professor and Weston Foundation Food Packaging Technology Chair
Rickey Y.Yada--Professor

Associated Graduate Faculty:
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Malcolm C.Bourne--Professor, Food Science and Technology, Cornell University
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Vladimir F.Rasper--Professor Emeritus and Adjunct Professor
David W. Stanley--Adjuct Professor
Samuel Wang--Vineland Research Station Adjunct Professor
O.P. Ward--University of Waterlooo, Adjunct professor

1.1 Organization Chart of Food Science Deparment University of Guelph, Ontario, Canada

```
                          .------>Dairy: Mansel W. Griffiths
                          .              Douglas G. Dalgleish
                          .              Arthur R. Hill
                          .              H. Douglas Goff
                          .
                          .------->Meat: Shai Barbut
                          .              Howard J. Swatland
                          .
                          .------->Microbiology: Mansel W. Griffiths
                          .                      Schraft Heidi
Food Science------>                              Ronald E. Subden
                          .
                          .------->Chemistry: Alejandro G. Marangoni
                          .                   Rickey Y.Yada
                          .                   Yukio Kakuda
                          .
                          .------->Physic/Material Science:
                          .                         DouglasG.Dalgleish
                          .                         H. Douglas Goff
                          .                         Marvin A. Tung
                          .                         David W. Stanley
                          .
                           ------->Engineering: Marc LeMaguer
                                                Robert W.J. Lencki
                                                Valerie J. Davidson
```

1.2 Coworkers in Food Microbiology Laboratory

Dr. Mansel Griffiths-Professor
Dr. Heidi Schraft-Assistant Professor
Dr. Jinru Chen-Research Association

Ph.D Students
- Lynn Mcintyre
- Derrick Bautista
- Reem Barakat

M.Sc. Students
- Stacy Favrin
- Andy Buechin
- Stephane Cadieux
- Shirley Lin

Undergraduate Research Student
- Suzanne Smith

Technician
- Yolanda Hirvi
- Ann Toner
- Sukhvinder Kaur

International Co-operative students
- Podjana Chumkhunthod from Thailand
- Hedwig Kasstra from Netherland
- Bianca Brunke from Germany

2. Outline of co-op workterm project

Main Project

"Rapid Monitoring Method to Assess Efficacy of Sanitizers against *Pseudomonas putida* Biofilms"

Part I Biofilm Production.

Part II Evaluation efficiency of 2 biocides to damage biofilm.

Special experiment

"Use of molecular biology to confirm the locations of the lux gene on the bacterial DNA chromosome."

consist of:

- DNA extraction
- Agarose gel electrophoresis
- RNA digestion
- Restriction of DNA
- Southern Blot Membrane
- Southern Hybridization
- Detection of DIG-labeled Nucleic Acids

....

2.1 Biofilm Production

-Test cultures

Five luminescent clone strains of *Pseudomonas putida* were used in this experiment.

<u>objectives</u>:

1. Identify clones with high luminescence and low luminescence.
2. Relate RLU (relative light units) reading to actual cell number by using luminometer and total viable count.
3. Make correlation curve by using Quatto Pro (computer program).

-Biofilm formation

<u>objectives</u>:

1. Try to produce biofilm on rubber gaskets.
2. Test efficiency of 3 different media for biofilm formation.
3. Previous information about clones.

Several methods are used to monitor and check biofilm formation.

- Vortex and ultrasound
- Luminometer
- Epifluorescence microscopy (EFM)
- Scanning electron microscopy (SEM)
- Viable count
- Bactometer
- CCD (charge coupled device)

2.2 Evaluation efficacy of 2 sanitizer to damage biofilm

objectives:

1. Test efficacy of sanitizers commonly used in dairy plant to biofilm of *Pseudomonas putida*.
2. Preform using bioluminescence for rapid microorganism monitoring to access efficacy of sanitizing compare with traditional plate count.

Two types of sanitizer are used for treatment.

- Non-foaming Acidic sanitizer (Divosan Activ)
- Liquid hypochlorite sanitizer (Dibac)

Monitoring methods

1. Bioluminescence
2. Aerobic plate count. In this case, Spiral plating are available.

2.3 Special experiment

Objectives:

1. Try to extract chromosomal DNA from Bioluminescence strains of *Pseudomonas putida*.
2. Isolate and Purify chromosomal DNA and confirm by Agarose Gel Electrophoresis.
3. Identify location of lux AB on chromosomal DNA by Southern Hybridization.
4. Previous Correlation of Lux gene location with Biofilm Production.

3. Rapid Monitoring Method to Assess Efficacy of Sanitizers against *Pseudomonas putida* Biofilms.

3.1 Abstract

Biofilms of luminescent *Pseudomonas putida* were developed on rubber surfaces by incubation in brain heart (BHI) infusion broth. Scanning electron microscopy (SEM) and Epifluorescence microscope (EFM) were used to examine biofilm formation. To test efficacy of two sanitizers commonly employed in dairy plants for CIP (Clean In Place) procedures, bioluminescence and aerobic plating were used to enumerate cell numbers. Immediately after the sanitizer treatments, an apparent 5 log reduction of biofilm associated cells was determined. However, when the samples were resusicitated for 18 h in BHI broth, high numbers of cells were detected which reached levels close to those of non treated controls. Results demonstrated that neither sanitizer could completely eliminate biofilm associated *P. putida*. The novel method, microbial bioluminescence, proved to be the best way for assessing efficiency of sanitizers against microbial biofilms.

Keywords: *Pseudomonas putida*, bioluminescence, biofilm, sanitizers.

3.2 Introduction

Bacterial attachment to solid surfaces and biofilm formation are growing to be a serious concern in the food industry (27). It is recognized that bacterial adhesion can be a potential source for food contamination affecting quality and safety of products (3, 16). Biofilms can be formed on a variety of materials commonly used in food plants. These food contact surfaces include glass, stainless steel, polypropylene, rubber and polytetrafluoroethylene (2, 3, 16, 21, 22, 24, 29). Although these materials appear to be smooth, they may have cervices or small cracks that could harbor bacteria which may shed into the food processing environment (3, 21). It has been documented that biofilm cells have a higher resistance to antimicrobial agents than bacteria in culture suspensions because they are embedded in extracellular substances which protect cells from direct sanitizer exposure. Thus, bacteria may survive on the surface of equipments after cleaning and sanitizing (8, 17, 24, 30).
To assess efficiency of sanitizers against biofilms, bacterial

bioluminescence could be a great choice to monitor survival of microorganisms (28). Bioluminescence is closely related to the basic metabolism of bacterial cells. It involves reducing a flaven mononucleotide which is catalyzed by the enzyme luciferase that is responsible for light emission (4, 10, 20). This reaction needs a long chain fatty acid aldehyde as substrate. Bacteria can be transformed to a luminescent phenotype by using genetic engineering to insert the luciferase gene (*luxAB*). The amount of light emitted by such bacteria is directly proportional to cell numbers and can be rapidly monitored by a luminometer. Many studies have demonstrated that the most dominant genus of the psychrotrophic microflora present in milk processing plants is *Pseudomonas* which is well known as a biofilm producer. In this case study, bioluminescent *P. putida* were used to form biofilms and subsequently treated with sanitizers commonly employed in dairy plants. Efficiency of the sanitizer treatments was evaluated by traditional plate counting and by using the novel method of bioluminescence. The goals of the study were i) evaluation of the efficacy of sanitizers commonly used in dairy plants against microbial biofilms, ii) to examine bacterial attachment of luminescent *P. putida* on Butyl rubber surfaces, iii) to compare advantages and disadvantages of plate counts and bioluminescence as enumeration methods and iv) to examine effect of post treatment resuscitation on the detection of surviving bacteria.

3.3 Materials and Methods

3.3.1 Bacterial cultures

Pseudomonas putida LV 2-4, which had been isolated from biofilm in a milk processing line by Dr. J. Austin, Bureau of Microbial Hazards, Ottawa was used in this study. To obtain a luminescent phenotype, *luxAB* was introduced into the chromosome of *P. putida* LV 2-4 by using the plasmid PT 7-5 according to the procedures described by Chen and Griffiths (5a). One clone, emitting a strong bioluminescent signal while still maintaining its ability to form biofilms was used in this study. Cultures were grown in brain heart infusion (BHI) broth at 30°C overnight.

3.3.2 Biofilm Formation

One mL of an overnight culture of *P. putida* LV 2-4-lux was inoculated into a sterilized flask containing 10 mL of BHI broth and 3 rubber septa (Butyl rubber/polytetrafluoroethylene, materials commonly used in dairy plants). Inoculated flasks were incubated at 22°C with 70 rpm shaking. Every 12 h the growth medium was replaced with 10 mL of fresh BHI broth (22). After 1, 2, and 3 days, samples were aseptically removed from the flasks and treated with various sanitizers.

Biofilm formation was veryfied using scanning electron microscopy (SEM), epifluoresence microscpoy (EFM) and enumeration by plating after removal of bacteria from the surfaces. For SEM, the sample surfaces were prepared by fixing the biofilm cells with standard buffer (0.07 M KH_2PO_4, 0.07 M Na_2HPO_4) containing 2% glutaraldehyde overnight at room temperature. Samples were then rinsed for 10 min. in standard buffer and dehydrated in following an ethanol series. Dehydration was completed by critical control point drying with CO_2. Samples were coated with Au/Pd 30nm with a Hummer VII sputter coater (Anatech JTD Alewandria, VA) and viewed in a scanning electron microscope (Hitachi S-570, Tokyo, Japan) at 50 KV.

For EFM the samples were stained with 1% acridine orange for 1 min. At room temperature and mounted onto a microscope slide. Attached cells were viewed in an epifluorescent microscope with a 100x oil immersion objective.

3.3.3 Enumeration of bacteria

Viable cell counts were determined by surface plating on BHI agar using a spiral plater (Spiral systems). Incubation was at 30°C for 24, 48 and 72 h. Bioluminescence which has a linear correlation to viable cell counts was determined as follows: One mL of the bacterial suspension was thoroughly mixed with with 10 μL of 1% n-decanal and light emission was determined in a luminometer.

3.3.4 Effects of sanitizer treatment on biofilms

Two types of sanitizers obtained from Diversey Inc. (Mississauga, ON) were tested: i) a non foaming acidic sanitizer (Divosan Activ) and a liquid hypochlorite sanitizer (Dibac). Working solutions were prepared according to the directions of the manufacture. Phosphate buffered saline (PBS [0.14M NaCl, 0.003M KCl, 0.01M Na_2HPO_4 and 0.002M KH_2PO_4])+ 2% Tween 80, was used as neutralizer for Divosan Activ. The hypochlorite sanitizer (Dibac) was neutralized with 0.01 M sodium thiosulfate.

At the end of the incubation period, each rubber septum was aseptically removed from the culture flask and rinsed 10 times in 50 ml of PBS to remove any unattached cells. After rinsing, the rubber septa were cut in 4 sections by a sterile scalpel and each segment was immersed in 10 ml of sanitizer solution for 30 sec at 25°C. Activity of the sanitizer was stopped in neutralizing solution for 5 min. Then the samples were transferred into PBS with 2% Tween 80 solution and biofilm cells were removed from the surface by vortexing for 2 min at maximum speed. The number of viable cells was determined in each sample before and after vortexing by spiral plates and luminometer. To evaluate survival of injured cells, the entire sample after vortexing (rubber septa and PBS+Tween 80 suspension) was transferred into 5 ml of BHI broth and incubated at 30°C. After 2 and 18 h bioluminescence of resuscitated cells was determined. For control samples, sanitizer and neutralizing solutions were replacedwith PBS; otherwise treatments were performed identical to the test samples.

3.4 Results

3.4.1 Biofilm formatiom

Bioluminescent *P. putida* grew well in BHI broth at 30°C and 22°C. Growth rates were identical for the parent and the bioluminescent strain. The cell numbers necessary to detect a positive luminescence signal were at 10^4 CFU. Preliminary experiments using a variety of culture media and conditions had shown that incubation at 22°C with shaking and regularly replacing the culture medium improved biofilm formation (data not shown). Formation of biofilms on the surface of the rubber septa after incubation for 1, 2 and 3 days was visually confirmed by EFM and SEM (Figure 1). Cells present on the rubber septa which had not been removed by rinsing were considered to be adherent. These adherent cells were readily removed by vortexing with PBS+Tween 80 for 2 min. Quantification of attached cells, determined by subtracting the cell numbers before vortexing from the number of cells detected after vortexing, showed the number of biofilm associated bacteria to be between 10^4 and 10^5 CFU/cm^2. Accordingly, the value of light emission was between 2 and 200 RLU /cm^2. The number of cells adhering to the surfaces did not significantly change over a 24 to 72 h period. Different ages of biofilms did not result in different numbers of attached cells.

3.4.2 Sanitizer treatment

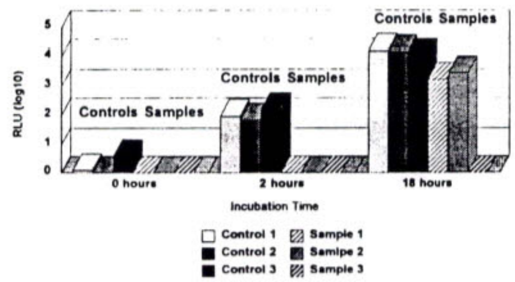
After biofilm cells were exposed to two types of commercial sanitizers with the maximum concentration recommended by the chemical manufacturer for 30 sec contact time, biofilm associated bacteria were reduced by more than 5 log cycles. No apparent differences in cell reduction were observed for 1-day, 2-day or 3-day old biofilms. There was no visible difference between sanitizer efficiency assessed with CFU or RLU. This would indicate that the sanitizers were effective for eliminating the biofilm associated *P. putida*. However, after the treated biofilm surfaces were resuscitated in fresh media of BHI and incubated at 37°C by shaking for 2 h, luminescence was again detectable. This light emission increased markedly after a prolonged incubation of the samples for 18 h.The RLU values increased to almost as high numbers as the non treated biofilm controls. Different ages of *P. putida* biofilms did not give different results and no marked difference in efficacy was observed between the non-foaming acidic sanitizer and the liquid hypochlorite sanitizer.

Figure 1: Scanning Electron Microphotograph of *P. putida* biofilm after 1 day incubation

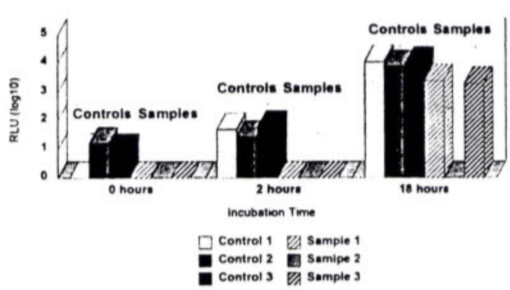
Figure 2: **Effect of two commercial sanitizers against biofilm associated *Pseudomonas putida***

Non-Foaming Acidic Sanitizer

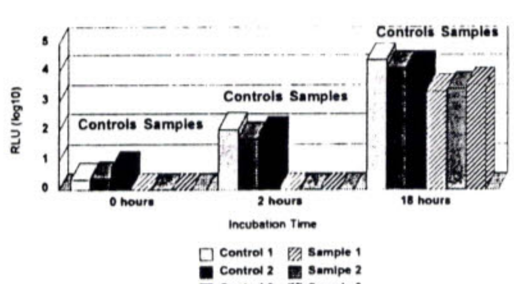
Biofilm 1 day old



Biofilm 2 days old

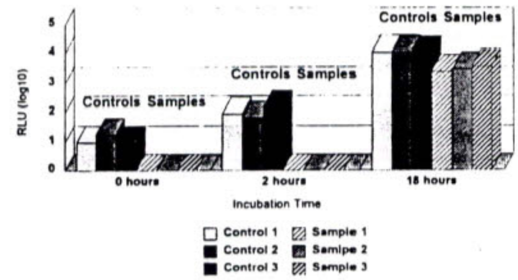


Biofilm 3 days old

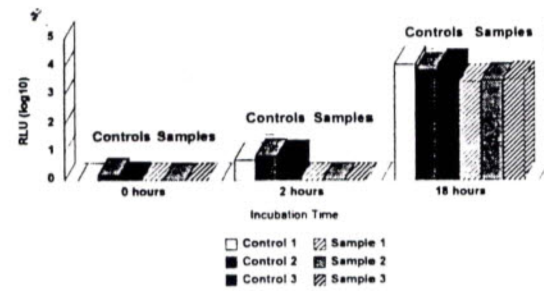


Liquid Hypochlorite Sanitizer

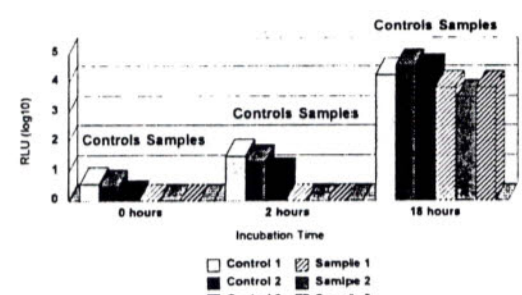
Biofilm 1 day old



Biofilm 2 days old



Biofilm 3 days old



3.5 Discussion.

The bacterial strain used in this study was obtained directly from a milk processing plant. Thus, the population of *P. putida* used could be considered a significant source of milk contamination. This research demonstrated that under circumstances close to those in food processing plants, *P. putida* can grow and form biofilms on rubber surfaces within 24 h.

Surface irregularities such as roughness, crevices and pits have been shown to increase bacterial adherence by increasing cell attachment and reducing the abilityto remove cells (1). In our study, we chose butyl rubber as contact surface. Visualisation of biofilm by SEM illustrated theoriginal rubber surface displayed a lot of crevices and small holes. In these regions most attached cells were found. It was wondering that very little of extracellular matrix (ECM) which believed to be polysaccharide in nature that may protect cells from antibacterial agents appeared.(24) It was possible that BHI broth are not rich media. Cell were starved and decreased polysaccharide production or that there were many porous on rubber surface which maked it easy for cells attached so it was not necessory to produce much ECM aid for adhesion. The other way was used to viewed biofilm formation is epifluorescence microscope.

Although Scanning electron microscope and epifluorescence were able use for confirm biofilm formation, visual biofilm structure or the presence of ECM. But they did not give quantitive results. So Spiral plating system was investigated for enumeration in this case study. However, viable plate count takes a long time and needs labour. This work we tried to use bioluminescence for asssessing efficacy of sanitizer treatment too. Luminometer was used compare with spiral plate count. Results indicated that bioluminescence had more efficiency than traditional plating because it needed only short time for whole procedure, did not need much labour and could used to measure while there were only small amount of sample left. Beside that, we found that there were some common problem from traditional plating. One was arised when cell were removed from surface is that large clumps. It might be not dispered. This leaded to be a source of error because cells cound not form colony on the agar surface. It was difficult to count accurately cells and the total number of cells might be unestimated.(13) The other point, Our study were unable to get accuratly results from enumeration by spiral plating in rescusitation step more than bioluminescence method because there were injuried cells unable to grow on BHI agar but still alived.

Results of works conducted by many researchers suggested that the resistance of microorganisms were affected by the ages of biofilm (3, 31). This study 1-day, 2-day and 3-day old biofilms were tested for sanitizer treatment with two commercial sanitizer. After 30 sec exposure time, the results of measuring showed that no different marks of efficiency between non forming acidic and liquid hypochlorite sanitizer on various ages of biofilm, probably the attachment and biofilm development were different in processes and culture.

In conclusion, This work has shown that (a) the behavior of biofilm cells in extracellular production was affected by the type of surface and nutrition media. (b) This research supposed with the earlier reports that the sanitizer efficacy was low in porous surfaces such as rubbers. (c) Engineering a lux gene construction into food isolated of Pseudomonas putida provided rapid monitoring method for assessing efficiency of sanitizer treatment. (d) Both sanitizers seemed to be effective to kill bacteria adherence after treatment but after injuried were enriched with fresh media, they can survived and reproduced themself quickly. So we concluded that non forming acidic and liquid hypochlorite sanitizer could not eliminate the biofilm associated Pseudomonas putida cells.

It's difficult to remove the biofilms completely from the surface and regular cleaning and sanitizing still be the best way to prevent biofilm. So the frequency and adequacy times of sanitizing should be important feasible point for controlling microbial attach in food processing plant.

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4. Special Experiment

"Use of molecular biology to confirm the location of the lux AB on the bacterial chromosome"

4.1 Objectives

1. Learn about molecular biology
2. Perform several steps to identify the location of lux gene of Pseudomonas putida in clone 4-8.
   - 2.1 DNA extraction
   - 2.2 DNA detection by Gel electrophoresis
   - 2.3 RNA digestion
   - 2.4 Restriction of DNA
   - 2.5 Southern transfer
   - 2.6 Southern hybridization
   - 2.7 Detection of DIG-labeled nucleic acids
3. Previous information of each clone.
4. Conclusion correlation of location of lux gene with biofilm production.

....

4.1.1 DNA Extraction

objective : Extract chromosomal DNA from Microorganism.

Materials & methods

- Bacteria cones 4-8 of *P.putida* are cultured in BHI broth to be sampled
- Take 6-10 ml of bacteria culture in centrifuge tubes and centrifuge at 5 degree c for 15 min.
- Suspend pellet in 800 ml of 6.7% sucrose by vortexing.
- Add 50 microlites of lysozyme (10 mg/ml and shake at 37 degree c for 30 min).
- Add 10 microlites of proteinase K (20 mg/ml and shake at 37 degree c for 30 min).
- Add 1 ml of Phenol/Chloroform/Isoamul alcohol (ratio, 25:24:1) underfumehood, shake quickly and then spin at full speed for 15 min by centrifuge at 5 degree c. After the first spin, the supernatant solution is collected.
- Add 1ml of Phenol/CH3Cl/Isoamyl (mix together).
- Spin full speed at 4 degree c for 15 min.
- 500 microlites are collected and tranferred to lock safe eppendorf vials.
- Add 50 microlites of Na-Acetate, pH 5.2 (0.1*volumn of last volume).
- Add chilled 100% ethanol (2 times of sample).
- Store overnight at -20 degree c
- Check for precipitate, spin down at maximum speed for 15 min at

4 degree c.

- Discard the supernatant
- Wash with 70% ethanol and spin again for 15 min, allow the pillet to dry. Then the pellet is resuspended in TE buffer, pH 7.6.
- Put it in the oven to dissolve for 1-2 hours at 42 degree c.
- Keep it in the fridge.

4.1.2 Agarose gel electrophoresis

Objective: Verify presence of chromosomal DNA.

Materials & Methods

- Agarose gel preparation (0.8% agarose in 1*TAE buffer)
- Add Ethidium bromide (10 mg/ml) and boil until it becomes clear.
- Cool down and pour in the gel chamber (make sure to set the comb ready).
- Immerse the gel in the chamber and cover with 1*Tris-Acetate-EDTA buffer (TAE buffer).
- Drop DNA sample (mixing solution of 2 micorlites of loading buffer, 2 microlites of sample and 5 microlites of distilled water).
- Run the gel at 50-100 volts for 45 min.
- Keep the remaining sample in the fridge for RNA digestion.

4.1.3 RNA digestion

Objective: Digest RNA

Materials & Methods

- Add 0.8 microlites of RNase in thawed sample and spin a little bit.
- Incubate at 37 degree for 2-3 hours.
- Keep at room temperature.
- Run gel electrophoresis for to verify complete digestion of RNA.

4.1.4 DNA restriction

Objective: Cut DNA chromosome into fragments

Materials & Methods

- Add 2 microlites of restriction enzyme (EcoRI), 1.5 microlites of buffer solution and 1.5 microlites of distilled water into tube containing 10 microlites of chromosomal DNA.
- Incubate at 37 degree c overnight
- Prepare agarose gel of appropriate composition (0.8%) a high purity nucleic acid grade agarose and a Tris-Acetate-EDTA

(TAE) buffer.

- Run the gel. If desired, the gel may be stained with Ethidium bromide to visualize the DNA fragments and confirm subsequent Southern transfer to membrane.

4.1.5 Southern transfer

Objective: Transfer chromosomal DNA fracments from the gel to membrane.

Materials & Methods

- Depurinate for 5 min by submerging the agarose gel in 250 mM HCL while shaking at room temperature.
- Rinse the gel with distilled water.
- Submerge the agarose gel in denaturation solution for 45 min at room temperature. Shake gently. This incubation denatures the DNA target prior to transfer.
- Rinse the gel with distilled water.
- Submerge the gel in neutralizaton solution twice for 15 min at room temperature to neutralize the gel.
- Blot the DNA from the gel by capillary transfer to the membrane (Nylon membrane), using 10*SSC buffer.
- Change tissue after first 1-2 hours before leaving it overnight at room temperature.
- Rinse membrane briefly with distilled water.

<u>DNA fixation</u>

Objective: To fix the DNA on the membrane.

Materials & Methods

- DNA is efficiently bound to the membrane by UV-crosslinking for 5 min.
- The membrane can be used immediately for hybridization. In this case, it was stored dry at room temperature for future use.

4.1.6 Souther Hybridization

Objective: Hybridize DIG-labeled probe with immobilized target nucleic acid.

Materials & Methods

<u>Prehybridization</u>

- Place the blot in roller tubes containing 20 ml standard prehybridization solution and incubate in hybridization oven at 60 degree c for 1-2 hours.
- Heat probe in boiling water for 10 min in order to denature the DNA and chill immediately on ice.
- Discard the prehybridization solution out.

Hybridization

- Add the hybridization solution containing the DIG-labeled probe and allow the probe to hybridize overnight at 60 degree c.
- At the end of Hybridization, pour the hybridization soluiton from the roller tube into a capped tube. Store the tube at -20 degree c. Hybridization solution can be reused several times.
- Wash the membrane twice, 5 min per wash, in 2x wash solution at room temperature to remove unbound probe.
- Wash the membrane twice, 15 min per wash, in 0.1x wash solution at hybridization temperature (long prove, >100 bp should be washed at 68 degree c).

4.1.7 Detection of DIG-labeled nucleic acids

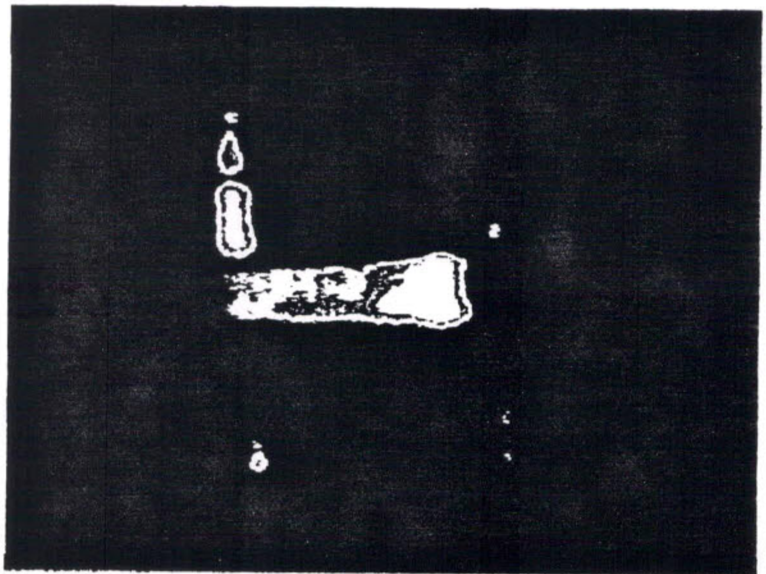
Objective: To detect DIG-labeled Nucleic acids.

Materials & Methods

- After hybridization and Post hybridization wash, equilibrate the membrane in buffer 1 for 1 min.
- Block the membrane by gently agitating in buffer 2 for 30-60 min.
- Incubate for 30 min in Antibody solution (containing 10 ml of 1% Blocking and 2 microlites antibody fragments)
- Discard the antibody solution twice for 15 min in buffer 1 (buffer 1 plus 0.3% Tween 20).
- Pour buffer 1 off and equilibrate the membrane in buffer 3 for 5 min
- Add lumigen PPD 5'(dilute 1:100 in buffer 3), wet membrane throughly for 5 min.
- Incubate in plastic seal at 37 degree c for 10 min.
- For detection, the membrane is measured by charge coupled device(CCD) camera.

4.2 Results and Discussion

After membrane was visualized by charge coupled device (CCD), the location of lux AB were performed. For each clone the location of lux gene are different spot. They were shown in picture 1.



clone 4
clone 5
clone 6
clone 7
clone 8

Almost every clones were able identify the location of lux AB in chromosomal DNA. Except clone 7, the location was not good performed. It is possible that supernatant collection was not done completely in DNA extraction step so there wer some chromosomal DNA got lost. There are small amount left. When it was detected with DIG-labeled nucleic acids. Low amount of light emission appeared by CCD camera.

4.3 Conclusion

- The location of the lux AB on chromosomal DNA were able to express.
- Each clone of *P. putida* (clone 4,5,6,7,8) have different location of lux AB.

4.4 Reference

- Boehringer Mannheim Biochemica. 1993. The DIG system user's guide for filter hybridization. Boehringer mannheim Gmbtt. Mannheim, Germany.

5. Summery all activities during work term.

5.1 Working in Laboratory for main project and special project every day.
5.2 Participate in Laboratory Meeting every two weeks and in the lab party each times.
5.3 Presentation of project in Laboratory Meeting.
5.4 Volunteer in Food Science Conference, Guelph, Ontario, Canada.
5.5 Traveling to Montreal, Quebec and Boston with co-workers from the Labolatory as a vacation.
5.6 Traveling around Ontario during Holidays.

Adventages

- Learning more culture and traditional of other country especially Canada.
- Improving adjustment for new surrounding
- Learning more about laboratory technique.
- Solving various problems with myself.
- Developing idea and knowledge in various areas.
- Improving English language.
- Learning more about using libraly such as using libraly database computer search the specific information.

6. Recommendation for co-op program.

International trainee student should have international student identification card to identify themself.

ACKNOWLEDGEMENT

Thanks you Dr.Mansel Griffith so much for accepting me to be trainee student in his laboratory and support everthing for all project.

Thanks Dr. Heidi Schraft for everthing her teaching and training all the time I was in Canada.

Thank you very much
The author

Appendix

Solutions required for Southern Blotting are listed below. Refer to Appendix C for details on preparing the additionally required solutions.

Solutions	Description
HCl	250 mM HCl.
H_2O	Sterile, distilled water.
Denaturation solution 1	0.5 N NaOH, 1.5 M NaCl.
Neutralization solution 1	0.5 M Tris-HCl, pH 7.5; 3 M NaCl.
20 x SSC buffer	3 M NaCl, 300 mM sodium citrate; pH 7.0.
5 x SSC buffer	750 mM NaCl, 75 mM sodium citrate, pH 7.0.
Standard prehybridization buffer	5 x SSC, 1.0% (w/v) Blocking Reagent for nucleic acid hybridization, 0.1% N-lauroylsarcosine, 0.02% sodium dodecyl sulfate (SDS). When using RNA probes, add formamide to 50% and increase Blocking Reagent to 2 (w/v)*.
Standard hybridization buffer	DIG-labeled probe diluted in standard prehybridization buffer.
2 x wash solution	2 x SSC containing 0.1% SDS.
0.1 x wash solution	0.1 x SSC containing 0.1% SDS.

*Added from the Blocking Reagent stock solution (100 mM maleic acid, 150 mM NaCl, pH 7.5, containing 10% [w/v] Blocking Reagent for nucleic acid and hybridization). See Preparation of Additionally Required Solutions and Buffers in Appendix C.

(Boehringer Mannheim Biochemica, 1993)

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5 x SSC buffer	750 mM NaCl, 75 mM sodium citrate, pH 7.0.
Standard prehybridization buffer	5 x SSC, 1.0% (w/v) Blocking Reagent for nucleic acid hybridization, 0.1% N-lauroylsarcosine, 0.02% sodium dodecyl sulfate (SDS). When using RNA probes, add formamide to 50% and increase Blocking Reagent to 2 (w/v)*.
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(Boehringer Mannheim Biochemica, 1993)

TUNS
Technical University of Nova Scotia
Graduate Studies

TO WHOM IT MAY CONCERN

I am writing this letter to confirm that Mr. Atit Koonsrisuk, a co-op student from the Suranaree University of Technology has successfully completed his four month work term in the Department of Mechanical Engineering under my supervision and the guidance of the
Two-Phase Flow Research Laboratory staff at the Technical University of Nova Scotia, Halifax, NS, Canada. Mr. Koonsrisuk's work term was between September to December, 1996, both inclusive. He was able to complete and report on every task and objective given to him to my satisfaction. I would be delighted to have him back either as a co-op student or as a practicing engineer with no reservation whatsoever.

Should you have any further questions please do not hesitate to call the undersigned.

Dated: January 10, 1997

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Operation Report

“Introduction to Fluidization”

At:
Technical University of Nova Scotia
PO Box 1000
Halifax, Nova Scotia B3J 2X4
Canada

Submitted by:

Atit Koonsrisuk

Submitted to:

Dr.Feridun Hamdullahpur

12/10/96

5231 Morris St.

Halifax, Nova Scotia

B3J 1B7

December 10, 1996

Dr.F Hamdullahpur
Technical University of Nova Scotia, Faculty of Engineering
PO Box 1000
Halifax, Nova Scotia
B3J 2X4

Dear Dr.Hamdullahpur:

I came to be the research assistant at Technical University of Nova Scotia for a course of Co-operative Education II. The period is from September 20, 1996 to December 11, 1996. Please accept the attached report, "Introduction to Fluidization" in fulfillment of the operation report requirement for the course 401444 - Co-operative Education II.

I hope all the above is clear. And I thank you for all your help while I have been in Canada

Sincerely,

Atit Koonsrisuk

Atit Koonsrisuk

ACKNOWLEDGMENT

I am very grateful to Dr.Feridun Hamdullahpur, of Department of Mechanical Engineering of TUNS, and Anne Marie Coolen, of Co-operative Education office of TUNS, for their invaluable help in everything for me. I also wish to express my thanks to those people at TUNS for their kindness and warm support.

Many people helped to make this report what it is, in particular Levent Ersoy, the graduate student of Department of Mechanical Engineering of TUNS, whose comments helped in shaping the report, to edit the manuscript and eliminating many errors. Other graduate student of the same department who have been helpful is Murat Köksal, who gave me many explanation about Fluidization.

My girlfriend, Sorada Khaengkarn, encouraged me by e-mail to carry on with job.

Atit Koonsrisuk

December 1996

ABSTRACT

Suranaree University of Technology has determined that Co-operative Education be a part of the undergraduate curriculum. Students participate in full time work at the actual site, after they begin their major studies. There are two trimesters of co-operative education, each worth six credits. After the University has made the institutional linkage and technical co-operation agreement with the Canadian Universities of Technology Consortium, whose members are Ryerson Polytechnic University, University of Guelph, University of Waterloo and the Technical University of Nova Scotia, for joint implementation of a human resource development project under partial funding support from the Canadian International Development Agency (CIDA). In this term of Suranaree University of Technology, I had a chance to study in the Technical University of Nova Scotia (TUNS) to follow this project. Dr.Feridun Hamdullahpur, a professor in the Department of Mechanical Engineering at TUNS, hired me as a research assistant for his studies. After that I was assigned to work under the supervision of Levent Ersoy, a graduate student in mechanical engineering. My duties included:

- Assistance to the laboratory supervisor
- Mechanical design of experimental systems
- Utilization of commercial software for presentations
- Preparation of a technical report in the topic of "Introduction to Fluidization"

And sometimes in my free time, I would assist other graduate students in the same department to run their experiments.

I had chances to get many academic experiences and improve my skill in many fields, such as computer skill and English, from this work term. Furthermore I wrote my own report in the topic of “Introduction to Fluidization”. The following report describes the parameters, phenomenon of fluidization and advantages and disadvantages of fluidized beds for industrial operations.

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Chapter 1

INTRODUCTION

1. Objectives of the report

First I expect that the undergraduate who have ever taken Thermodynamics and Fluid Mechanics should get the concept about fluidization. Next the researcher should be interested in using the definition that is presented. Furthermore I hope that this report could also be used as a beginning document for the student who is interested in Fluidization.

2. The details about The Technical University of Nova Scotia (TUNS)

Mailing Address:

Technical University of Nova Scotia
PO Box 1000
Halifax, Nova Scotia B3J 2X4
Canada
Phone: (902) 420-7500
FAX: (902) 420-7551

TUNS Historical Notes

The Technical University of Nova Scotia (TUNS) has a unique place in Canadian higher education. As an independent Canadian technical university, TUNS is dedicated to professional education and research in engineering, architecture, planning and computer science.

TUNS was founded as the Nova Scotia Technical College in 1907. Its mandate was to carry out research and offer degree programs in Engineering with the cooperation of universities and colleges in Nova Scotia and New Brunswick and to accept students with previous studies at the university level.

The College was established in a building on Spring Garden Road that is now occupied by the TUNS Faculty of Architecture. The original faculty of six taught courses in mining, metallurgical, civil, electrical and mechanical engineering. The first degrees were conferred in 1910 on nine students. Over the years, new departments of agricultural, chemical, food science, and industrial engineering were added.

In 1961, the TUNS School of Architecture was established. Today, degrees in environmental design, architecture and urban and rural planning are offered through the Faculty of Architecture. More recently, the TUNS School of Computer Science was established. A cooperative degree is offered by the Faculty of Architecture, School of Computer Science and several engineering departments.

TUNS' commitment to graduate studies and research is worthy of special note. In the 1950s, graduate studies programs were developed, first at the Master's level, and then at the Ph.D. level.

To encourage research activities, TUNS supports, or is associated with, several research institutes and centers: Center for Water Resources Studies (CWRS); Canadian Institute of Fisheries Technology (CIFT); Center for Marine Vessel Design and Research (CMVDR); Vehicle Safety Research (VSRT); Minerals Engineering Center (MEC); Nova Scotia CAD/CAM Center; Nova Scotia Center for Environmentally Sustainable Economic Development (CESED); Advanced Materials Engineering Center (AMEC); Applied Microelectronics Institute (AMI); Atlantic Industrial Research Institute (AIRI). In addition, an active program in international development is pursued and there is a significant commitment to continuing education.

From a single building, TUNS has grown to a complex of buildings on the main campus at Spring Garden Road and Barrington Street. The facilities include a gymnasium and a student center, built with funds raised by alumni and corporate donations. Recently, additional nearby space has been leased to accommodate university programs.

3. The job position and the duties:

Name: Atit Koonsrisuk

Job position: research assistant

Job description:

- Assistance to the laboratory supervisor
- Mechanical design of experimental systems
- Utilization of commercial software for presentations
- Preparation of a technical report in the topic of "Introduction to Fluidization"

4. Job supervisor

In this section, there are the curriculum vitae of my job supervisors. The first is Dr.Feridun Hamdullahpur's, and the second is Levent Ersoy's.

CURRICULUM VITAE

Personal

Name:	Hamdullahpur, Feridun
Birth Date:	November 3, 1954
Marital Status:	Married, Two children
Address:	Department of Mechanical Engineering Technical University of Nova Scotia PO Box 1000 Halifax, Nova Scotia B3J 2X4

Educational Background

May, 1985	Ph.D. in Chemical Engineering Technical University of Nova Scotia
May, 1979	M.Sc. in Mechanical Engineering Technical University of Istanbul
May, 1976	B.Sc. in Mechanical Engineering Technical University of Istanbul

Academic Experience

1995-present	Dean of Graduate Studies and Research
1993- 1995	Associate Dean of Graduate Studies and Research
1992-1993	Visiting Professor, Bosphourus University, Turkey
1995- present	Professor Department of Mechanical Engineering, TUNS
1990 - 1995	Associate Professor Department of Mechanical Engineering, TUNS
1987 - 1990	Assistant Professor, Department of Mechanical Engineering, TUNS

1985 - 1987	Assistant Professor, Faculty of Engineering, Center for Energy Studies, TUNS
1981 - 1985	Research Engineer, Centre for Energy Studies, TUNS; Lecturer, Chemical and Mechanical Engineering Departments, TUNS.
1977 - 1981	Research Engineer and Lecturer, Technical University of Istanbul

Thesis Work

Two Phase Flow Behaviour in the Freeboard of a Gas Fluidized Bed (Ph.D., 1985)

Loading of Solid Particles into the Main Transportation Line by a Jet-Pump (M.Sc., 1979)

Determination of the Suction Loss Coefficient for Moving Nozzles (B.Sc., 1976)

Industrial Experience

1980 - 1981 Consulting Engineer (Capacity analysis on pulp and paper industry), Istanbul Chamber of Industry

1979 - 1980 Consulting and Project Engineer (Hydraulic system design for food and beverage industry), Turkish Industrial Development Bank

1977 - 1978 Energy and Project Engineer (heating and ventilation systems), Gural Engineering and Consulting Company, Istanbul

PUBLICATION LIST

1. REFEREED JOURNAL PUBLICATIONS

MacGregor, W., I. Ugursal and F. Hamdullahpur, "A Design Methodology for Small Scale Bubbling Fluidized Bed Boilers", International Journal of Energy Research, vol.19, 6, p.535-553, 1995.

DiMattia, D.G. , P.R. Amyotte and F. Hamdullahpur, "Slugging of Group D Particles in Fluidized Beds", Accepted for publication in the Canadian Journal of Chemical Engineering, 1996.

DiMattia, D.G., P.R. Amyotte and F. Hamdullahpur, "Fluidized Bed Drying of Large Particles" ASAE, November 1996.

Hamdullahpur, F. and I. Ugursal, "Fluidized Bed Combustion" in Coal, Resources, Properties, Utilization, Pollution, Ed. O. Kural, pp. 279-291, I. T. U. Press, 1994.

Ugursal, I., A. M. Al Taweel, F. Hamdullahpur, E. Ozil and T. S. Uyar, "Economics of Coal Utilization" in Coal, Resources, Properties, Utilization, Pollution, Ed. O. Kural, pp. 417-431, I. T. U. Press, 1994.

Fung, A. and F. Hamdullahpur "A Gas and Particle Flow Model in the Freeboard of a Fluidized Bed Based on Bubble Coalescence." Powder Technology, 74, pp121-133, 1993.

Isigigur, A., F. Karaosmanoglu, H.A. Aksoy, F. Hamdullahpur and O.L. Gulder, "Safflower Seed Oil of Turkish Origin as a Diesel Fuel Alternative." Applied Biochemistry and Biotechnology Journal, Vol.40/41, pp89-105, 1993

MacGregor, W., F. Hamdullahpur and I. Ugursal, "Space Heating Using Small Scale Fluidized Beds: A Technoeconomic Evaluation" Journal of Energy Research, Vol.17, 1993

Fung, A. and F. Hamdullahpur, "Effect of Bubble Coalescence on Entrainment in Gas Fluidized Beds" Accepted for publication (in print) in Powder Technology, 1993

Ergudenler, A., A.E. Ghaly and F. Hamdullahpur, "Quality of Gas Produced from Wheat Straw in a Dual-Distributor Type Fluidized Bed". Accepted for publication in Biomass and Bioenergy Journal, September 1992.

Fung, A., V. I. Ugursal, and F. Hamdullahpur" Design and Construction of a Computer Controlled Laboratory Air Conditioning Unit " International Journal of Mechanical Engineering Education, vol.19, No.1, pp69-76, 1991

Al Taweel, A.M., J. Militzer, J.M. Kan and F. Hamdullahpur, "Motion of Hydrodynamic Aggregates", Powder Technology, 58, pp117-126, 1989

Militzer, J., J.M.Kan, F. Hamdullahpur, and A.M.Al Taweel "Drag Coefficient for Axisymmetric Flow Around Individual Spheroidal Particles" Powder Technology, 57, pp193-195, 1989

Hamdullahpur, F., M.J. Pegg and G.D.M. MacKay, "A Laser Fluorescence Technique for Two-Phase Turbulent Flow Measurements", International Journal of Multiphase Flow, Vol. 13, No.3, pp. 379-385, 1987.

Hamdullahpur, F. and G.D.M. MacKay, "Two-Phase Flow in the Freeboard of a Fluidized Bed" AIChE Journal, Vol. 32, No. 12, pp. 2407-2055, 1986.

2. ARTICLES SUBMITTED TO REFEREED JOURNALS

DiMattia, D., P. R. Amyotte and F. Hamdullahpur, Onset of Slugging in Fluidized Bed of Coarse Particles", Submitted to AIChE Journal, 1993

Ghaly, A., I. Ugwu, A. Ergudenler, A.M. Al Taweel, and F. Hamdullahpur, "Effect of Distributor Configuration on Pressure Drop in a Bubbling Fluidized Bed Reactor", Submitted to Energy Resources Journal, 1992

Ghaly, A., A. Ergudenler, I. Ugwu, A.M. Al Taweel, and F. Hamdullahpur, "Mixing Patterns and Residence Time Determination in a Bubbling Fluidized Bed System", Submitted to the Canadian Journal of Chemical Engineering, 1992

Ergudenler, A., A.E. Ghaly and F. Hamdullahpur, "Mathematical Modelling of a Fluidized Bed Straw Gasifier. I- Model Development" Submitted for publication in Biomass and Bioenergy Journal , 1992

Ergudenler, A., A.E. Ghaly and F. Hamdullahpur, "Mathematical Modelling of a Fluidized Bed Straw Gasifier. II- Model Sensitivity" Submitted for publication in Biomass and Bioenergy Journal , 1992

Ergudenler, A., A.E. Ghaly and F. Hamdullahpur, "Mathematical Modelling of a Fluidized Bed Straw Gasifier. III- Model Verification" Submitted for publication in Biomass and Bioenergy Journal, 1992

Kan, J., A. M. Al Taweel, F. Hamdullahpur, J. Militzer, and E. El-Masry, "Processing LDA Signals from the Freeboard of a Fluidized Bed" Submitted for publication in the Rev. of Sci.Inst, 1991.

4. NON-REFEREED CONTRIBUTIONS

Fung, A.S. and F. Hamdullahpur, "Effect of Bubble Coalescence on Particle Motion in the Freeboard of a Bubbling Fluidized Bed" Proceedings of the Spring Technical session of the Canadian Section of the Combustion Institute, pp. 34-37, Edmonton, Alberta, May 1992

Ergudenler, A., A.E. Ghaly, F. Hamdullahpur and A.M. ALTaweel, "Mathematical Modelling of a Fluidized Bed Straw Gasifier" Proceedings of the ASAE International Summer Meeting, Charlotte, North Carolina, ASAE Paper No. 92-6030, June 1992

Ghaly, A.E., A. Ergudenler and F. Hamdullahpur, "Fluidized Bed Gasification of Wheat Straw" International Conference on Agricultural Engineering, Uppsala, Sweden, June 1992

Zayed, R.S. and F. Hamdullahpur, "Mathematical Modelling of Particle Motion in the Freeboard of a Swirling Fluidized Bed" Proceedings of the Spring Technical session of the Canadian Section of the Combustion Institute, pp. 7-8, Halifax, N.S., June 1988

Hamdullahpur, F., G.S. Trivett and Z.Q. Zhou, "Design and Operation of a CWS Fuelled Small Scale Atmospheric Fluidized Bed Combustor", Proceedings of the 9th International Conference on Fluidized Bed Combustion, (Poster Session) ASME, Boston, MA, May 1987.

Zhou, Z.Q. and F. Hamdullahpur, "The Influence of Fluidization Velocity on the Combustion of CWS Droplets in a Binary FBC", Proceedings of the 9th International Conference on Fluidized Bed Combustion, pp 1171-1176, ASME, Boston, MA, May 1987.

Kan, J.M., J. Militzer, A.M. Al Taweel and F. Hamdullahpur, "Effect of Aggregate Formation on Multiphase Flow" CANCAM '87, ppB-68, Edmonton, June 1987.

Zhou, Z.Q. and F. Hamdullahpur, " Ash Deposition in Utility Boilers: A Prediction Based on the Thermal Properties of Fly Ash", Proceedings of the Spring Technical session of the Canadian Section of the Combustion Institute, pp. 111-114, Vancuver, BC, 1987

Zhou, Z.Q., G.S. Trivett and F. Hamdullahpur, "The Experimental Investigation on Combustion of Pulverized Coal in Gas Flow", Proceedings of the Third Annual Coal Conference, pp. 655-663, Pittsburgh, PA, 1986.

Hamdullahpur, F. and G.D.M. MacKay, "An Investigation of the Freeboard Region of a Fluidized Bed Combustor", Proceedings of the Spring Technical session of the Canadian Section of the Combustion Institute, pp. 58-60, Banff, 1986.

5. TECHNICAL AND INTERNAL REPORTS

Hamdullahpur, F. " Results of Freeboard Modifications and Ash Collection of the CWS Fuelled Small Scale Fluidized Bed Combustor" Final Report on CBDC Contract No. C84180, 1989.

Fels, M. and F. Hamdullahpur, "Evaluation of the Combustion Characteristics of Strawlogs" Final Report, DEBCO, Albany, PEI, March 1989.

Al Taweel, A.M. and F. Hamdullahpur, "LDV Bibliography" Technical Report No. 008, Department of Chemical Engineering, Technical University of Nova Scotia, 1986.

Hamdullahpur, F. " Good Progress Fundamentally, Commercially, But Gaps Prevent Optimization of Industrial Design. On the First International Conference on Circulating Fluidized Beds." Energy World, Bulletin of the Institute of Energy. No. 135, 7, 1986.

6. CONFERENCE PRESENTATIONS

Katalambulla, H., P. R. Amyotte and F. Hamdullahpur, "The Effect of Distributor Parameters on Drying Rate of Coarse Particles in Fluidized Beds" International Conference on Agricultural Engineering, Uppsala, Sweden, Poster No. 9203-108, June 1992

Ergudenler, A., A. Ghaly, F. Hamdullahpur, and A. M. Al Taweel, "Fluidized Bed Gasification of Cereal Straw" Paper presented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990.

BasiratTabrizi, H., A.M. Al Taweel, and F. Hamdullahpur, "Mathematical Modelling of Gas solid Distribution in a Cyclone Separator", Paper presented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990

Al Taweel, A.M., P.R. Amyotte, P. Basu, A. Ghaly, F. Hamdullahpur, G. D. M. MacKay, and J.Militzer, "An Overview of Fluidization and Fluidized Bed Combustion Research at the Technical University of Nova Scotia",Pesented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990

Al Taweel, A.M., J.H.Kan, F.Hamdullahpur, and J.Militzer, "Monitoring the Motion of Aggregates in the Freeboard of a Bubbling Fluidized Bed", Paper presented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990

Zayed, R.S., F. Hamdullahpur, and A.M. Al Taweel, "Effect of Secondary Swirling Air on the Behaviour of a Freeboard of a Fluidized Bed", Paper presented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990

Katalambulla, H., P.R.Amyotte, and F.Hamdullahpur,"Fluidized Bed Drying of Coarse Uniform Size Particles", Paper presented at 73rd Canadian Chemical Conference, Halifax, N.S., 1990

Hamdullahpur, F. "Fluidization and FBC Research Activities at TUNS. Results of Solid Phase Measurements in the Freeboard with Secondary Air Injection" The 3rd National Canadian Institute of Fluidized Bed Technology Technical Workshop, Fredericton, N.B., 1989 (Invited Speaker)

Busaiffi,M.A., A.M.Al Taweel, and F. Hamdullahpur,"Pipeline Transportation of Oil Emulsions" Presented at the 38th Canadian Chemical Engineering Conference, Edmonton, October 1988.

Al Taweel, A.M., J. Militzer, J.M. Kan, F. Hamdullahpur and M. Fayed, "Sedimentation of Flocculated Particles", CSChE 1987 Centennial Meeting, Montreal, PQ, May 1987.

Zhou, Z.Q., G.S. Trivett and F. Hamdullahpur, "Further Improved Operation of an Atmospheric Pressure Fluidized Bed using Coal/Water Mixtures", Proceedings of the Sixth International Workshop on Coal-Liquid and Alternate Fuels Technology, Halifax, N.S., 1986.

Hamdullahpur, F., G.S. Trivett, R.B. Boak and J.C. Campbell, "Performance Tests of a Light Industrial (150 kW) AFBC Fuelled with Coal-Water Slurry", Proceedings of the Sixth International Workshop on Coal-Liquid and Alternate Fuels Technology, Halifax, N.S., 1986.

7. COURSE NOTES

Hamdullahpur, F. "Energy Conversion Systems" Technical University of Nova Scotia (TUNS)

8. SUPERVISED THESES (COMPLETED)

M. Gagne, "Turbulence modeling of swirling gas-particle flow in a sudden expansion geometry" TUNS, 1996, (MASc)

A. Ergudenler, "Fluidized Bed Gasification of Cereal Straw" TUNS, 1992, (PhD) (Dr. A Ghaly, Co-supervisor)

D. G. DiMattia, "Onset of Slugging in Fluidized Bed Drying of Large Particles" TUNS , 1992, (MASc.)

A. S. Fung, "Particle Dynamics in the freeboard of a Fluidized Bed" TUNS , 1991, (MASc.)

W. McGregor, "A Technoeconomic Evaluation of Fluidized Bed Furnaces for Space and Hot Water Heating" TUNS, 1991 (MASc), (Dr. I. Ugursal, Co-supervisor)

A. El-Aghili, "Heat Transfer in Fluidized Bed Furnaces" TUNS, 1991 (MASc)

H. Basirattabrizi, "Modelling of Two-phase Flow in a High Temperature Cyclone Separator" TUNS , 1990, (PhD)

R. S. Zayed, " Particle Motion in the Freeboard of Swirling Fluidized Bed" TUNS, August 1990, (PhD)

H. Katalambulla, " Fluidized Bed Drying of Coarse Uniform Sized Particles" TUNS, April 1989, (MASc) (Technical Supervisor)

M. Busaiffi, " Pipeline Transportation of Oil Emulsions " TUNS, April 1989, (MASc) (Dr. A. M. Al Taweel, Co-supervisor)

Participated in the organization of the following conferences and workshops:

Session Chairman, 9th International Conference on Fluidized Bed Combustion, May, 1987, Boston, MA.

Assistance Conference Chairman - The First International Conference on Circulating Fluidized Bed, Halifax, N.S., November 16, 1985.

Member, Editorial Board - An International Workshop on the Design and Operation of Atmospheric Pressure Fluidized Bed Boiler Combustor, Halifax, N.S., June 23, 1983.

Areas of Interest

- *Applied Fluid Mechanics and Heat Transfer*
- *Energy Conversion*
- *Combustion, Incineration*
- *Fluidization and Fluidized Bed Combustion*
- *Two-Phase Flow*
- *Non-Intrusive (LDV) Flow Diagnostics*

Professional Memberships

- *Association of Professional Engineers of Nova Scotia*
- *American Society of Mechanical Engineers*
- *Canadian Society of Chemical Engineering*
- *Chemical Institute of Canada*
- *Canadian Combustion Institute*
- *American Flame Research Foundation*

CURRICULUM VITAE

Personal

Name:	Ersoy, Levent
Birth Date:	January 1, 1968
Marital Status:	Single
Address:	Department of Mechanical Engineering Technical University of Nova Scotia PO Box 1000 Halifax, Nova Scotia B3J 2X4

Educational

January 1994 - Present	*TUNS (Technical University of Nova Scotia), Halifax, Canada* Ph. D candidate in Mechanical Engineering Subject: Experimental And Computational Two Phase Flow Expected graduation date : September-1997
1990-93	*MIDDLE EAST TECHNICAL UNIVERSITY (METU), Ankara, Turkiye* MS in Engineering Sciences Solid Mechanics: Fracture mechanics. Advanced stress analysis. Thesis on "Stress Analysis of a Long Cylinder Under Different Shaped Indenters"
1984-89	*MIDDLE EAST TECHNICAL UNIVERSITY (METU), Ankara, Turkiye* BS in Mechanical Engineering Concentration on Thermodynamics, HVAC, Combustion, Gas Turbines and IC Engines

Work Experience

January 1994-Present *TECHNICAL UNIVERSITY OF NOVA SCOTIA, Halifax, NS*

Teaching and Research assistant in the department of "Mechanical Engineering"

-Tutorials and assignment marking for Thermodynamics I and Thermodynamics II courses.

-Tutorials and assignment marking for Heating Ventilating and Air Conditioning Cource.

-Tutorials and assignment marking for Steam Power Plant course.

-Lab assistant for Heating Ventilating and Air Conditioning, Refrigeration and Compressors Labs

-Lab assistant for Non Intrusive Flow Measurements Lab (Maintenance and upgrading of Laser Doppler Velocimeter equipment)

-Research papers on "Two Phase Flow", "Fluidization", "Fluidized bed Combustion"
-Experimental works on "Design and Production of a Laboratory scale Circulating Fluidized Bed"
-Measurement of Particle Velocity and Velocity Fluctuations in CFB's with an optical probe",
-Measurement of Pressure and Pressure Fluctuations in Gas- Solid Two Phase Flow"
-Fluidized Bed Drying".

April 1991- January 1994, *ASELSAN MILITARY ELECTRONICS Inc., Ankara, Turkey*

Production Engineer responsible from Elecromechanic Assembly and Cable Harness lines.
-Worked for the design of fully automated production lines. Designed necessary jigs, fixtures and apparatus for efficient capacity usage and productivity purposes.
-Implemented ManMan Production software to shop floor for MRP, MPS and capacity planning
purposes.
-Familiar with the assembly of electromechanical parts. Hand soldering, wave soldering, insertion machines, printed circuit boards, flexible cables, ESD control.
-Attended a series of seminars on 'Total Quality Management', and implemented the principles
of TQM to the production personnel. Organized quality circles among the 70 technicians and
lead the quality circle for 'Material Handling and Plant Layout' committee.
-Designed an efficient test set-up for the 'water tightness' requirements according to MIL standards.
-Prepared the departments successfully to get the ISO 9000 Certificate,
-Advised the mechanical R&D team in designing 9600 Family frequency hopping military radio receiver and transmitters for productivity.
-Timing and rooting control.
-Supervised the electromechanical production lines of : Philips 4600 family radio receiver and transmitter, FT 6200- family field telephones, VT 7220 Proximity Fuse (Mechanical; production and foaming, Philips licensed), CX - series power cables, and cable harnesses for the above devices, Antenna cables.

June 1987-Sept. 1987, *KUTLUTAS Inc., Ankara, Turkiye*

Student Engineer. Worked in the production lines of mixer trailers. Assisted the machine operators for every station. Designed a more efficient machine layout for the production lines
Worked for the accounting office for one week

June1986 - Sept. 1986, *EFE TARIM Inc., Izmir, Turkiye*

Student Engineer. Worked in the production lines of agricultural goods: Trailers and Harvesting machines. Assisted the operators in the production of hydraulic pistons and cylinders.
Performed the quality endurance tests on the hydraulic garbage collecting trucks.

1983-Present *PRIVATE*

Professor
- Tutoring, English and Mathematics and Physics to the secondary and high school students

1986-1991 Ankara Kolejliler Spor Klubu, Ankara, Turkiye.

Semi - Pro. Athlete Played basketball in the Turkish National Basketball League.

1991-1993 Mulkiye Spor Klubu, Ankara, Turkiye.

Semi - Pro. Athlete. Basketball Team captain.

Academic and Social Achievements

- Attended an international seminar for one week on 'Material Handling and Plant Layout'. Middle East Technical University, Ankara, Turkiye.
- Attended Production Machines and Equipment Fair' 1993, Hannover, Germany
- Proud to be a starting lineup member of METU'88, Turkish Universities Basketball League Champion Team.
- Played for Nova Scotia All Star Basketball Team - Hall of Fame - December'94, Halifax
- All Star -Atlantic Collages Athletic Association '1993-94, 94-95
- Most Valuable Player - TUNS Varsity Basketball Team '1994-95
- Striker, TUNS Varsity Soccer Team '1995-96
- Honors during high school and university years
- Member of Mechanical Engineering Association, Ankara, Turkiye
- Mechanical Engineering Department Representative in Graduate Student Society 1994 - Present
- Secretary, TUNS International Student Organization, 1995- Present
- Traveled All Around Europe, Eastern United States and Cuba
- Reid Schollar-1995.

Skills & Abilities

- Languages Turkish, English and have been taking French
- Programs in Turbo Pascal, FORTRAN, C, C++, Labveiw, Basic, Visual Basic
- Operating systems: UNIX, Makintosh DOS and Windows.
- Computational Fluid Dynamics and Stress analysis: FLUENT, PHOENICS, ALGOR.
- Drafting: AUTOCAD,
- Data acquisition and control: LABVIEW.
- Numerous DOS/Windows software for Mathematical and statistical analysis packages, spreadsheets, word processors, etc.
- Manufacturing Management Software MAN-MAN
- Quick to learn any computing software
- Capable of employing advanced mathematical and physical modeling.
- Performant in individual and team work
- Able to efficiently communicate at all levels of an organization
- Familiar with international environments
- Landed Immigrant of Canada
- Practical, self initiative, dynamic

-References on request-

Chapter 2

Introduction to Fluidization

Fluidization

Fluidization is a process in which the particles are lifted by the drag of the fluid and the mass of particles looked like a boiling liquid. On the other hand, it is the phenomenon that the solid particles behave as a fluid with a density as that of the solids and fluid combined.

If the fluid passed upwards through the bed, the pressure drop will be directly proportional to the rate of flow, when the frictional drag on the particles becomes equal to their apparent weight (actual weight less buoyancy), the particles become rearranged so that they offer less resistance to the flow of fluid and the bed starts to expand. This process continues as the velocity is increased, with the total frictional force remaining equal to the weight of the particles, until the bed has assumed the loosest stable form of packing. If the velocity is then increased still further, the individual particles separate from one another and become freely supported in the fluid and the bed is said to be *fluidized*. Further increase in the velocity causes the particles to separate still further from one another, and the pressure difference remains approximately equal to the weight per unit area of the bed.

A fluidization vessel usually consists of two zones, a *dense bubbling phase* having a more or less distinct upper surface separation it from a *lean or dispersed phase*. The section of the vessel between the surface of the dense phase and the exiting gas stream from the vessel is called the *freeboard*, and its height is called the *freeboard height* H. Some of the particles in the freeboard zone are carried a significant distance above the bed surface and are elutriated, whereas others simply fall back to the surface. Eventually the rate of entrainment appears nearly constant, the freeboard height at this point is referred to as the *transport disengaging height* TDH.

The use of the fluidized solids technique was developed very largely by the petroleum and chemical industries, for processes where the very high heat transfer coefficients and the high degree of uniformity of temperature within the bed enabled the development of processes which would otherwise be impracticable. Fluidized solids are now used quite extensively in many industries where it is desirable to bring about intimate contact between small solid particles and a gas streams. In many cases it is possible to produce the same degree of contact between the two phases with a very much lower pressure drop over the system. Drying of finely divided solids is now carried out in a fluidized system, and some carbonization and gasification processes are now in operation. Fluidized beds are employed in gas purification work, in the removal of suspended dusts and mists from gases, in lime burning and in the manufacture of phthalic anhydride.

The Phenomenon of Fluidization

If a fluid is passed upward through a bed of fine particles, as shown in Fig. 1(a), at a low flow rate, the fluid merely percolates through the void spaces between stationary particles. This is a *fixed bed*. With an increase in flow rate, particles move apart and a few vibrate and move in restricted regions. This is the *expanded bed*.

At a still higher velocity, a point is reached where all the particles are just suspended by the upward-flowing gas or liquid. At this point the frictional force between particle and fluid just counterbalances the weight of the particles, the vertical component of the compressive force between adjacent particles disappears, and the pressure drop through any section of the bed about equals the weight of fluid and particles in that section. The bed is considered to be just fluidized and is referred to as an *incipiently fluidized bed* or a bed at *minimum fluidization*; see Fig. 1(b).

In liquid-solid systems, an increase in flow rate above minimum fluidization usually results in a smooth, progressive expansion of the bed. Gross flow instabilities are damped and remain small, and heterogeneity, or large-scale voids of liquid, are not observed under normal conditions. A bed such as this is called a *particulately fluidized bed*, a *homogeneously fluidized bed*, or a *smoothly fluidized bed*; see Fig. 1(c). In gas-solid systems, such beds can be observed only under special conditions of fine light particles with dense gas at high pressure.

Generally, gas-solid systems behave quite differently. With an increase in flow rate beyond minimum fluidization, large instabilities with bubbling and channeling of gas are observed. At higher flow rates, agitation becomes more violent and the movement of solids become more vigorous. In addition, the bed does not expand much beyond its volume at minimum fluidization. Such a bed is called an *aggregative fluidized bed*, a *heterogeneous fluidized bed*, or a *bubbling fluidized bed*; see Fig. 1(d). In a few rare cases, liquid-solid systems also behave as bubbling beds. This occurs only with very dense solids fluidized by low-density liquids.

Both gas and liquid fluidized beds are considered to be dense-phase fluidized beds as long as there is a fairly clearly defined upper limit to the bed.

In gas-solid systems, gas bubbles coalesce and grow as they rise, and in a deep enough bed of small diameter they may eventually become large enough to spread across the vessel. In the case of fine particles, they glow smoothly down by the wall around the rising void of gas. This is called *slugging*, with *axial slugs*, as shown in Fig. 1(e). For coarse particles, the portion of the bed above the bubble is pushed upward, as by a piston. Particles rain down from the slug, which finally disintegrates.

At about this time another slug forms, and this unstable oscillatory motion is repeated. This is called a *flat slug*; see Fig. 1(f). Slugging is especially serious in long, narrow fluidized beds.

When fine particles are fluidized at a sufficiently high gas flow rate where the terminal velocity of the solids is exceeded, the upper surface of the bed disappears, entrainment becomes appreciable, and, instead of bubbles, one observes a turbulent motion of solid clusters and voids of gas of various sizes and shapes. This is the *turbulent fluidized bed*, shown in Fig. 1(g). With a further increase in gas velocity, solids are carried out of the bed with the gas. In this state we have a *disperse-*, *dilute-*, or *lean-phase fluidized bed* with *pneumatic transport of solids*; see Fig. 1(h).

In both turbulent and lean-phase fluidization, large amounts of particles are entrained, precluding steady state operations. For steady state operation in these contacting modes, entrained particles have to be collected by cyclones and returned to the beds. In turbulent fluidized beds, inner cyclones can deal with the moderate rate of entrainment, as shown in Fig. 2(a), and this system is sometimes called a *fluid bed*. On the other hand, the rate of entrainment is far larger in lean-phase fluidized beds, which usually necessitates the use of big cyclone collectors outside the bed, as shown in Fig. 2(b). This system is called the *fast fluidized bed*.

In fluid beds and fast fluidized beds, recirculation of solids through the dipleg or other solid trapping device is crucial for smooth operations. These beds are called *circulating fluidized beds*.

The *spouted bed*, sketched in Fig. 3, represents a somewhat related contacting mode wherein comparatively coarse uniformly sized solids are contacted by gas. In this operation, a high-velocity spout of gas punches through the bed of solids, thereby transporting particles to the top of gas punches through the bed of solids, thereby transporting particles to the top of the bed. The rest of the solids move downward slowly around the spout and through gently upward-percolating gas. Behavior somewhere between bubbling and spouting is also seen, and this may be called *spouted fluidized bed* behavior.

Compared to other methods of gas-solid contacting, fluidized bed have some rather unusual and useful properties. This is not the case with liquid-solids fluidized beds. Thus, most of the important industrial applications of fluidization to date are with gas-solid systems.

Identification of fluidization parameters

1. Superficial gas velocity, u_c

Superficial gas velocity is the gas velocity in the containing vessel that if there were not any solid particles in it. It can be calculated from the ratio of the volume flow rate of the fluid to the cross section area of the containing vessel.

$$u_c = \frac{\dot{V}}{A_c}$$

u_c is the superficial gas velocity.

$\dot{V}$ is the volume flow rate.

A_c is the cross section area of the column.

2. Interstitial gas velocity, u_i

Interstitial gas velocity is the gas velocity in the containing vessel that there are the solid particles in it. It can be calculated from the ratio of the volume flow rate of the fluid to the outcome of the cross section area of the containing vessel minus the area that possessed by the solids particles in the same plane.

$$u_i = \frac{\dot{V}}{A_c - A_{solids}}$$

u_i is the interstitial gas velocity.

A_{solids} is the area that possessed by the solids particles in the same plane with the cross section area of interest.

The interstitial gas velocity is defined as the average velocity of the gas in containing vessel that there are the solid particles in it. However when we want to define any velocity, such as, minimum fluidization velocity or minimum bubbling velocity, we will define based on the superficial gas velocity. Since interstitial gas velocity is not constant throughout the bed, its value changes with the cross sectional solid concentration.

3. Minimum fluidization velocity, u_{mf}

It is the superficial gas velocity at which the weight of the particles in the bed is counterbalanced by the drag force on them. As the upward velocity of flow of fluid through a packed bed(see fixed bed) of uniform spheres is increased, the point of incipient fluidization is reached when the particles are just freely supported in the fluid.

Most of the bubbling beds are designed by using the minimum fluidization velocity as a major parameter, it is desirable to standardize a method of determination so that the characteristics of different systems can be compared. This is most conveniently done by using the graph of frictional pressure drop against velocity. If separate lines are drawn through the points for the fixed(flow decreasing) and fluidized regions, and the points in the intermediate region are ignored the point of intersection of these two lines will give a reproducible value for the minimum fluidization velocity. The whole of the bed is not fluidized until all the particles are fully supported in the fluid and the pressure drop becomes exactly equal to the buoyant weight per unit area Δp_{eq}. The minimum velocity at which this occurs will be called the "full supporting velocity", u_{fs}. This is a difficult quantity to determine accurately because the pressure drop reaches its limiting value gradually. Furthermore, the value of u_{fs} may well be influenced by the initial packing of the solids and the bed support, and may not therefore have a consistent value for any particular system. For the experimental results, u_{fs} is more than 50% greater than u_{mf}. The whole problem of measurement can be complicated too, especially in beds of small diameter, by frictional effects between the circulating solids and the walls of the container.

In the absence of the facility to carry out an experimental determination, it is useful to be able to calculate approximately the value of the minimum fluidization velocity. This may be done by using an expression for the relation between pressure drop and superficial gas velocity for a fixed bed and putting the pressure drop equal to the buoyant weight of the particles. This does, of course, necessitate a knowledge of the voidage of the bed at the minimum fluidizing velocity(e_{mf}). This will depend on the shape and size range of the particles, but a value of about 0.4 would be appropriate for approximately spherical particles. Various attempts have been made to relate the value of e_{mf} to a shape factor for the particle, but these have not been entirely satisfactory.

The corresponding minimum fluidization velocity(u_{mf}) is obtained by the following procedure [Coulson & Richardson, 1991].

From

$$G_a = \left(150 \times \frac{1-e_{mf}}{e_{mf}^3} \times \mathrm{Re}'_{mf}\right) + \left(\frac{1.75}{e_{mf}^3} \times \mathrm{Re}'^{2}_{mf}\right)$$

By definition:

$$u_{mf} = \frac{\mu}{d \cdot \rho} \mathrm{Re}'_{mf} \qquad \text{-----------}❶$$

$$G_a = \frac{d^3 \cdot \rho \cdot (\rho_s - \rho) \cdot g}{\mu^2}$$

For a typical value of $e_{mf} = 0.4$:

$$\left(\mathrm{Re}'_{mf}\right)_{e_{mf}=0.4} = 25.7 \times \left\{\sqrt{1+5.53 \times 10^{-5}\, Ga} \; - 1\right\} \text{-----------}❷$$

And substitute the value of Re'_{mf} from equation ❷ into equation ❶. Then the corresponding value is obtained. (see the example that the minimum fluidization velocity is calculated in Appendix A.)

4. Minimum bubbling velocity, u_{mb}

In gas solid fluidized beds, only a bed limited expansion takes place as the gas velocity is increased from a minimum fluidization velocity. At higher gas flow rates much of gas passes through the bed in the form of bubbles and makes a relatively small contribution to the expansion of the bed. The upper limit of gas velocity for particulate expansion is termed as the minimum bubbling velocity, u_{mb}. There are a lot of difficulties; because its value may depend on the nature of the distributor, on the presence of even tiny obstructions in the bed, and even on the immediate history of the bed. The ratio u_{mb}/u_{mf} gives a measure of the degree of expansion of the bed. The ratio might also be considered as a measure of the sizes of the bed particles. It usually has a high value for fine light particles and a low value for large dense particles.

5. Terminal velocity

If a particle of mass m and weight mg, initially at rest, is allowed to fall under the action of gravity force, at some later time, the particle will accelerate to a definite velocity. During its downward flight the particle is subjected to the resistance of the surrounding fluid medium. This resistance increases as the particle velocity increases up to the point in time when accelerating and resisting forces are equivalent. From this point, the particle continues to fall at a constant maximum velocity, know as the terminal velocity

6. Entrainment

In general, entrainment refers to the removal of solids from the bed by fluidizing gas in both single component and multicomponent systems. For a freeboard height less than TDH, the size distribution of solid in the freeboard changes with position, and entrainment decreases as the freeboard height approaches the TDH. When the gas stream exits above the TDH, then both the size distribution and entrainment rate become constant and are given by the *saturation carrying capacity* of the gas stream under pneumatic transport conditions. This term also applies to the entrainment above the TDH for a single size of solid.

7. Elutriation

Elutriation refers to the selective removal of fines by entrainment from a bed consisting of a mixture of particles sizes. The rate of elutriation of solids of size d_p from a mixture is characterized by the net upward flux of this size of solid,

$$\begin{pmatrix} \textit{rate of removal of solids} \\ \textit{of size } d_p \textit{ per area of bed} \\ \textit{surface, gm / cm}^2 \cdot \sec \end{pmatrix} = \chi^* \begin{pmatrix} \textit{fraction of bed} \\ \textit{consisting of} \\ \textit{size } d_p \end{pmatrix}$$

If $W(d_p)$ is the weight of solid of size d_p, A_t is the cross-sectional area of bed and W is the weight of all solids in the bed, then the equation become

$$-\frac{1}{A_t}\frac{dW(d_p)}{dt} = \chi^{\bullet}\left(\frac{W(d_p)}{W}\right)$$

where χ^{*} (gm/cm^2 · sec) is an elutriation (rate) constant. In a mixture χ^{*} varies with size of solids; a large value for χ^{*} corresponds to a rapid removal rate, and $\chi^{*} = 0$ means that particular size of solid is not removed at all by entrainment.

The elutriation rate is also defined by

$$\begin{pmatrix} \text{rate of removal} \\ \text{of solids of size } d_p \end{pmatrix} = \chi \begin{pmatrix} \text{weight of that size} \\ \text{solid in the bed} \end{pmatrix}$$

or

$$-\frac{dW(d_p)}{dt} = \chi\, W(d_p)$$

In comparing definitions we see that

$$\chi^{*} = \chi\,\frac{W}{A_t}$$

Although χ (sec^{-1}) is also called an elutriation constant, one should note that it varies proportionately with bed section and inversely with bed height. Also, in batch or unsteady-state experimentation χ should change during a run as material is elutriated from the bed (W changes). The constant χ^{*} is unaffected by these changes as long as the quality of fluidization remains the same.

8. Voidage

Depending on the shape of particles and packing characteristics, a certain volume of space in between the particles remains unoccupied such space is called a void volume and is specified as voidage or porosity, defined as

$$voidage = porosity = \frac{void\ volume}{Total\ volume}$$

9. Emulsion phase

Emulsion phase is the region of high solids density in a fluid bed, whereas, those of low solids density are referred to as gas pockets or voids.

When we increase the gas flow through the solids bed, this act can cause the gas to flow in the form of *bubbles*. The section of the bed outside the bubbles is the emulsion phase.

10. Fixed Bed

Consider a column that is filled with loose solids. If a fluid is passed upward through the bed of solids at a relatively low velocity, then the fluid will merely percolate through the void spaces between solid particles. The solid particles in this case will remain undisturbed. This system is referred to as a *fixed or packed bed.* In *moving packed beds*, the solids move with respected to the wall of the column. In either case the particles do not move relative to each other. As the gas flows through the solids, it exerts a drag force on the particles, causing a pressure drop across the bed. the pressure drop through unit height of a fixed bed of uniformly sized particles, $\Delta P/L$, is correlated as (Basu & Fraser, 1991)

$$\frac{\Delta P}{L} = 150\frac{(1-\varepsilon)^2}{\varepsilon^3}\cdot\frac{\mu u_c}{(\phi d_s)^2} + 1.75\frac{(1-\varepsilon)}{\varepsilon^3}\cdot\frac{\rho_g u_c^2}{\phi d_s}$$

where u_c is the superficial gas velocity

d_s is the diameter of bed particles

ϕ is the sphericity of bed particles [1]

μ is the viscosity of fluid

ρ_g is the gas density

[1] Sphericity describes the departure of the particle from a spherical shape, for example, a spherical particle has a sphericity of 1.0

$$\text{Sphericity}(\phi) = \frac{\text{Surface area of a sphere with the volume same as the particle}}{\text{Actual surface area of the particle}} = \frac{\pi d_v^2}{S}$$

d_v (Volume diameter) is the diameter of a sphere that has the same volume as the particle

$$d_v = \left(\frac{6}{\pi} \times \text{volume of particle}\right)^{\left(\frac{1}{3}\right)} = \left(\frac{6V}{\pi}\right)^{\left(\frac{1}{3}\right)}$$

11. Bubbling fluidized bed

If the gas flow rate through the fixed bed is increased, the pressure drop continues to rise, until the superficial gas velocity reaches the minimum fluidization velocity. At this stage the particles feel "weightless", and the fixed bed transforms into an incipiently fluidized bed. In this regime the body of solids behaves like a liquid.

12. Turbulent bed

When the velocity of gas through a bubbling fluidized bed is increased above the minimum bubbling velocity, the bed expands. A continued increase in the velocity may eventually show a change in the pattern in the bed expansion. This may be due to an increase in the bubble fraction, an expansion of the emulsion phase, and thinning of the emulsion walls separating the bubbles. At this stage the bubble phase loses its identity due to rapid coalescence and breakup . This results in a violently active and highly expanded bed, and a change in the pattern of bed expansion. Particles are thrown into the freeboard(freeboard is the zone of the vessel, between the surface of the dense bed and the top of the bed where the gas stream exits) above the bed. Such beds are referred as the turbulent beds.

13. Fast Bed

The fast bed may be defined as a high velocity gas-solid suspension where particles, elutriated by the fluidizing gas above the terminal velocity of single particles are recovered and returned to the base of the furnace at a rate sufficiently high as to cause a degree of solid refluxing that will ensure a minimum level of temperature uniformity in the furnace.

It was described as a regime lying between the turbulent fluidized bed and the pneumatic transport(see pneumatic transport). In a typical fast fluidized bed, one observes a non-uniform suspension of slender particle agglomerates moving up and down in a very dilute up-flowing gas-solid continuum.

14. Pneumatic transport

If the gas is flowing upwards through a vertical column to which solid is fed at a given rate. The suspension is initially in pneumatic transport.

The definition of pneumatic transport is similar with fast bed. But in pneumatic transport, solid particles merely flow upwards through the column. In fast bed, there are the solid particles flow upward and downward in the column.

Transition from pneumatic transport to fast fluidization may occur when the rate of solid circulation is increased while keeping the gas velocity fixed above a certain velocity.

15. Circulating fluidized bed

As the velocity of gas flow through a fluidized bed of fine powder was raised, the breakdown of the slugging regime into a state of continuous coalescence, is observed. The bed has the appearance of turbulence and if solid is introduced into the bottom of the fluidized bed and withdrawn from the top, we have the recirculating fluidized bed operating in the turbulent regime. This recirculating fluidized bed has been termed "circulating fluidized bed".

16. Distributor plate

Distributor plate is a perforated grid which a bed of particles sit on. Its diameter is smaller than the diameter of particles; but the gas from the blower can pass through it.

Types of Distributors

Distributor plates can be broadly classified in to three groups:

1. *Porous* and straight-hole orifice type: it generally uses vertical orifices through a grid plate or sintered plates.

2. *Nozzle* type or bubble caps: air enters into nozzles, which distribute air into the bed through horizontal or vertically downward holes.

3. Sparge tube type: air-carrying tubes with holes are introduced directly into the fluidized bed; does not require a grid plate or a *plenum box* (the section between the air inlet jet and the distributor plate) below it.

Typical designs of above type of distributors are shown in Figure 4. In addition to these, there are a few novel designs used by some companies with considerable success. For example, the bent-tube nozzle used by Pyropawer Corporation (Figure 4), prevents back-flow of solids and is easy to clean up.

Desired Properties

The primary function of the distributor grate is to distribute the fluidizing air uniformly over the cross section of the bed. The formation of bubbles (in the external heat exchanger or seal pot) or the random mixing in the bed often changes local pressure above the gas distributor. This causes the flow through individual orifices to change. More air flows through the orifices that are subjected to lower downstream pressures. Thus channels or flow paths of low voidage are established above these orifices, which further increases the flow through these orifices, while depriving other orifices. This leads to a nonuniform flow. For example, solids flowing along the wall create a dense region near the wall. As a result, the flow through orifices near the wall experiences a high downstream pressure and, therefor, a smaller amount of air flow through it.

The desired properties of the distributor may be listed as follows:

1. Uniform and stable fluidization over the entire range of operation
2. Minimum attrition of bed materials
3. Minimum erosion of bed internals or heat exchanger tubes.
4. Minimum back-flow of solids into the plenum chamber
5. Minimum amount of dead zones on the distributor
6. Minimum plugging over extended periods of operation.

17. Cyclones

A cyclone is a device which separates solid particulate from a relatively dry gas stream. Hydroclones are essentially the same device, which effect solids separations from liquids. Both devices are the simple and economical separators. Their operation is identical, whereby both inertial and gravitational forces are capitalized upon. Their primary advantages are high collection efficiency in certain applications, adaptability and economy in power. The main disadvantage lies in their limitation in achieving high collection efficiencies for small particles. In general, cyclones are not capable of high efficiencies when handling gas streams containing large concentrations of particulates less than 10 μm in size.

Cyclones generally are efficient handling devices for a wide range of particulate sizes. They are capable of collecting particles ranging in size from 10 to above 2,000 μm, with inlet loading from less than one grain per scfm to greater than 100 grains per scfm. There are many design variations of the basic cyclone configuration. Because of its simplicity and lack of moving parts, a wide variety of construction materials can be used to cover relatively high operating temperatures of up to 2000°F.

Cyclones are employed in the following general applications:

1. Collection of coarse dust particles
2. Handling high solid concentration gas streams between reactors such as Flexicokers (concentration typically above 3 grains/sfc)
3. For classifying particulate sizes
4. In operations where extremely high collection efficiency is not critical
5. As precleaning devices in line with higher efficiency collectors for fine particles

18. L-valve

L-valve is one popular type of nonmechanical valve. It's a controllable valve. Nonmechanical valves are devices that allow the flow of solids between the return leg (standpipe) and the furnace without any external mechanical force. Solids in nonmechanical valve are moved by air. This air is added at a short height above the exit of the valve. The bulk of the aeration air generally flow in the desired direction of solid flow. This is governed by the pressure balance around the valve. The L-valve consists of a right-angled, bent (L-shaped) pipe connecting the two vessels between which the solids are to be transferred. In a CFB boiler the vertical leg of the L-valve is connected to the solid hopper of the cyclone(or any gas-solid separator). The horizontal arm of the L-valve is connected to the CFB furnace. The L-valve would usually have a moving packed bed in the vertical leg and a less dense bed in the furnace into which the solids is fed. A small amount of air is injected into the vertical leg of the L-valve at a short distance above the axis of its horizontal arm. These air (or gas) moves solids from the dense vertical leg to the relatively dilute bed. The aeration air moves downwards through the particles and then through the constricting bend of the L-valve. Solid flow commences only beyond a certain minimum value of air rate.

19. Bed material

In fluidized bed coal combustion processes, coal generally constitutes around 1-3% by weight of the total solids in the bed. The remaining solids, known as bed materials, are coal ash and reacting or spent sorbents. The bed material includes

1. Sand or gravel (low ash fuels, such as wood-chips).

2. Fresh or spent limestone(boilers burning high-sulfur coal and requiring control of sulfur emission).

3. Ash from coal(boilers firing high or medium ash coal requiring no sulfur retention).

Particle Classification

In the light of fluidization experience, Geldart (1973) classified solids broadly under four groups, **A**, **B**, **C** and **D**. This classification is important in understanding the fluidization behavior of solids particles, because under similar operating conditions particles of deferent groups may behave entirely differently.

Group A

These particles (density of solids, ρ = 2500 kg/m^3) are typically in the range of 30-100 μm. These particles fluidized well, but expand considerably after crossing the minimum fluidization velocity and before bubbles start appearing. Many circulating fluidized bed systems use Group A particles.

Group B

These particles are normally in the range of 100-500 μm (if ρ = 2500 kg/m^3) size. They fluidize well. Bubbles appear as soon as the minimum fluidization is exceeded. The majority of the CFB boilers use this group of particles.

Group C

These particles are very fine and are typically smaller than 30 μm (ρ = 2500 kg/m^3). The interparticles forces are comparable to the gavitational force on these particles. These particles are very difficult to fluidize. An attempt at fluidization often results in channeling. Special techniques are required to fluidize these particles.

Group D

These are the coarsest of all particles (> 500 μm) (for ρ = 2500 kg/m^3). They require a much higher velocity to fluidize these solids. Spouted beds (see The Phenomenon of Fluidization) generally operate on this size of solids.

A comparison of properties of particles of different groups is given in Table 2

20. Riser

Solids can be transported up or down an inclined or vertical pipe. Such a pipe, with solids traveling downwards cocurrently or countercurrently to a fluid, is referred to as a standpipe. A pipe in which solids are lifted upwards by a fluid is known as a riser. Standpipes and riser together often form part of a solid circulatory loop. The solid flow rate may be controlled by means of a slide valve affixed to the bottom end of the standpipe or by other means.

21. Downer

Downer is the crucial element in a pneumatic circulation system for solids return, its function being to transfer solids from an upper zone or vessel at low pressure to a lower zone of higher pressure while providing a gas seal between vessels. In this operations, gas tries to flow up the pipe to the low-pressure region but is hindered by the downflowing solids [Flu. Eng. P.371].

Advantages and Disadvantages of Fluidized Beds for Industrial Operations

The fluidized bed has desirable and undesirable characteristics. Table 1 compares its behavior as a chemical reactor with other reactors. Its *advantages* are;

1. The smooth, liquidlike flow of particles allows continuous automatically controlled operations with easy handling.

2. The rapid mixing of solids leads to close to isothermal conditions throughout the reactor; hence the operation can be controlled simply and reliably.

3. The whole vessel of well-mixed solids represents a large thermal flywheel that resists rapid temperature changes, responds slowly to abrupt changes in operating conditions, and gives a large margin of safely in avoiding temperature runaways for highly exothermic reactions.

4. The circulation of solids between two fluidized beds makes it possible to remove (or add) the vast quantities of heat produced (or needed) in large reactors.

5. Heat and mass transfer rates between gas and particles are high when compared with other modes of contacting.

6. The rate of heat transfer between a fluidized bed and an immersed object is high; hence heat exchangers within fluidized beds require relatively small surface areas.

Its disadvantages are;

1. For bubbling beds of fine particles, the difficult-to-describe flow of gas, with its large deviations from plug flow, represents inefficient contacting. This becomes especially serious when high conversion of gaseous reactant or high selectivity of a reaction intermediate is required.

2. The rapid mixing of solids in the bed leads to nonuniform residence times of solids in the reactor. For continuous treatment of solids, this gives a nonuniform product and poorer performance, especially at high conversion levels. For catalytic reactions, the movement of porous catalyst particles, which continually capture and release reactant gas molecules, contributes to the backmixing of gaseous reactant, thereby reducing yield and performance.

The solution of two above disadvantages is using Circulating Fluidized Bed, CFB.

3. Friable solids are pulverized and entrained by the gas and must be replaced.

4. Erosion of pipes and vessels from abrasion by particles can be serious.

5. For noncatalytic operations at high temperature, the agglomeration and sintering of fine particles can require a lowering in temperature of operations, thereby reducing the reaction rate considerably.

6. It is suitable for large-scale operations.

The compelling advantage of overall economy of fluidized contacting has been responsible for its successful use in industrial operations. But such success depends on understanding and overcoming its disadvantages.

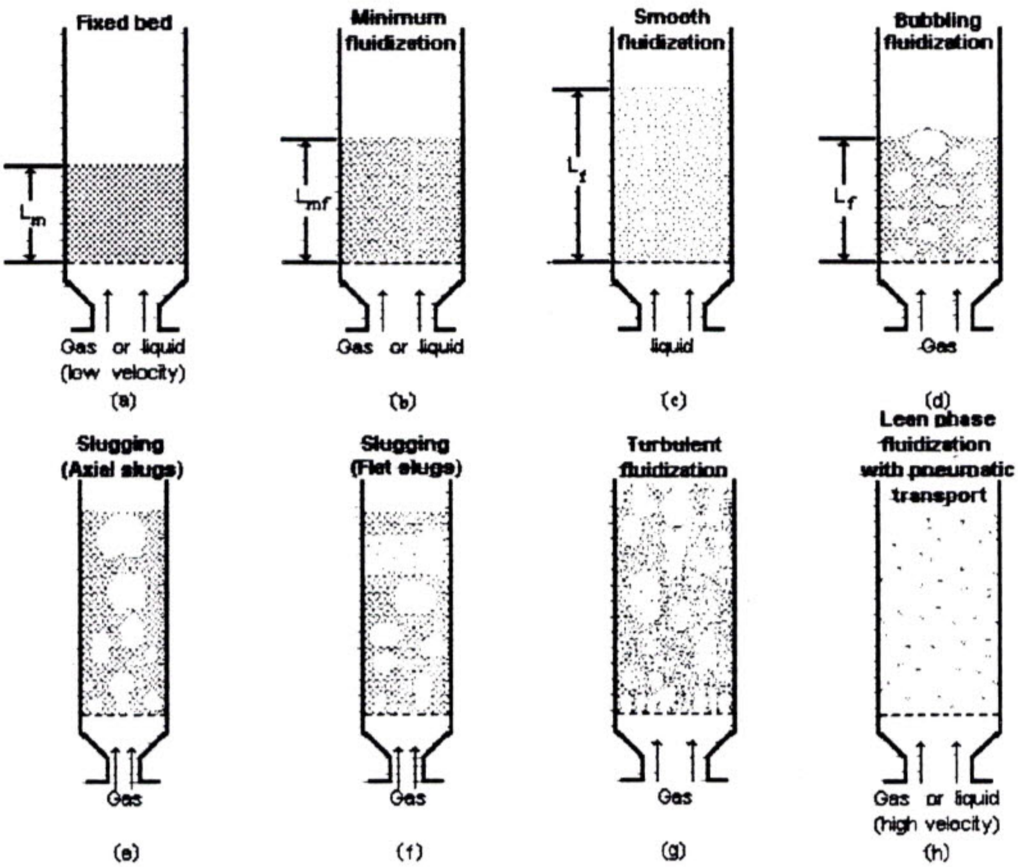

Figure 1 Various kinds of fluidized bed regimes

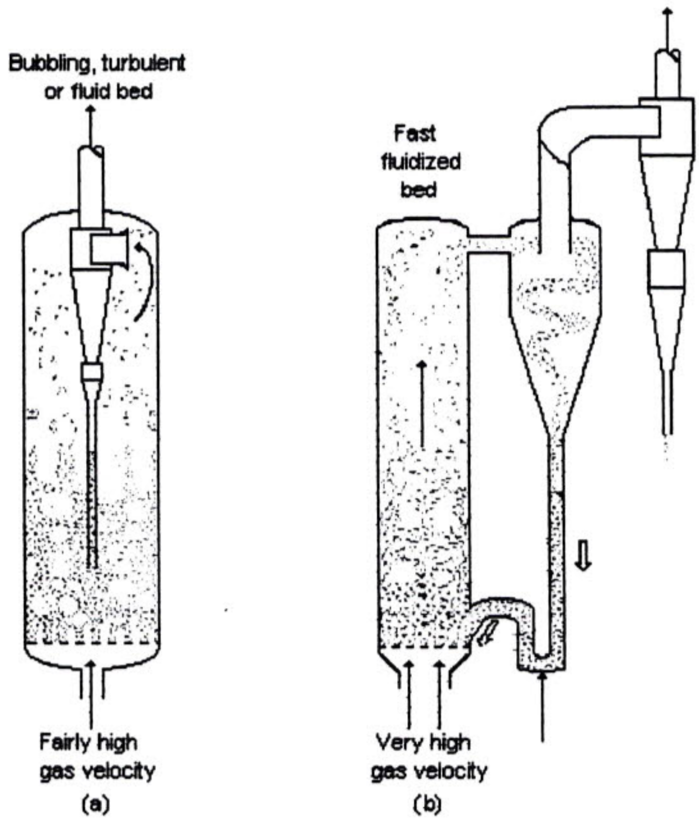

Figure 2 Collecting modes of entrained particles

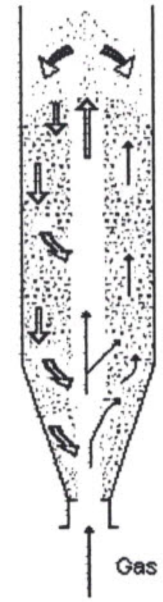

Figure 3 Spouted bed

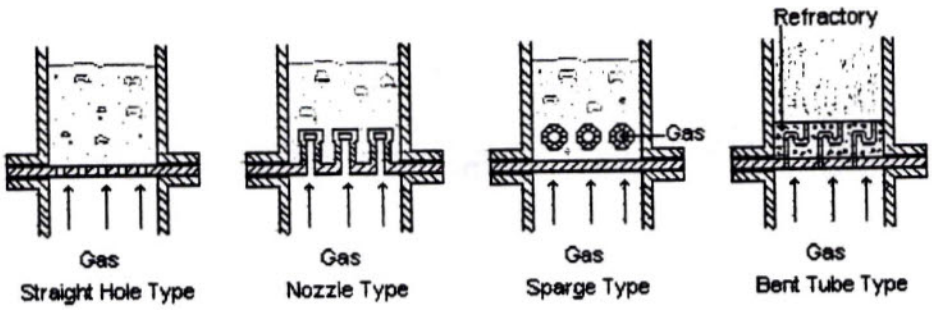

Figure 4 Types of gas distributor plates

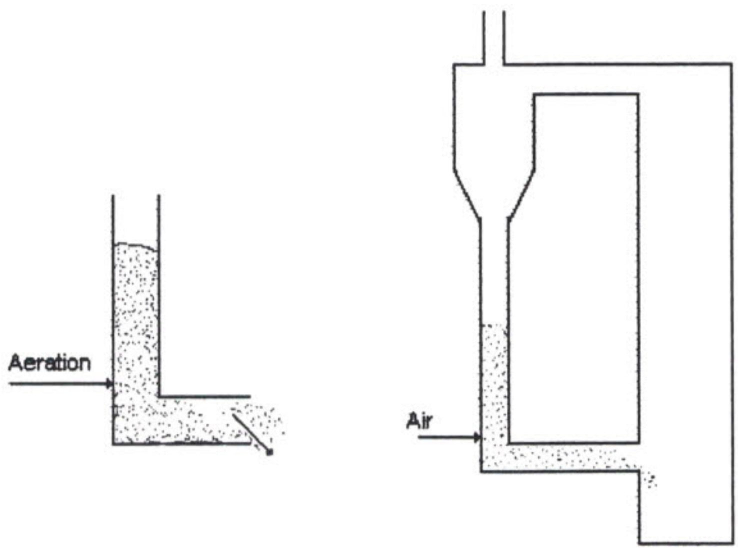

Figure 5 L-valve

	Solid-Catalyzed Gas-Phase Reaction	Gas-Solid Reaction	Temperature Distribution in the Bed	Particles
Fixed Bed	Only for very slow or nondeactivating catalyst. Serious temperature control problems limit the size of units.	Unsuited for continuous operations yield nonuniform product.	Where much heat is involved large temperature gradients occur.	Must be fairly large and uniform. With poor temperature control these may sinter and clog the reactor.
Moving Bed	For large granular rapidly deactivated catalyst. Fairly large-scale operations possible.	For fairly uniform sized feed with little or no fines. Large-scale operations possible.	Temperature gradients can be controlled by proper gas flow or can be minimized with sufficiently large solid circulation.	Fairly large and uniform; top size fixed by the kinetics of the solid recirculation system, bottom size by the fluidizing velocity in reactor.
Bubbling and Turbulent Fluidized Bed	For small granular or powdery nonfriable catalyst. Can handle rapid deactivation of solids. Excellent temperature control allows large-scale operations.	Can use wide range of solids with much fines. Large-scale operations at uniform temperature possible. Excellent for continuous operations, yielding a uniform product.	Temperature is almost constant throughout. This is controlled by heat exchange or by proper continuous feed and removal of solids.	Wind size distribution and much fines possible. Erosion of vessel and pipelines, attrition of particles and their entrainment may be serious.
Fast Fluidized Bed and Cocurrent Pneumatic Transport	Suitable for rapid reactions. Attrition of catalyst is serious.	Suitable for rapid reactions. Recirculation of fines is crucial.	Temperature gradients in direction of solids flow can be minimized by sufficient circulation of solid.	Fine solids, top size governed by minimum transport velocity. Severe equipment erosion and particle attrition.

Table 1 Comparison of Types of Contacting for Reacting Gas-Solids Systems.

RECOMMENDATIONS

During the time I worked at TUNS, there were some problems that I encountered. These problems include:

1. There are a small number of text book in Fluidization; and there is only one copy for each book. So I have many problems for find the information that I looked for.
2. In my opinion, the number of personal computer are not sufficient for the students. Sometimes there is no a personal computer for me to use; because every workstation is possessed.

Two problems that I mentioned are a big problem to solve; because their origin is the money. We must spent a long time for solve these problems. However I really like many systems about the library and the computer room at TUNS.

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Appendix A

The calculation examples about Fluidization

Example 1 Calculation of Minimum Fluidization Velocity

A bed consists of uniform spherical particles of diameter 3 mm and density 4200 kg/m^3. What will be the minimum fluidization velocity in a liquid of viscosity 3 mNs/m^2 and density 1100kg/m^3?

Solution

By definition:

$$\textit{Galileo number}\ Ga = \frac{d^3 \rho(\rho_s - \rho) g}{\mu^2}$$

$$= \frac{(3 \times 10^{-3})^3 \times 1100 \times (4200 - 1100) \times 9.81}{(3 \times 10^{-3})^2}$$

$$= 1.003 \times 10^5$$

Assuming a value of 0.4 for e_{mf},

from $$\left(\mathrm{Re}'_{mf}\right)_{e_{mf}=0.4} = 25.7 \times \left\{\sqrt{1 + 5.53 \times 10^{-5}\, Ga} - 1\right\}$$

$$\left(\mathrm{Re}'_{mf}\right)_{e_{mf}=0.4} = 25.7 \times \left\{\sqrt{1 + (5.53 \times 10^{-5})(1.003 \times 10^{-3})} - 1\right\}$$

$$= 40$$

$$u_{mf} = 40 \times \frac{3 \times 10^{-3}}{3 \times 10^{-3} \times 1100}$$

$$= 0.0364\ m/s$$

$$= 36.4\ mm/s$$

Ans.

It is specified that the volume flow rate of air is 0.2 m^3 / sec. Assume the operating conditions is atmospheric pressure and the temperature is 800°C, so the air can be treated as an ideal gas since it is at a high temperature and low pressure relative to its critical values (T_{cr} = -147°C and P_{cr} = 2290 kPa for nitrogen, the main constituent of air).
To determine the mass flow rate of air, we need to find density of the air first. This is determined from the ideal-gas relation at the inlet conditions:

$$\rho = \frac{P}{RT} = \frac{101.325}{0.287 \times 1073}$$

$$= 0.329 \ kg / m^3$$

Then

$$\dot{m}_{air} = \rho \times \dot{V}$$
$$= 0.329 \times 0.2$$
$$= 0.0658 \ kg / \sec$$

Also, the fuel flow rate is determined by

$$AF = \frac{\dot{m}_{air}}{\dot{m}_{fuel}} = 8.469$$

$$\dot{m}_{fuel} = \frac{\dot{m}_{air}}{8.469}$$

$$= 7.769 \times 10^{-3} \ kg / \sec$$

That is, 7.77×10^{-3} kg of lignite is supplied every second during this combustion process.

b) The theoretical sorbent requirements are 3.15 kg of limestone per kg sulfur in the fuel [Feridun Hamdullahpur & V.Ismet Ugursal].
Recall that

$$\dot{m}_{fuel} = 7.769 \times 10^{-3} \ kg / \sec$$

The percentages of surfer in lignite is 1%, so the mass flow rate of sulfur is determined by

$$\dot{m}_{sulfur} = 7.769 \times 10^{-3} \times 0.01$$
$$= 7.769 \times 10^{-5} \ kg / \sec$$

And the mass flow rate of limestone is determined by

$$\dot{m}_{\lim estone} = 7.769 \times 10^{-5} \times 3.15$$

$$= 2.447 \times 10^{-4} \quad kg/\sec$$

That is, 2.45×10^{-4} kg of limestone is supplied every second during this combustion process.

c) The size of fuel particles do not necessarily have a major bearing on that of bed materials, because they constitute only a minor fraction (1-3%) of the total bed materials in the CFB furnace. (from Prabir Basu, Scott A.Fraser, *Circulating Fluidized Bed Boilers: Design and Operations*, Page 6, Butterworth-Heinemann, Boston, 1991.)

Assume there are 2% of lignite in bed materials, so the mass flow rate of bed materials is determined by

$$\dot{m}_{fuel} = 7.769 \times 10^{-3} \ kg/\sec$$

So

$$\dot{m}_{bed\,materials} = \frac{98}{2} \times 7.769 \times 10^{-3}$$

$$= 3.807 \times 10^{-1} \ kg/\sec$$

That is, 3.81×10^{-1} kg of bed materials is supplied every second during this combustion process.

Ans.

Appendix B

The example of figures of experiment in Fluidization

Name: Levent Ersoy

Name of Thesis: The effect of Secondary air injection on the Hydrodynamics of Circulating Fluidized Beds

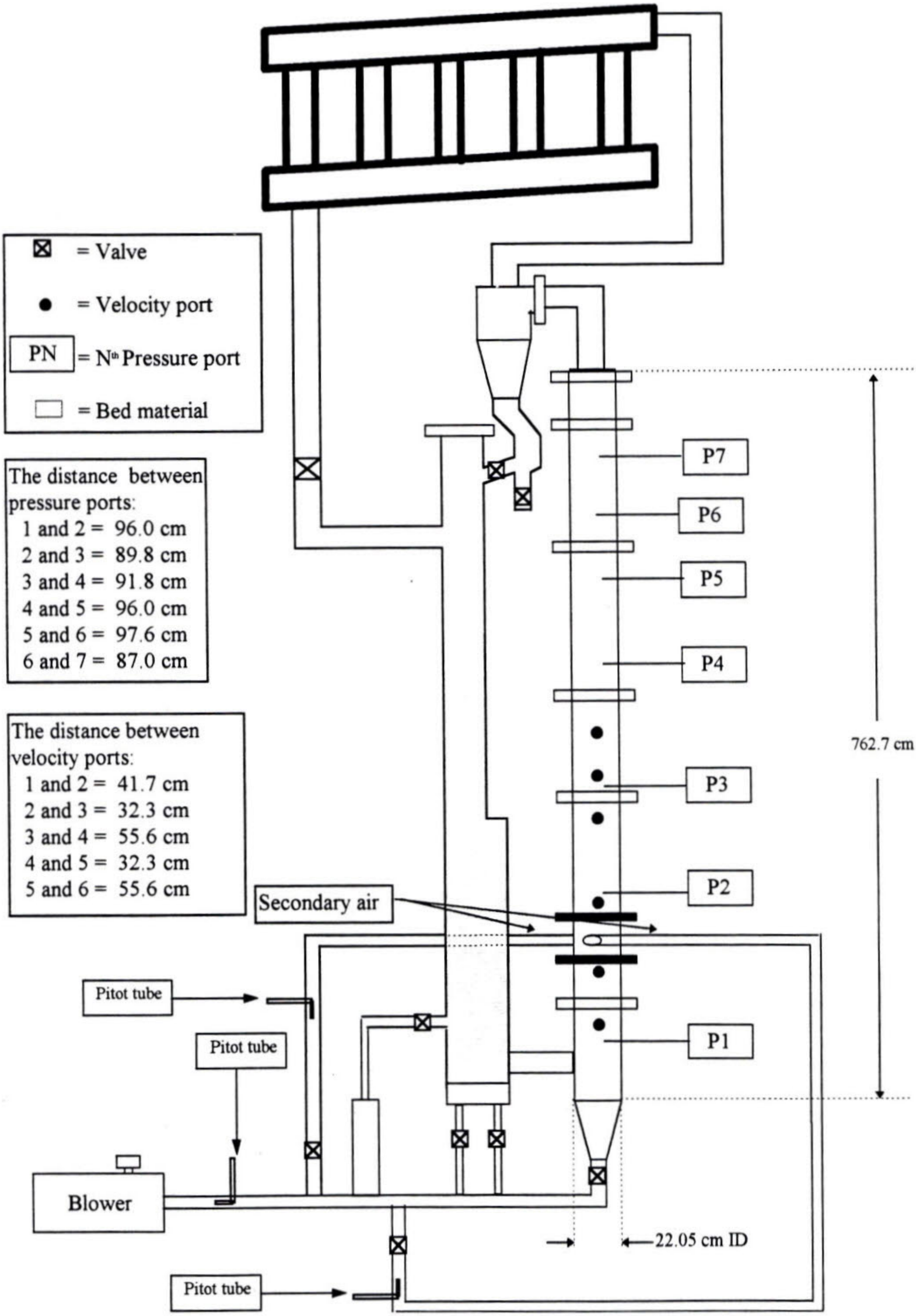
Descriptions:

Differential pressures are measured by pressure transducers.

Particle velocity is measured by fiber optical velocity probe (Vector).

Fluid flow rates are measured by using pitot tubes.

Figure 1: The whole experiment set-up


= Valve
= Velocity port
PN
= Nth Pressure port
= Bed material
The distance between pressure ports:
1 and 2 = 96.0 cm
2 and 3 = 89.8 cm
3 and 4 = 91.8 cm
4 and 5 = 96.0 cm
5 and 6 = 97.6 cm
6 and 7 = 87.0 cm
The distance between velocity ports:
1 and 2 = 41.7 cm
2 and 3 = 32.3 cm
3 and 4 = 55.6 cm
4 and 5 = 32.3 cm
5 and 6 = 55.6 cm
P7
P6
P5
P4
P3
P2
P1
762.7 cm
Secondary air
Pitot tube
Pitot tube
Pitot tube
Blower
22.05 cm ID

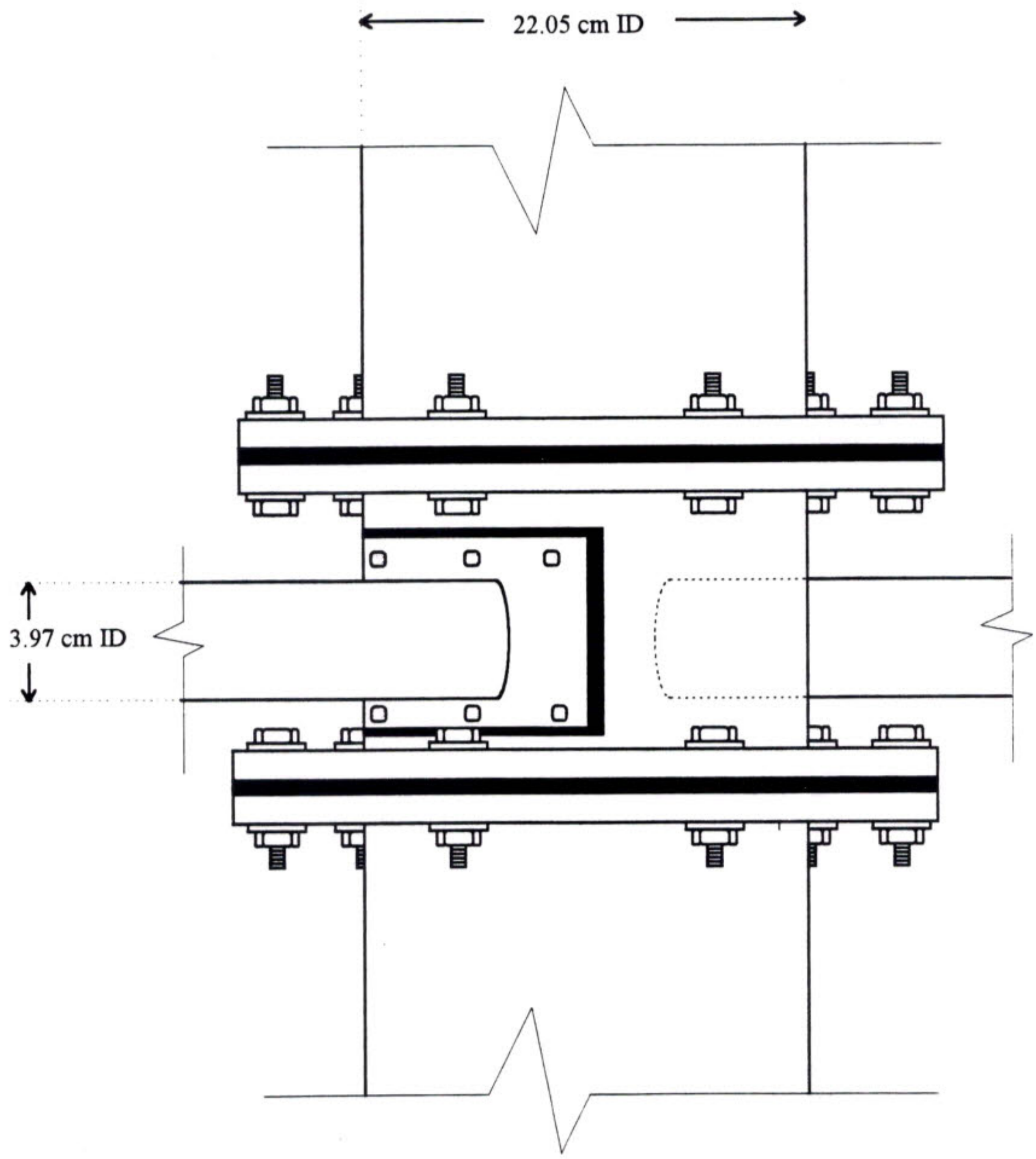


Figure 2 Injector column with secondary air port

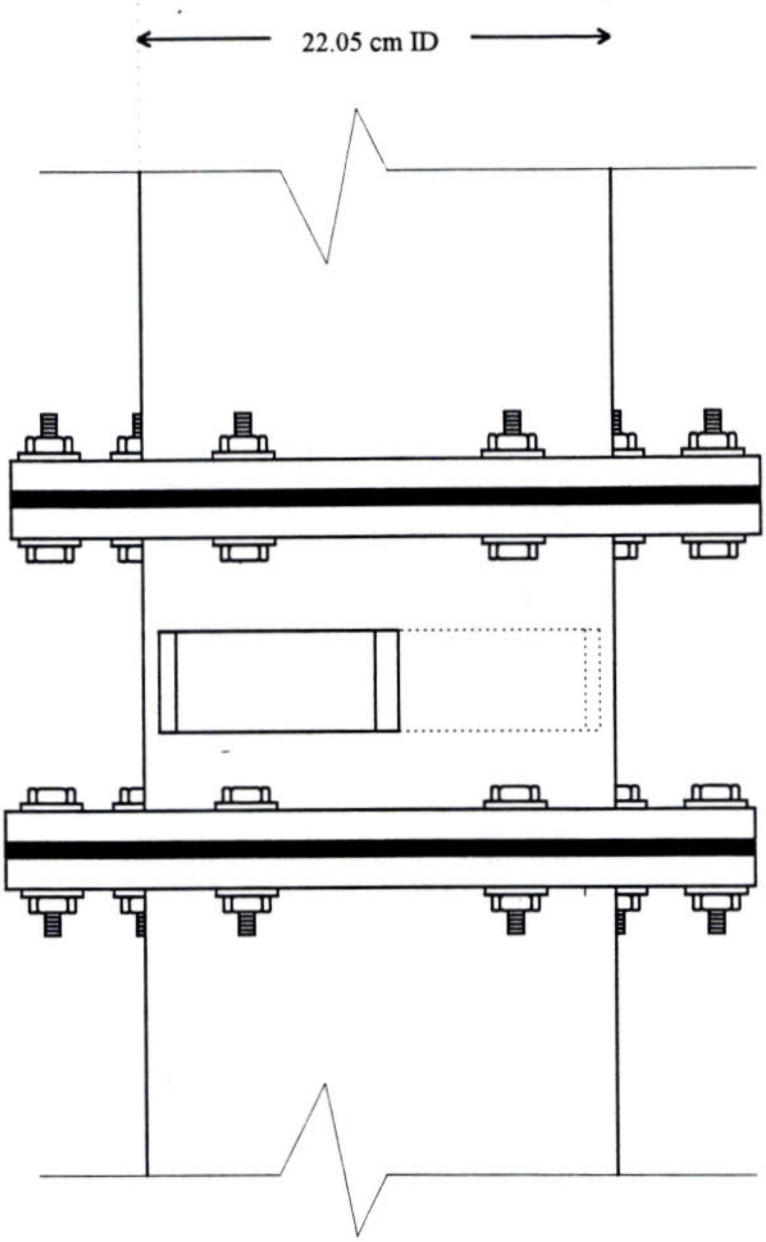


Figure 3 Injector column without secondary air port

TUNS Technical University of Nova Scotia

Department of Chemical Engineering

Jan.21, 1997

TO WHOM IT MAY CONCERN

Ms. H. Miliwat worked as a research assistant in my lab for a period of 4 months ending in Dec. 28, 1996. During this period she undertook several tasks related to literature search, data analysis and presentation, as well as an experimental investigation of the dynamic surface tension of industrial streams.

I found her to be an exceptionally intelligent and hard working person. Through her perseverance, she was able to solve some very difficult problems encountered during her experimental work. She is also a very pleasant person to work with and her communication skills are good in spite of the short exposure to an English language environment. I strongly recommend her for an industrial career or as a graduate student.

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SCHOOL OF TECHNOLOGY OF RESOURCES
Major: Chemical Engineering

BY
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This report is a part of Co-Operative Education I (502 321)
submitted to the Faculty of Engineering
School of Technology of Resources
Suranaree University of Technology

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NOMENCLATURE

Symbol	Definition
A	Interfacial Area
Ci	Concentration of component i
E	Surface Elasticity
E(S)	Laplace Transform of Error signal
e(t)	The error signal
g	Gravitational acceleration
h	Immersed Depth
i	Component i
Kc	Proportional gain
M(S)	Laplace transform of the output from the controller
m(t)	The output from the controller
P	Pressure
P_{max}	The maximum pressure inside the bubble
P_s	The pressure inside the bubble
P_h	The hydrostatic head
R	Gas constant
r1,r2	Probe radius
T	Temperature

Greek Symbol

Δ	Incremental change of variable
∂	Patial differention of variable
ρ	Density
σ	Surface Tension
τ	Rate of Time constant
Γ_i	The amount of Surfactant adsorption

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ABSTRACT

Gas-Liquid Contacting is extensively used for providing the application in the Chemical Industries. The study about its process is involved in terms consideration of the characteristics, affecting factors on the transport phenomena by concerning the dynamic surface tension related to the diffusivity, adsorption, interfacial properties, including elasticity.

The measurement of dynamic surface tension of the surfactant, SDS aqueous solution at the different concentration; 2, 5, 10, 20, 50, 100, 200 ppm is presented with the time scale (bubble interval), to determine the relationship between the surface tension and the concentration due to the interficial properties, elasticity, bubble breakup, coalescence and mass transfer.

As the concentration of the solution is higher, the dynamic surface tension due to the equilibrium values are decresed, tending the dispersion process is most occured during the high concentration of the solution. The dynamic surface tension is rapidly decreased within the short time scale and slidely flatten until the equilibrium value is achieved.

In order to be certain that the standard criteria is met, the way that should be carried during the experimental run to obtain the correct data is an experimental set-up, step-by-step to gain the accuracy. The response is verified by the display data on the softwear program screen.

1.INTRODUCTION

As part of this work term, the author has worked for three months, in the position of a research assistant, in Chemical Engineering Department, Technical University of Nova Scotia, involved in experimental measurement dynamics surface tension and chemical engineering cctivities: group meeting for organizing laboratory setting, seminar and data analysing Liquid-Liquid Dispersion, supervised by Dr. A. M. Al Taweel, Professor of Chemical Engineering Department, Technical University of Nova Scotia.

The Technical University of Nova Scotia (TUNS) has a unique place in Canadian higher education. As an independent Canadian technical university, TUNS is dedicated to professional education and computer science.

TUNS was founded as the Nova Scotia Technical college in 1907. Its mandate was to carry out research and offer degree programs in Engineering with the cooperation of universities and college in Nova Scotia and New Brunswick and to accept students with previous studies at the university level.

The original faculty of six taught courses in mining, metallurgy, civil, electrical and mechanical engineering. Over the years, new department of agriculture, chemistry, food science and industrial engineering were added.

In 1961, the School of Architecture was established. Today, degree in environmental design, architecture, and urban and rural planning are offered through the Faculty of Architacture. Recently, the School of Computer Science has been established. A co-operative degree is offered by the Faculty of Architecture, the School of Computer Science and several engineering departments.

TUNS' commitment to graduate studies and researches is worthy of special note. In the 1950's, graduate studies programs were developed, first at the Master's level and then at the Ph.D. level.

To encourage research activities, TUNS supports or is associated with, several research institutes and centres: Centre for Water Resources Studies (CWRS); Canadian Institute of Fisheries Technology(CIFT); Centre of Marine Vessel Design and research (CMVDR); Vehicle Safety Research(VSR); Minerals Engineering Centre(MEC); Nova Scotia CAD/CAM Centre; Advanced Materials Engineering Centre(AMEC); Applied Microelectronics Institute(AMI); Atlantic Industrial Research Institute(AIRI).

In addition, an active program in international development is pursued and there is a significant commitment to continuing education. (Academic Calender, 1996)

1.1 Gas-Liquid Mixture

Gas liquid contacting techniques are frequently encountered in petroleum, chemical, biochemical, food processing, and many other industries. In certain operations, mass transfer with or without reaction is involved, and maximizing the mass transfer rate between gases and liquids is usually required. Examples of such applications are gas absorption in bubble columns, chemical or biochemical reactions in agitated tanks, distillation, waste water treatment by ozonization/oxidation, aerobic waste water treatment, selective flowtation of constituents, etc.

Industrial streams usually contain a mixture of compounds (e.g. solutes such as alcohol, proteins, organic acids, surfactants, or finely-divided particulars such as catalysts, clays). The presence of these impurities affects interfacial characteristics. However, most published investigations were conducted using pure air-water systems. The most significant difference between the air-water and air-aqueous solution systems is that, in the former, the bubble coalescence rate id high, while in the letter, the rate is low. The impurities reduce the bubble coalescence rate, and hence strongly affect gas-liquid contacting behavior.

Most investigators try to correlate gas-liquid contacting characteristics with the static (or equilibrium) surface tension. However in many processing applications, the gas-liquid contacting time is very short, and the time scale of the process does not allow for impurity molecules to be in equilibrium at the gas-liquid interface. In these processes, the dynamic surface tension may yield a better insight of what really happens at the interface.

Gas and liquid phases are known to extensively circulate within most constants. Wide residence time distributions are therefore observed when stirred tanks and bubble columns are used for gas-liquid contacting purposes. These results in reduced performance effectiveness and the need to use excessive energy inputs in order to improve contacting efficiencies(Jie,1996). Another application is involved in enhancing the mass transfer, by generating very small gas bubble, produced by static mixers or motionless mixers, depending on the objectives. Those mixing elements redistribute or direct fluids across the flow channel and thus produce a large interfacial area between the two ommiscible fluids (Chen,1996)

In this report, firstly the detail of an experimental set-up is presented. In the second part, the dynamics surface tension is quantitatively investigated. Using the diffusion controlled dynamic surface tension model to fit the experimental data, the effect of surface tension on the elastic characteristics were considered and determined due to the behavior different concentration. Efforts were made to find the effects of interfacial properties (surfactant) on the gas-liquid contacting characteristics.

1.2 Backgroud

1.2.1 Interfacial Characteristics of Industrial System

Interfacial characteristics are most widely concerned in two phases contacting between gas and liquid. The study involved to the sifnificant factors that are importance and have an effect to the bubble breakage & coalescenc rate and the equilibrium bubble size in the gas-liquid contactor.

One of the important factors in the transport phenomena is the effect's factor. In bubble case, the balancing or controlling of the dynamic equilibrium between the opposing process bubble dispersion and bubble coalescence is used to characterize the gas-liquid contacting.

• Interfacial Properties

Interfacial is a thin layer at an intermediate region or boundary which has the important properties to the bubble dispersion and coalescence.

The Interfacial area in the liquid phase is a region where the imbalance attractive van der Waals occured between the molecules, the contracting force at the surface is known as the surface tension. The equilibrium or static surface tension is defined thermodynamically as the energy per unit area, while the physical surface tension is defined as the force per unit length (equilibrium's measurement), for reducing the interfacial area of contact. A fresh interface is said to be a zero age which corresponds surface/interfacial tension which is called pure dynamic surface/interfacial tension. The surface/interfacial tension is reduced with the time during the aging of the surface, and it successive values are called intermediate dynamic surface/interfacial tension. The surface pressure (Π) is one of the parameters affecting the dynamic surface tension and is defind as the surface tension of pure solvent minus that of the surfactant solution at the same concentration.

The amount of material absorbed per unit area of the interface is directly calculated from the surface tension measurement. A plot of the surface tension as the function of concentration is used to describe the amount of the surfactant absorbed per unit area of the interface by using of the Gibbs adsorption equation as followed:

$$\Gamma i = (Ci/RT)*(d\sigma/dCI) \qquad (1)$$

The amount of surfactant adsorption on the interface depends on the directly influence of the bubble dispersion and coalescence, the quantity of $d\sigma/dC$ greatly affects the dynamics of the film and should therefore form a suitable basis for the prediction of the coalescence behavior of a "contaminated" solution.

• Surface elasticity and Surface diffusivity

A gas-liquid film must be somewhat elastic in order to be able to withstand deformations without rupturing. The Surface-chemical explanation for film elasticity comes from Marangoni and Gibbs (Cluine et al.,1971). In contaminated system, if a film undergoes a sudden expansion, the expanded portions of the film must have a lower degree of surfactant adsorption than the unexpanded portions because the surface area has increased (Figure 1). This exapnsion causes an increased local surface tension that provides increased resistance to further expansions. The local rise in surface tension produces immediate contraction of the surface, which induces liquid flow from the low tension region to the high-tension region. The transport of bulk liquid due to surface tension gradients is termed the Marangoni effect and provides the resisting force to film thinning. The rate of drainage of thin liquid films is thus hampered, and, is controlled by the transport properties at the surface, which is time dependent. The elasticity from the surface tension variation during the deformation process of liquid lamella. Surface elasticity can be described by the Gibbs equation:

$$E = \partial\sigma/\partial \ln A = -RT(\partial\Gamma/\partial \ln A) \quad (2)$$

where Γ is the surface excess and is a measure of the surfactant concentration at the interface.

- **Effect of the Interfacial Properties on the bubble breakup & Coalescence**

To characterize the factors affecting to the transport phenomena, dispersion and coalescence processes which are known as the opposing process has been extensively studied for years (Figture 2).

The characteristics of the gas-liquid contacting are controlled by the dynamic equilibrium between the opposing process of bubble dispersion and coalescence (Figure 3).

For a gas-liquid contactor, the total surface area produced increases as the bubble size that is produced decreases. Free-energy increases as well with decreasing bubble size because it is associated with surface area. Energy has to be added to the system to achieve

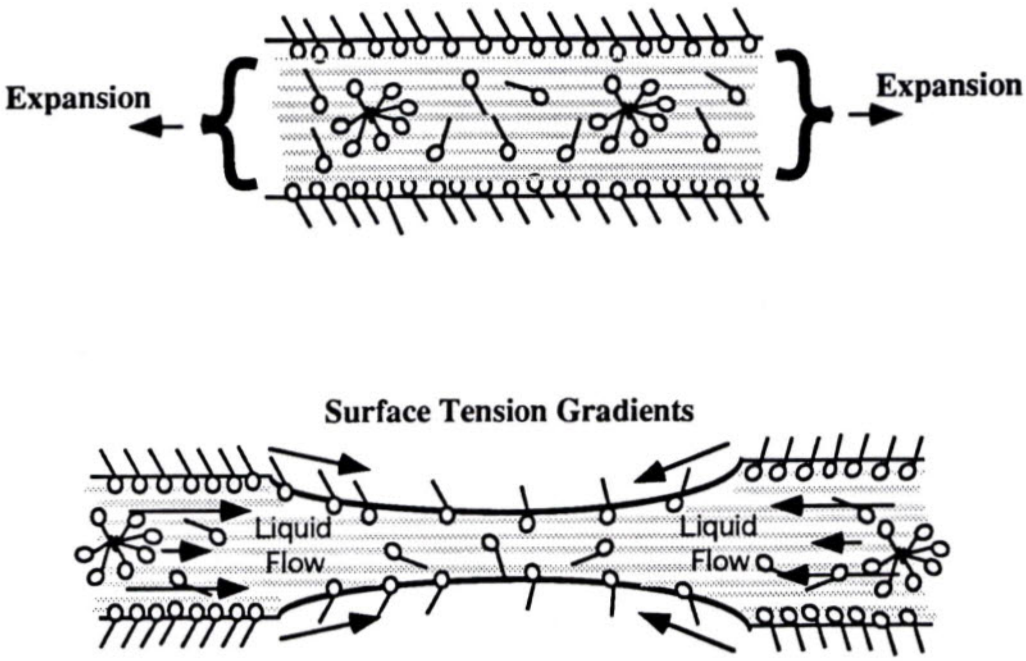


Figure 1: Marangoni effect (Surface Tension) (Schramm, 1994)

the dispersion of small bubbles. If sufficient energy can not be provided though the mechanical energy input, then another alternative is to use surfactant to lower the interfacial free energy, or interfacial tension (Schramm, 1994).

As the bubble grows, the surface expands with time. These results in a surface concentration are different from the equilibrium value, thus producing the surface concentration gradient and the surface tension grqdient (Figure 4). To restore the equilibrium surface concentration the surfactnat molecules in the bulk diffuse to the expanded surface. This diffusion controlled adsorption process depends upon the time scale of the bubble creation. Therefore, at fix bulk contaminant concentration, the less time is allowed for contaminant molecules to diffuse to the surface, the larger is the difference between the surface and bulk concentrtion. On the other hand, in the same diffusion time period, system with faster diffusion rate, the small difference exists between the surface concentration and the bulk concentration, which causes the low surface tension. For the same kind of surfactant, increasing bulk surfactant concentration yields a larger concentration gradient and diffusivity which causes the lower surface tension.

The "Dynamic" surface tension can be calculated from the Laplace equation:

$$Pmax = Ph + Ps = (2\sigma/r) + \rho gh \qquad (3)$$

where Ps is the pressure inside the bubble due to surface forces; Ph is the hydrostatic head; Pmax is the maximum pressure inside the bubble when the bubble radius of curvature equals the capillary radius r; h is an immersed depth; σ is the surface tension; ρ is the density of the liquid; and g is the gravitational acceleration. The differential maximum bubble pressure method involves two capillaries of differing internal radii (r1, r2) but with equal immersion depth, thus the effect of hydrostatic forces was cancelled out.

ΔP_{12}

$$\Delta P12 = 2\sigma((1/r1)-(1/r2)) \qquad (4)$$

This measurement can be made for varying gas flow rates (that is, varying bubble

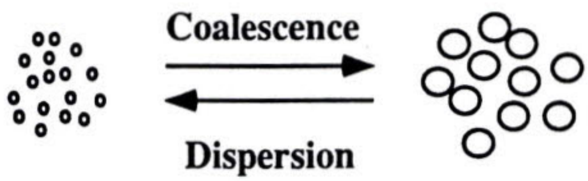


Figure 2 : Dynamic equilibrium between dispersion and coalescence process

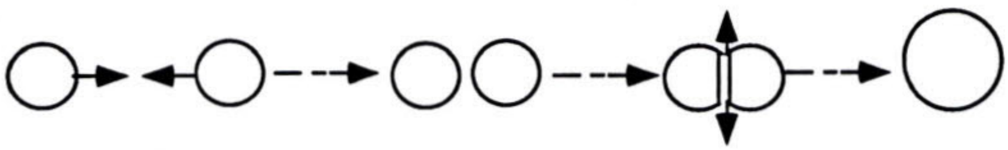


Figure 3: Film drainage in bubble coalescence process

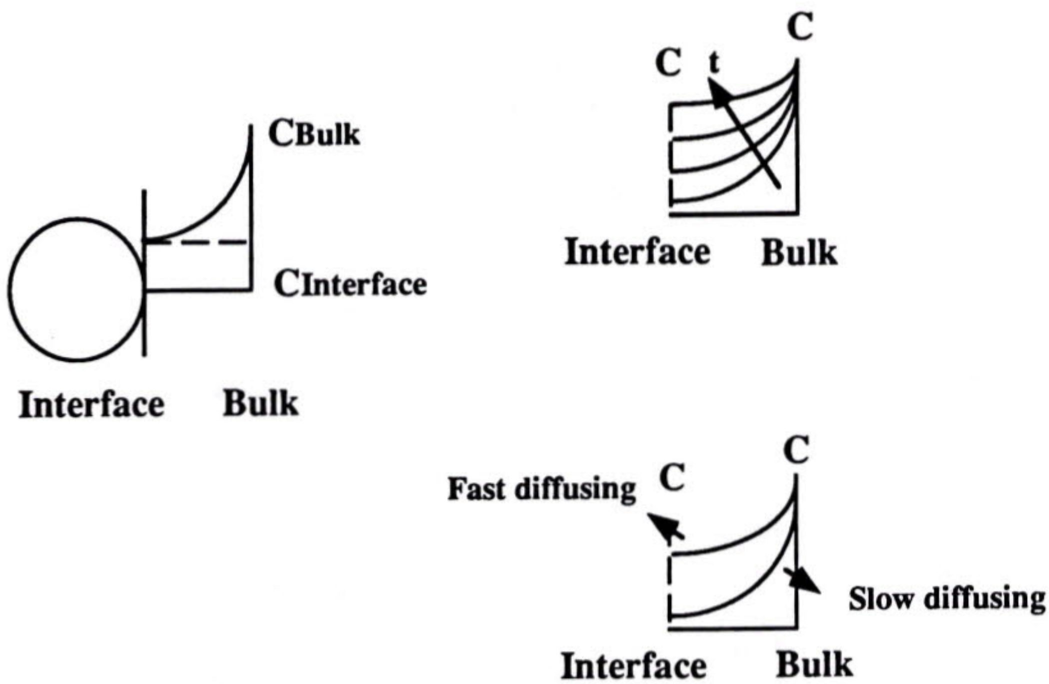


Figure 4: Diffusion controlled interfacial concentration

2. EXPERIMENTAL SET-UP

2.1 Apparatus

1. Probe:

To measure the Dynamic Surface Tension, the standard two probes are necessary for calibration; 4.0 mm. & 0.5 mm. These probes should be used to do the initial checkout procedure.

Before measuring any required samples, the initial checkout procedure is done by set zero and span that will be discussed in the later section.

The two above probes are used at low bubble frequency adjustment (< 4 bubbles/s). The another samller one that is used at high bubble frequency (> 4 bubbles/s) is 0.25 mm. The selection of the correct probes depend on the particular application.

As the smaller probe approaches the smallest physically possible diameter, the pressure measurement approach more accurately the true surface tension value. However, the limitation using arise in operation because of the physical configurations, like fluids that tend to coagulate or are high in particulates that plug extreamely small probes. On the other hand, the larger the probe, the less of signal amplitude, and therefore, decreased accuracy. (Operator Manual)

Any change in probes (even change from one probe to another of the same size and shape) must likely require a new calibration to be performed.

To connect the probes with the probe holder, the correct different position of the probes should be done to obtain the true data. As the connection is achieved, the larger probe have to be uppper than the smaller probe 2/3 r1, where r1 is the larger probe diameter as shown in figure 5.

The Both of the glass and teflon, coated glass probe, are in the figure 6.

2. Probe holder:

The probe arm may be raised and lowed, or rotated radially about the base by loosening the locking knob (k1). A retaining ring clamp (c1) sets the

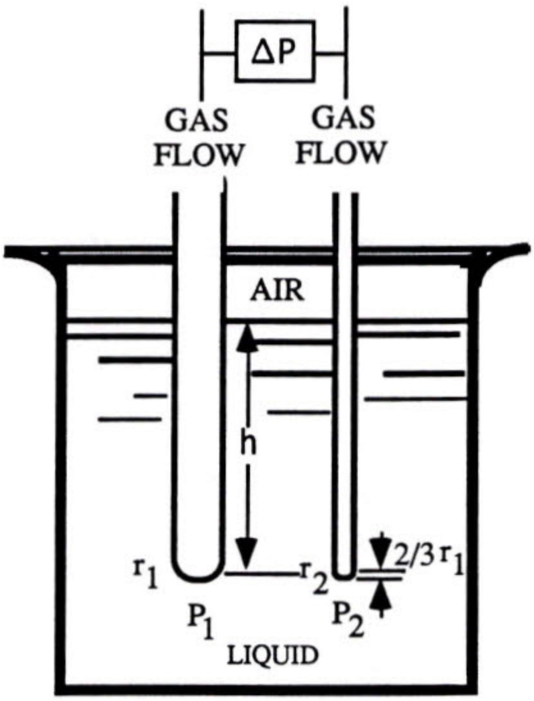
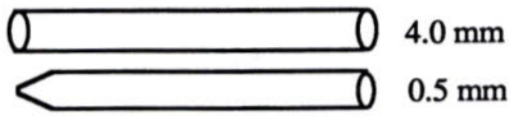
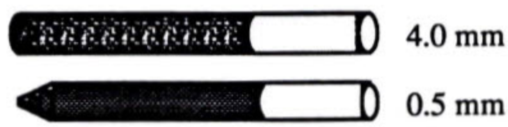


Figure 5: The correct connecting position



Glass Probes



Teflon Probes

Figure 6: Glass and Teflon Probes

bottom-most position of the arm and allows consistent and repeatable depth of probe penetration in fluids when repeat reading are taken. The arm also be extended horizontally, away from the base, using the other lock knob (k2) as shown in the figure 7. (Operator Manual)

3. Temperature Controller:

For the Long time constant process (large capacitance), for example the temperature loop, the temperature controller recommended is Proportional Integral Derivative Controller,PID, having three tuning parameters: the gain or proportional band, K_C, the reset time or reset rate, τ_I or τ_{IR}, and the rate time constant, τ_D .

PID controller has the new mode added the derivative action, its purpose is "anticipate" where the process is heading by looking at the time rate of change of the error, the operational equation is followed:

$$m(t)=m_{ave}+ K_C e(t)+ (K_C/\tau_I)\int e(t)\, dt+ K_C \tau_D(de(t)/dt) \qquad (5)$$

Where m(t) is output from the controller,m

e(t) is error signal,mA. This is the different between the set point and cotrolled variable.

m_{AVE} is bias value, or mA. The significance of this value is the out- from the controller when the error is zero. This value is usua lly set during calibration of the controller, at 12 mA.

The derivative action allows the controller "look Ahead" by calculating the derivative of the error. The amount of "anticipate" is decided by the value of the tuning parameter, τ_D. By looking at the derivetive of the error, the controller knows that how the controlled variable is heading away from the set point, consequently, it uses this fact to help in controlling and the amount of the control correction provided by the Proportional and Integral mode. For awaring the Noise in the Long time constant process is produced by the noise transmitter. Inthis case, before the PID controller is used,the transmitter must be fixed.

The transfer function provided by

$$M(S)/E(S) = K_C(1+(1/\tau_I S)+\tau_D S) \qquad (6)$$

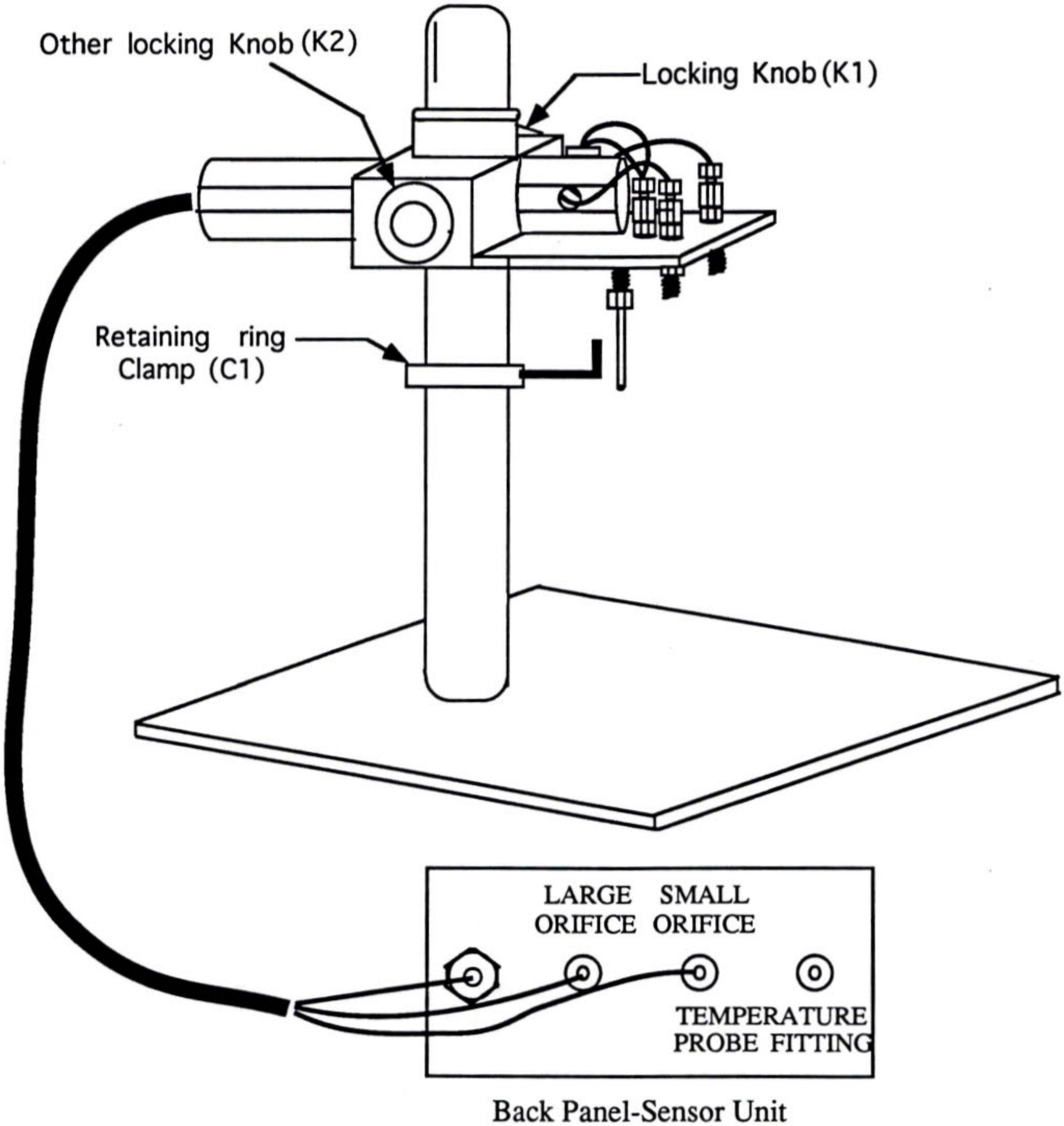


Figure 7 : Probe Holder

This transfer function is called "ideal" because in the real practice the implementation of the derivative calculation is impossible to obtain. The derivative is then approximated by the use of a lead/lag, resulting in the "actual" transfer function as followed:

$$M(S)/E(S) = K_C(1+(1/\tau_I S)(\tau_D S+1)/(\alpha \tau_D S+1) \quad (7)$$

During the experiment, to reject or reduce the errer the temperature controller acts approach to retain the set piont by heating up or cooling down the temperature process. The operating controlled variable is obtained depending on the situation. The Temperature controller is shown in figure 8.

4. <u>SensaDyne 6000</u>:

The SensaDyne 6000 is contained with the electronics system; the Computer/Interface board, SensaDyne circuit board with four important components, Zero-Span-Temperature-Filter potentiometer, and Peak Detector IC, Pressure Transducer.

The Span and Zero potentiometers are importance in the initial checkout procedure to make sure the amplitude of the displayed pressure graph starts from the low zero set to the high between 3-4 volts as shown in the figure 9.

To select the correct data at the remained set point temperature and fit the rejection of the noise, the Tempreature and Filter poteniometers are respectively done by adjusting on both of them.

The differential pressure is determinted and transfered signal achieved by the Pressure transducer, and the capturing the maximum bubble pressure signal (sawtooth peak value), store it until the next peak occures including to the updated values are allowed by the Peak Detector, as shown in the figures 10-11.

5. <u>Software PC9000 (version 5.1)</u>:

All of the results are transfered and displayed by the software, which called, PC9000, containing 5 items in the main menu; FILE (F2), CALIBRATION (F3), OPTIONS (F4), CHANNEL (F5), and ALARMS (F7), as shown in the figure 12.

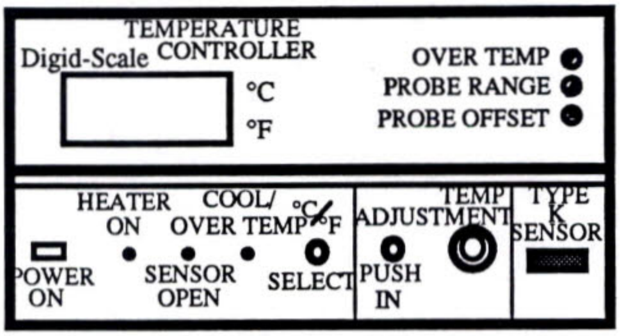


Figure 8: Front view of the Temperature Controller

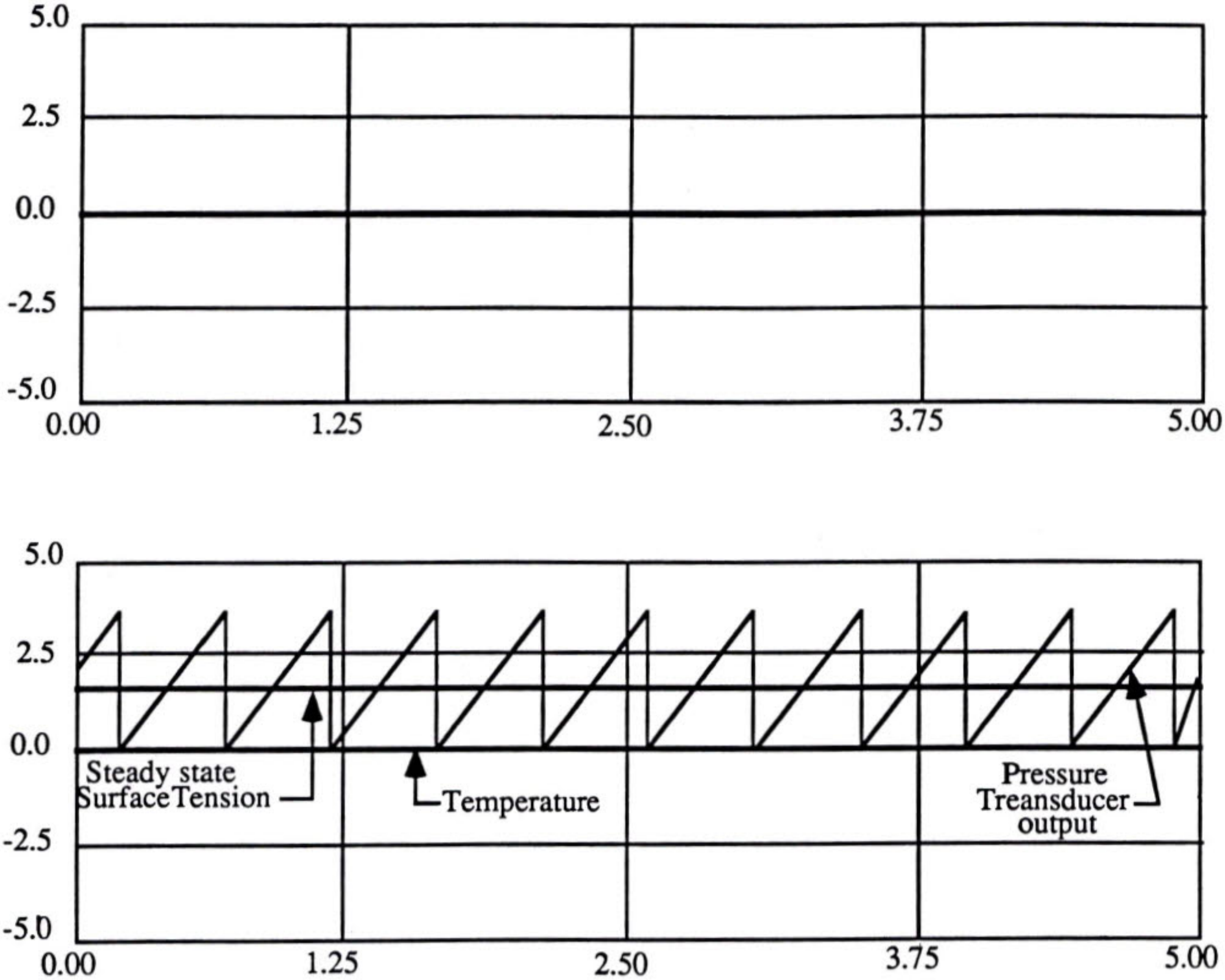


Figure 9: The regular display of the Set Zero and Span

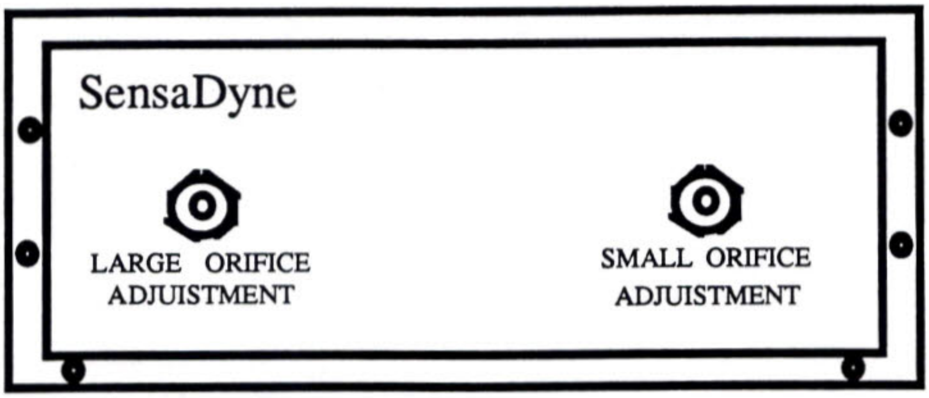


Figure 10: Front view of SensaDyne 6000

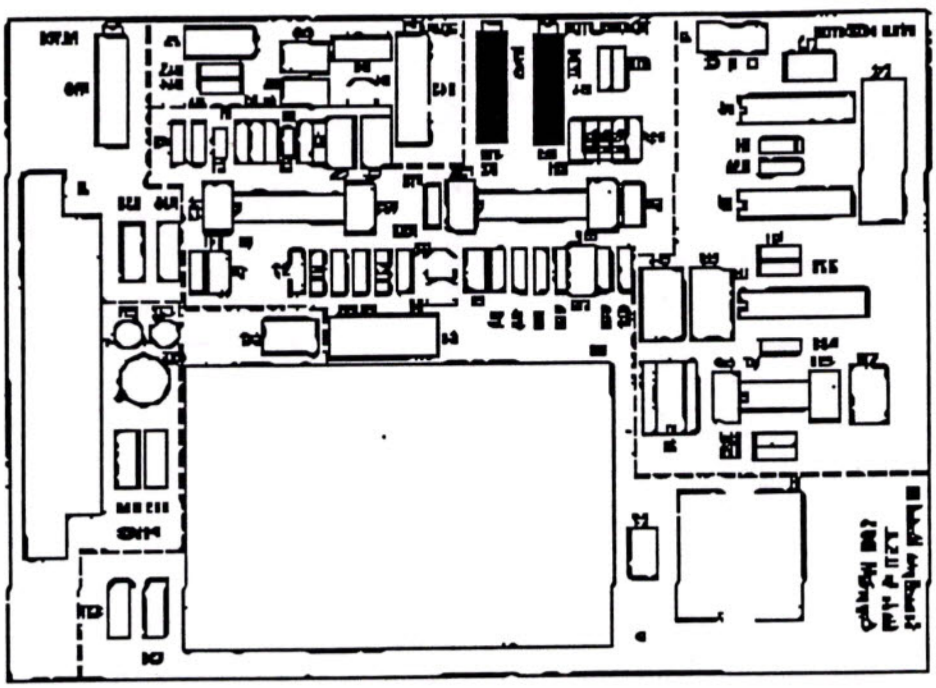


Figure 11: Electrical Circuit contain; Zero, Span, Temp.,and Filter Potentiometer

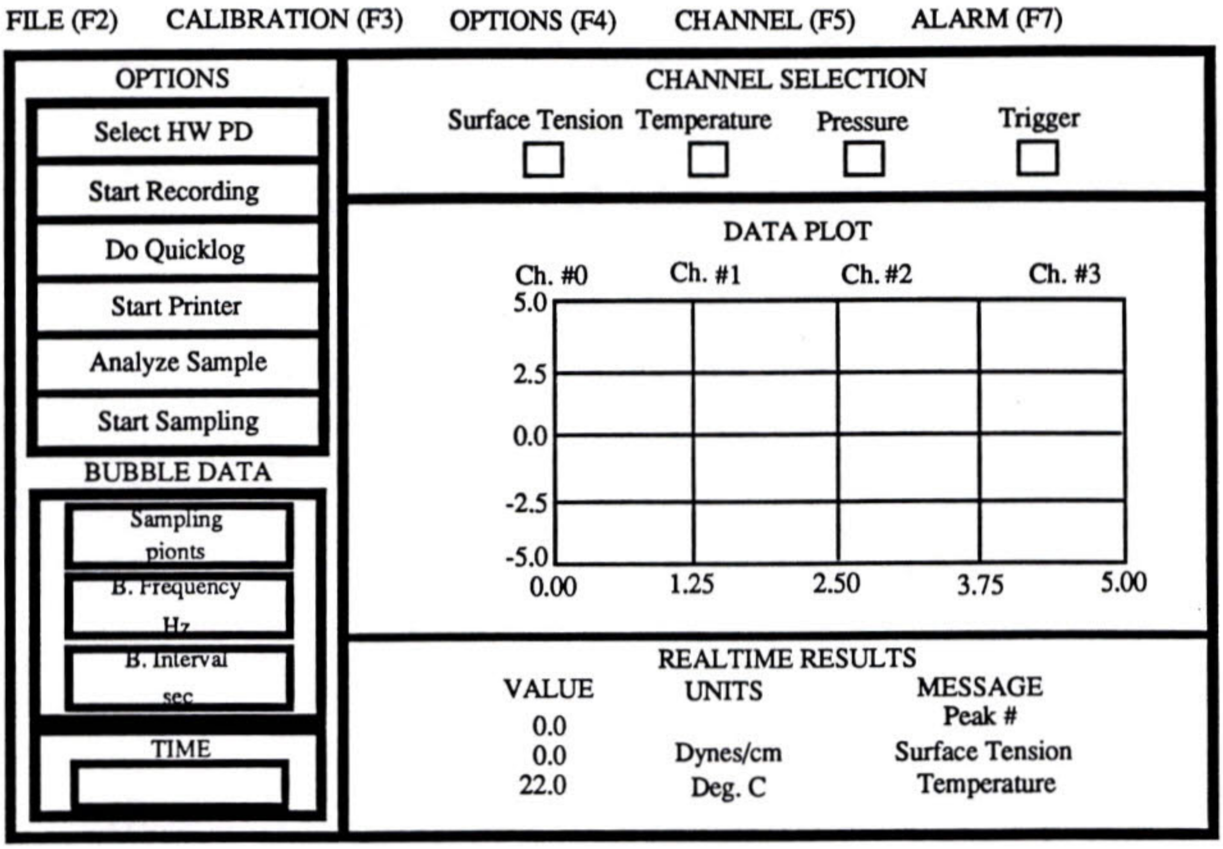


Figure 12: Program screen of PC9000

The allowing convenient experimental procedure is provided in the step by step by the PC9000 that will be discussed in the Appendix.

2.2 Material

1. De ionized water and standard methyl alcohol.
2. The different concentrations of the Surfactant (Sodium Dodecyl Sulfate, SDS); 2, 5, 10, 20, 50, 100, 200 PPM.
3.Extra Dry Nitrogen, is used at 50 psi.
4. Volumetric flashes; 200 ml.
5. Beagers; 100 ml.
6.Earimeyer flash;2000 ml.
7.Water bath
8.Heater and Magnetic bar
9.Pipette
10. Glass termometer

2.3 Procedures

To allow the instrument analize the correct data, the complete step-by-step should be done to keep being familar with the previuos software version.

Step 1 : Starting the program

On the hard disk where where software is install, switch to the program directory.

PC 9000: Type pc9000

Then the program screen appears. In the lower left corner, the current DOS time being updated every time.

Step 2 : Setting up Data & Quicklog file

On the program screen, click the file item, then the sup-items are appeared, select the "New Data File". The appropriate directory, sup-directory and file name should be selected as follow:

PC9000:\pc9000\data, type (?: file name.sdd)

To allow the computer accept, the OK item is clicked or the ENTER key is pressed, then the setting up data is complete.

On the program screen, click the file item, then the sup-items are appeared, select the "New Quicklog File". The appropriate directory, sup-directory and the file name suold be selected as follow

Figure 13: Quantitative Extra Dry Nitrogen

PC9000:\pc9000\data, type (?: file name.sdq)
To allow the computer accept, the ok item is clicked or the ENTER key is pressed, then the setting quicklog file is complete.

Step 3 : Temperature Calibration

To calibrate the temperature, the standard materials, De-Ionized Water and Alcohol are prepared here, the methanol is used

- A hot water bath, temperature 75°C- 90°C
- A cool water bath, temperature 2°C- 10°C

Insert the prob in to the hot water bath. Observe the temperature value. As soon as the reading is constant, the high temperature calibration can be done by:

Selecting the "High Temperature" from the menu, type the current high stable value. To allow the computer accept, the OK item was clicked or the ENTER key was pressed.

After a short pause, insert the prob to the cold water bath, observe the temperature reading, as soon as its reading conatant, the low temperature calibration can be done by selecting the "Low Temperature" from the calibration manu and then type the current low stable value. To allow the computer accept, the OK item was clicked or the ENTER key was pressed.

During Tempeture Calibration, the temperture is quickly cool down, this is a sign for the accuracy that was careful protacted.

Step 4 : Adjusting the bubble frequency for Surface Tension Calibration

Adjust the appropriate bubble frequency by starting from the lower up to the higher value in each time's calibration. To allow the suitable illustration purposes, the ways was done as followed

From "OPTION" in the main menu and select "Sampling Interval"

Olick on the five seconds by the mouse or move by the cursor and accept by clicking on the OK item or pressing ENTER key.

Step 5 : Select Tolerance Window

To approach the correct data, from the "OPTION" the "Narrow" was selected in the Detection Tolerance by the mouse clicked on or move it up or down by the cursor, Pressing ENTER key or clicking OK item by the mouse.

Step 6 : Surface Tension Calibration

Prepare the standard samples for calibration:

A sample of deionized water at the room temperature.

A sample of Methyl alcohol at the room temperature.

Insert the temperature controller's probe in the sink which contains the water that is used to carrying the stable room temperature. Before inserting the probes to measure the standard samples, the "ZERO Adgustment" was done as followed:

Take the temperature probe out of the fluid. From the "OPTION" select the analize sample or click the analize sample on the program screen by the mouse. After that, when the computer sampling reaches 5116 sampling points, the straight blue line pressure is displayed (it should be at the 0.0 Volt, because when the temperature probe is taken out of the fluid in the air, the pressure between both of small orifice and large orifice probes are equal to the air pressure, so the pressure drop or the different pressure is equal to zero).

To make sure that the peak-to-peak and the magnitude of the graph is correct, the "SPAN" is involved to set within the suitable range (3-3.5 volts).

From "OPTION" in the main menu select "Analyze sample". After sampling for five seconds the sweep graph is displayed, as the narrow tolerance is acieved, the sweep grapg is reset to clear all previous data as weel as, then the sampling botton is selected off state (green color). The sampling botton stays ON (reading "Stop Sampling"), showing that the measurement procedure is in progress. The program now enters the Advanced Peak Detection mode (SensaDyne Software manual version 5.1).

As soon as the computer reads the constant surface tension, from the calibration, the "High Softwear Surface Tension" is selected. The high surface tension is clicked by mouse or can be moved UP or DOWN by the cursor. The high surface tension is typed at the current temperature. To accept, the OK item is clicked by the mouse or pressure the ENTER.

AutoCal:

From "CALIBRATION" in the main menu select "Autocal D.I. Water", then the surface tension is calculated autometically, the high sreface tension calibration is completed and the current calibration data is written autometically to the setup file.

To verify the calibration, let the softwear sample a little longer, as soon as the peak to peak looks like the sawtooth then the "Stop Sampling" (green color)is clicked by the mouse or selected the "Stop Sampling" from the option. The current display is shown after the softwear finish the circle running.

Now, insert the temperature probe in to the methyl alcohol and allow the software analizes, from the "OPTION", select the "Analize Sample" by moving the cursor UP or DOWN or click the program screen. When the software starts to analize the state is ON (Red screen). The updated data will display after it finished the reset before the graph is appear. **During analization, none of the other results, including bubble data, is updated.**

As soon as the reading low surface tension is stable, the low surface tension calibration is done. From the "CALIBRATION" in the main menu select the "Low Software Surface Tension" by the mouse or move it UP or DOWN by the cursor, enter the correct surface tension of the Methanol. To accept the OK botton is clicked by the mouse or ENTER key is pressed.

To verify the Surface Tension calibration reading, let the temperature analyze little longer. As soon as the value is verified, push the "Stop Sampling" botton, or from the "OPTION" in the main menu select the "Stop Sampling". The botton is reset to the OFF state (green color), if the system is running, it will stop immediately then the program reach the idle state.

Note :
To make sure that all the results are correct, The surface tension calibration should be done every time when the measurement of the samples are required. Before the calibration, the set point temperature should be select at the room temperature, including the reading values on the program screen and temperature controller should be equal to each other.

Step 7 : Measuring the test sample

Prepare the Samples; 2, 5, 10, 20, 50, 100, 200 ppm, whose surface tension is to be measured and insert the probes in to the samples.

Note :
Remenber that as the probes are insert in to the samples, the software has to be analize. To obtain the equal temperature values, the sink of water is

used to carry the sample beager to acquire the stable value and protect the temperature fluctuation.

Either

From "OPTION" in the main menu select the "Analyze Sample" with the mouse click on the "Analyze Sample" botton.

Make sure, the sawtooth fit compleately in to graph window. If the peaks are clipped, the signal is out of the range. Let the software selects the sampling points long enough.

As a narrow tolerance window is selected, ten peaks are captureed for analyzation. As soon as this is achieved, the sweep graph is reset to clear all previous data as well as the analyzation botton set to its OFF state (green color). The sampling botton stays ON (reading "Stop sampling"), showing that the measurement procedure is in progress. The program now enters the Advanced Peak Detection mode. **During analyzation, non of the other results, including bubble data, is updated.**

All of the results are updated every it is reset, including the real time increases while the analyzation is progressing. The surface tension is shown as the surface tension of the sample under the test.

Step 8 : Collecting data to disk

Note:

Before the data is collected, the two specific files should be created. If these two files are not done, the allowing way as followed:

From the "OPTION" in the main menu select the "Start Recording" or click at the "Start Recording" botton with the mouse.

Data collection to disk is started at the adjusted rate in to the specified data recording file.

At any point, the current data, including the numeric label and an optional comment, can be stored by the quicklog storage as followed:

From "OPTION" in the main menu select "Do Quicklog" or click on the "Do Quicklog" botton with the mouse.

The Quicklog dialog box is displayed. In the first entry box enter the numeric label, that is used later for the graphing. Move the cursor DOWN on the optional comment. This optional comment can be up to 30 characters long. To accept both of them, the OK botton is clicked with the mouse or Press on the ENTER key.

During the peak detaction process, sampling can be stop any time. The program completes data display and result update for the whole data sample.

If sampling is stopped during data acquisition (running sampling counter), the acquisition process is stopped immediately. When a new acquisition process is started, the sampling counter is reset, so that no gap is left in the data sample. This function can be used to "freeze" the data display for manual analyzation.

Step 9 : Exit the program

To exit the program, it is necessary that the program is in the idle state, by turn off sampling first. Then, from "FILE" in the main menu select "QUIT". The program is stopped, all files are closed and screen is reset to text mode.

3.RESULTS AND DISCUSSION

The Dynamic Surface tension for the various SDS concentrational aqueous are shown in figure 14. The surface tension of the various SDS concentration is significally found that lower than the pure standard compounds or even those of the mixture of the pure compounds. These are responded to reduce the bubble coalescence and hence the mass transfer in the low energy requirement.

The surface tension was found decrease at the bubble generated time. The values of the surface tension decreased very rapidly at the shot period time, the curve is flatten until the equilibrium surface values. The time required the equilibrium surface tension values depend on the different concentration. The high surface tension has a sooner time to achieve the equilibrium values.

From the results, in case diffusional consideration, the higher SDS concentration allowed the the high diffusion because there is the more difference between the bulk of the surfactant concentration and the interface causing the larger diffusion driving force higher interface surfactant concentration due to lower surfactant. The effect of the surfactant concentration of SDS on the surface tension is shown in the figure 15.

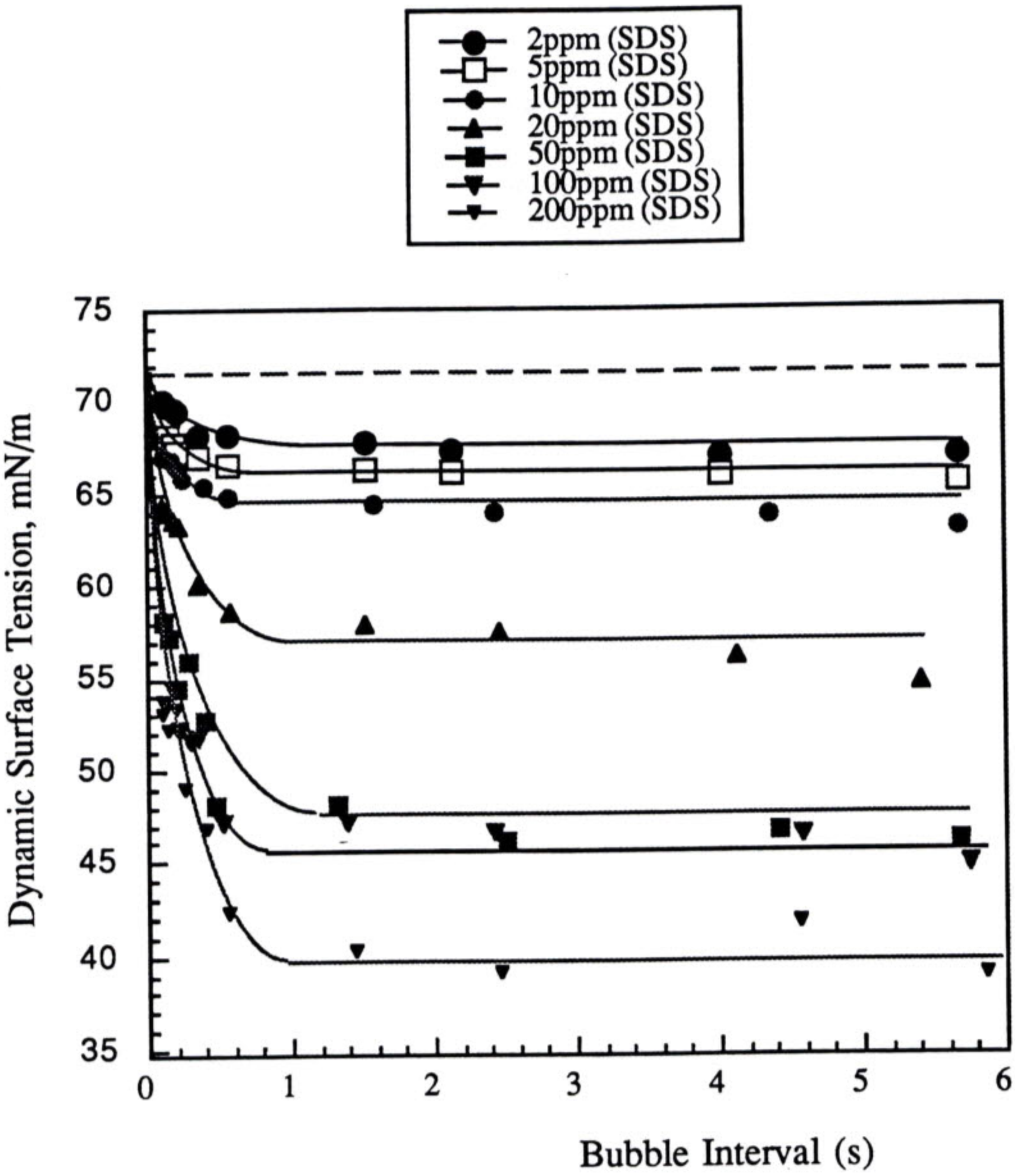


Figure14 : Effect of SDS concentration on dynamic surface tension of aqueous solution

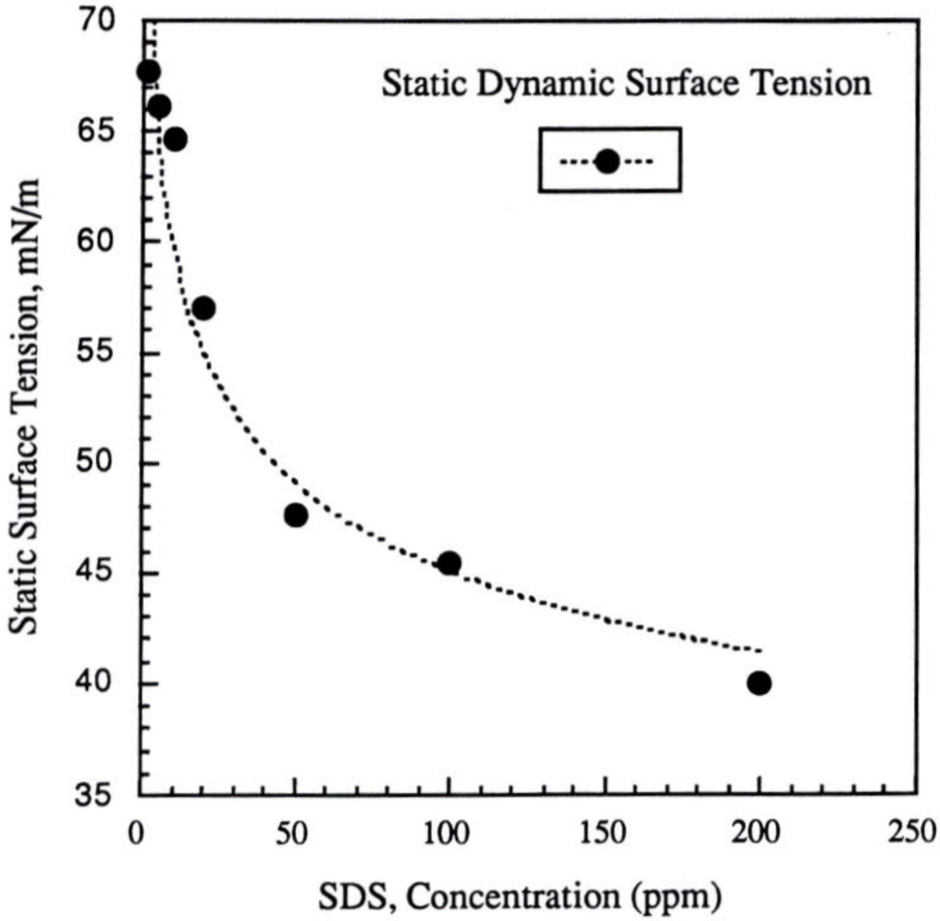


Figure 15: Effect of Various SDS concentration
on Static Surface Tension

4. CONCLUSION

1. The presence of the different SDS surfactant concentrations affect on the surface tension and hence the gas-liquid contacting behavior, such as bubble break-up, bubble coaleacence including to mass transfer rate.

2. The increased surfactant concentration causes the bubble breakage as shown that lower dynamic surface tension including to the lower equilibrium values.

3. At the high surfactant concentration, the diffusion is allowed to increase, hence decreasing the low surface tension at the interface.

5. RECOMMENDATION

The important fitting the correct data should have been obtained since the initial checkout procedure; the set zero and span, the standard suitable probes at any situation until the appropriate bubble frequency adjusment, the bubble frequency of the smaller orifice should be slightly faster than the larger one.

The graph should be looks like the sawtooth, allowing to check the bubble frequency adjustment is suitable or not.

The experimental set-up is exactly step-by-step and every thing should be very clean.

Before measuring any samples, the surface tension calibration should be done every requirement with the standard probes even change in the same size and shape.

To allow the correct data, the temperature of the system should be obtainly more accuracy and constant by the water bath with magnetic spinding to retain the small fluctuation of the temperature.

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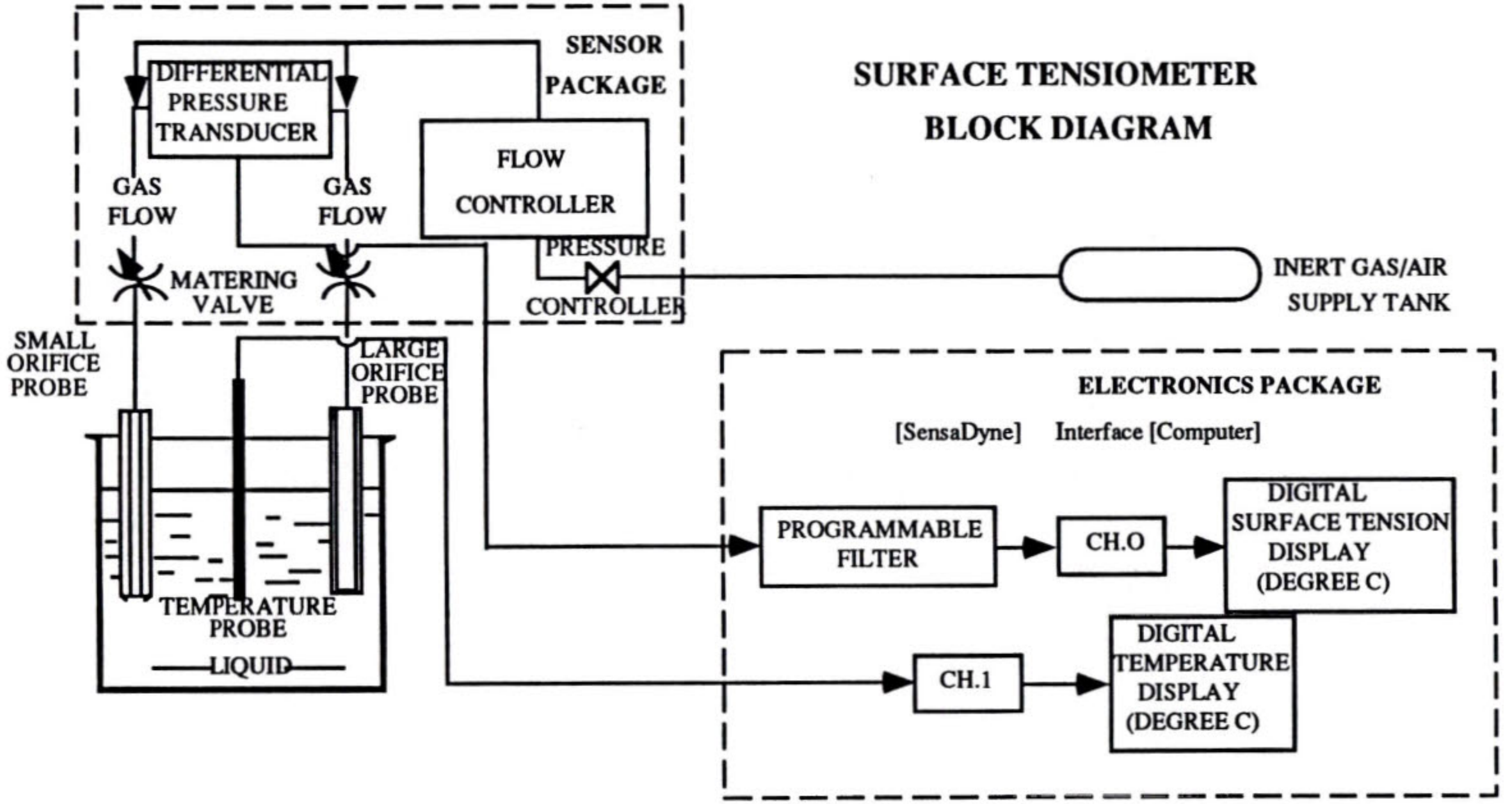

Figure 16: Surface Tensiometer Block Diagram

APPENDICES

Appendix A. Glossary PC9000

Advanced Peak Detection Mode:

Patented algorithm that allows evaluation of each detected peak for its validity. Due to this algorithm, highly accurate measurements independent fron any noise are possible, even under pressure.

Alarm(s):

The values of surface tension and temperature are checked against user selected alarm limits. Alarms are audible and are logged to disk. Also, a drastic change in surface tension, which the software can not follow without (-> Analization), causes an alarm.

Analog Input Board:

Interface from the PC to the instrument, which is installed in a free slot in the PC. Analog data from the instrument is collected using this board, and then stored digitally in PC memory (-> Sensor Electronics).

Analyzation Mode:

Mode in which the software works in standard peak detection mode, where every peak is accepted. A filtering algorithm is used to determine the valid peaks and calculate the average. The software enters Analyzation mode, if there is a change in surface tension, either due to a new fluid, or changed instrument parameters (-> Calibration Interval).

Bubble Frequency:

Number of bubbles that release per second. Inverse of (-> Bubble Interval)

Bubble Interval:

Time period between two released bubbles. Inverse of (-> Bubble Frequency)

Calibration:

In order to measure accurately, the instrument has to be calibrated for temperature and surface tension. Calibration is done at the upper point (High Calibration) and a lower point (Low Calibration) of the calibration curve. (-> Standard Calibration Fluid)

Clibration Interval:

Temperature calibration is recommended every 6-8 months, depending on the drift of the temperature probe.
Surface tension has to be calibrated each time, whenever a parameter of the instrument changed:

- Flow Rate
- Span Potentiometer Adjustment
- Zero Potentiometer Adjusment
- Change of pronbe Size or Material

CANCEL Button:

Clicking this button with the mouse discards all inputs or changes mode.THe dialog box closes. Pressing the ESC key has the same effect.

Channels:

The QC3000 and the QC6000 software each read and display two channels, which are:

- Channel 1: Temperature
- Channel 2: Pressure Transducer Output (-> Sawtooth Signal)

THe PC9000 software reads the display four channels, which are:

- Channel 0: Steady State Surface Tension (-> Sensor Electronics)
- CHannel 1: Temperature
- Channel 2: Pressure Transducer Output (-> Sawtooth Signal)
- Channel 3: Peak Trigger Signal (-> Sensor Electronics)

The channel display can be turned on and off using the switches and the mouse, or the channel menu.

Configuration File:

The configuration file holds on this data describing the current setting, such as sampling interval, paths, and calibration parameters. Each time a setting is changed, the configuration file used for the initial setup at program start is updated autometically. THe user has possibility to save a setup at any time, allowing the retrieval of calibration setting for specific flow rates.

Data File:

To record data over the period of time, it is stored in the data file (default file extension *.sdd). The data file format is standard ASCII, the data values are stored in the following order (1 data set per point):

- Scan number
- Surface Tension [Dynes/cm]
- Temperature [°C]
- Bubble Frequency [bubbles/s]
- Bubble Interval [s]
- Total Process TIme [s]

Dialog Box:

An interface for specific user input. Dialog boxes can consist of one or two input boxes. They all have a (-> OK button) and a (-> CANCEL button). The input focus can be moved with the cursor keys from one input window to the next, or with the TAB key to the buttons, which then appeare in dark red, or to another input box.

Hardware Peak Detection:

Only available for the PC9000 instrument and software. The PC9000 (-> Sensor Electronics) sets a digital output each time a peak appears (so-called *trigger*). In Hardware Peak Detection Mode, when this trigger is detected the signal on channel 0 (-> Channels) is read and used to calculate the surface tension. Hardware Peak Detection is more susceptible to noise than (-> Software Peak Detection).

OK Button:

Clicking this button with the mouse accepts all input or changes made. The dialog box closes. The new values are processed. Pressing the ENTER key has the same effect.

Peak #:

The peak # is displayed in the first line of the *REALTIME DATA* window. It is increased on every peak that was detected and accepted as valid in Advanced Peak Detection Mode. In Analyzation Mode, it display the number of peaks detected, until the mode is automatically awitched to advanced Peak Detection.
This indicator is a way to vertify the correct measurement procedure, as the number of peaks that are visible in the sweep graph can be compared to this number.

Quicklog:

The Quicklog function is used for data recording on demand. Only one set of values is stored in a Quicklog file (default file extension *.*sdq*) per call. If more than one set of values is recorded to one Quicklog file, the data sets are appended. THe Quicklog file format is standard ASCII, the data values are stored in the following order (1 data per line):

- Surface Tension [Dynes/cm]
- Temperature [°C]
- Bubble Frequency [bubbles/s]
- Bubble Interval [s]
- Numeric Label
- Comment

Sampling Interval:

The sampling interval defines the time period for data collection from the (-> Analog Input Board). The software uses the so-called post-processing method to measure surface tension. Thereby, data is collected in real time, and then evaluated.

Sawtooth Signal:

This signal is display as channel#2. It is the output of the differential pressure transducer,which is used for (-> Software Peak Detection).

Sensor Electronics:

The electronics located in the instrument enclosure. It conditions the output signal from the temperature probe and the pressure transducer to different voltage levels, making them readable for the (-> Analog Input Board).
PC9000 only: The PC9000 electronics also provides a trigger signal on each peak, and a steady state output signal (-> Channels) proportional to the surface tension, which can be used for process control.

<u>Software Peak Detection</u>:

(-> Advanced Peak Detection)

<u>Standard Calibration Fluids</u>:

Deionized water and Ethyl alcohol are commonly used as standard fluid for calibration, their surface tension is known, and does not change with the flow rate, as thay are non-active.

<u>Start Sampling function</u>:

The Start Sampling function starts data collection from the (-> Analog Input Board). The correct installation of the analog input board can be vertified by invoking this function and watching the counter in the first panel of the BUBBLE DATA window, which indicate the number of data points that are collected. The time period of this counter running must be equal to the (-> Sampling Interval) value.

<u>Tolerance Window</u>:

For the Advanced Software Peak Detection Mode, a bandwidth around the peak average has to be the spacified, in which peaks whose values are within this bandwidth are accepted as valid.
The user has the choice of three bandwidths:

- Narrow
- Medium
- Wide

This setting also effects the number of peaks that have to be detected during Analyzation. The wider the Tolerance Window, the more peak have to be detected before a valid average is calculated.

<u>Total Process Time</u>:

Time period beginning and ending with the data recording. Can be used alternatively to the scan numbers to graph recorded data (Operator Manual).

Appendix B. Experimental Data of Dynamic Surface Tension

Dynamics Surface Tension VS Bubble Interval (SDS 2PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.12	70.12
2	0.15	69.80
3	0.18	69.68
4	0.21	69.50
5	0.35	68.25
6	0.56	68.12
7	1.52	67.67
8	2.13	67.35
9	4.02	67.02
10	5.67	66.98

Dynamics Surface Tension VS Bubble Interval (SDS 5PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.12	68.24
2	0.15	68.13
3	0.18	67.78
4	0.21	67.25
5	0.35	67.02
6	0.56	66.56
7	1.52	66.23
8	2.13	66.14
9	4.02	65.98
10	5.67	65.52

Dynamics Surface Tension VS Bubble Interval (SDS 10PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.11	67.02
2	0.17	66.83
3	0.20	66.42
4	0.25	65.87
5	0.39	65.46
6	0.57	64.78
7	1.58	64.35
8	2.43	64.03
9	4.35	63.75
10	5.67	63.16

Dynamics Surface Tension VS Bubble Interval (SDS 20PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.12	64.28
2	0.16	64.02
3	0.19	63.54
4	0.23	63.20
5	0.36	60.08
6	0.58	58.64
7	1.53	57.92
8	2.48	57.41
9	4.13	56.13
10	5.42	54.72

Dynamics Surface Tension VS Bubble Interval (SDS 50PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.12	58.17
2	0.16	57.23
3	0.20	54.56
4	0.28	56.02
5	0.40	52.81
6	0.48	48.06
7	1.32	48.13
8	2.51	46.13
9	4.42	46.59
10	5.68	46.01

Dynamics Surface Tension VS Bubble Interval (SDS 100PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.14	53.64
2	0.18	54.32
3	0.22	52.18
4	0.31	51.60
5	0.36	51.76
6	0.52	47.13
7	1.40	47.05
8	2.43	46.48
9	4.58	46.39
10	5.76	44.83

Dynamics Surface Tension VS Bubble Interval (SDS 200PPM)

Run	Bubble Interval ; s	Dynamics Surface Tension ; σ mN/m
1	0.12	52.98
2	0.16	52.12
3	0.20	53.36
4	0.26	49.02
5	0.42	46.86
6	0.56	42.26
7	1.45	40.19
8	2.48	39.11
9	4.56	41.66
10	5.87	38.98

APPENDIX D

ACTIVITY A 4.33 MINI-PRC MEETING
THAILAND - SUT, FEBRUARY 12, 1997
DR. STALIN BOCTOR - REPORT

Report on
SE Asia Deans of Engineering Conference and Mini-PRC (SUT/CUTC)
February 10-14, 1997

On arrival in Bangkok, I received a fax from SUT informing me that the mini-PRC on Friday, February 14, 1997 is cancelled due to other commitments, even though this meeting was scheduled and reconfirmed over the past two months. The mini-PRC was finally rescheduled for Wednesday, February 12, 1997 between 5-7 p.m.

The four members of the Canadian CUTC delegation delivered four papers in one session, on Tuesday, February 11, 1997, scheduled for 1:30-3:30 p.m., as originally planned. The conference was reasonably attended (about 35 people, including 4 from Canada and 4 from France).

The mini-PRC was held on February 12, 1997. It was attended by:

a) Dr. Schneider, Dr. Hamdullahpur, Dr. Boctor and Dr. Otten from the CUTC
b) Dr. Tavee, Dr. Tawachai, Dr. Sarawut, Dr. Umaly, and the new VP Planning.
   Both sides exchanged submitted discussion items (see attached appendix). Dr. Boctor presented the on-going and agreed upon activities (3rd PRC meeting in Waterloo) and the contracts requiring SUT signature. He also presented SUT with the latest 6 month project report. He then presented some ideas for relevant additional activities to use the remaining funds in the budget. Dr. Tavee and Dr. Umaly informed the CUTC that the Thai Project Committee met last week, presided upon by Dr. Wichit, to examine the project's activities and future collaboration. However, there was a clear indication that:
   a) the IUP (3rd trimester June-Sept. 1997 for the 5 remaining Electrical Engineering students) may be cancelled
   b) all agreed upon activities during the 3rd PRC meeting may be cancelled due to budget cutbacks at SUT
   c) Dr. Wichit has yet to decide upon the anniversary theme and dates and that he will inform Dr. Boctor. All that is known at present is that the festivities will be from July 22-27, 1997. Also, no discussion has yet been made regarding speakers or topics.

The CUTC suggested that Dr. Prasart could be included in the Thai SUT delegation to the 4th PRC meeting in Halifax, for the sake of continuity, particularly since the SUT project management has changed considerably.
There was no time for discussions, reflections or exchange of ideas beyond the items referred to above.

During the conference breaks, Dr. Hamdullahpur met with four prospective Ph.D candidates from SUT. Also Dr. Boctor met with the remaining 4 (of 5) EE IUP students, with Prof. Barta and Dr. Sarawut in attendance. The students were given RPU advanced-standing application forms for foreign students, and were informed about the final decision to cancel the third trimester (June-Sept. '97). They were also informed that once they successfully completed the present second trimester, they could be admitted to RPU next January 1998 in the second semester of Year I, since they have not completed the year I curriculum. They were also advised that it would be very beneficial if they came in September 1997 to take intensive ESL for one term. They were informed that they could transfer to SUT's regular Thai Engineering Programs if they so wished. It may even be conceivable that they may want to apply to other Canadian universities on their own.

On Thursday, February 13, 1997, just before Dr. Boctor was to meet with the IUP students, Dr. Boctor met briefly with Dr. Tavee. He was informed that:

a) The SUT's project budget has been severely cut, and that they will not be able to fund their remaining committed share of the project cost. Unless CIDA's funds completely covers the remaining activities, it may not be possible to implement them.
b) On the basis of (a) above, the IUP will be cancelled for the remaining EE students. Also the visits to help SUT prepare their graduate programs in engineering will be cancelled. The proposed visits by Ph.D advisors from TUNS to promote sustainable future research collaboration were also cancelled.
c) The following exceptions to the cancelled activities will remain:
   1. The proposed visits by Dr. Goff and Dr. Demann in September '97
   2. One Ph.D supervisor's (Dr. El Taweel from TUNS) visit, yet to be determined. (Please note that the relevant contracts which were left with Dr. Tavee are still to be signed!)
   3. Since two Canadian co-op students from TUNS have already obtained job offers and placements, one additional Canadian co-op student can be supported.
d) The Halifax meeting should reflect on "lessons learned", and possible future collaborations/sustainable activities.

No further information regarding the proposed RPU President's visit in July was received.

Conclusion

Since a major change in the project funding agreement has occurred at SUT, and since the majority of the approved and assigned project activities (see 3rd PRC meeting's minutes) will not be funded by SUT as previously agreed to, the CUTC has no other option but to inform the ARA and CIDA about the present circumstances. Except for those activities presently taking place, and those that may be approved by SUT (see item (c) above), the funds allocated for all the cancelled activities in Programs I, II, III, and IV may have to be returned back to CIDA through the ARA. An approximate summary of those funds is attached.

Dr. S.A. Boctor

c. All CUTC member universities

Funds Remaining in Cancelled Project Activities

	Approximately	( ) means deficit
Program I	$17,620	
Program III	($2,630)	
A2.11	$22,000	
A2.12	$46,000	
A2.21	0	
A2.23	$5,200	
A2.25	($4,700)	
A2.26	$16,920	
A2.27	$18,900	
A2.31	0	
A2.32	($4,000)	
A4.311	25,500	
A4.33(c)	$25,000	
Total	$165,810	

APPENDIX E

PROJECT STATUS UPDATE
DR. STALIN BOCTOR, APRIL 22, 1997
LETTER TO ARA

RYERSON
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
FACULTY OF ENGINEERING AND APPLIED SCIENCE

April 21, 1997

Mr. Roger Griffin, Project Coordinator, Thai-Can. HRD Project
The ARA Consulting Group Inc.
121 Bloor Street East, Suite 405
Toronto, Ontario, Canada, M4W 3M5

Re: Status of Project L-3004 Deliverables and Project Activities Adjustments based on resolutions of the 4th PRC meeting (Halifax, April 1997)

Dear Roger:

The following summary of the status of the project deliverables, and adjustments to projects activities (and hence funding allocations), describe the resolutions reached at the 4th PRC meeting in Halifax, on April 3-4, 1997. The minutes of the 4th PRC meeting and the most up-to-date Project Deliverable Status summary budget (including adjustments) are attached. Details of the completed activities will be provided in the Annual Report (April, 1997).

A2.11b) Contributions of the CUTC to the S.E. Asia Deans of Engineering meeting at SUT, Feb. 1997, and the mini-PRC: This activity was **completed**. Actual expenditures: $16,709.

A2.11c) **Unchanged**. Total expenses budgeted: $21,681.

A2.12b) This activity relating to Postgraduate Engineering Program development was **cancelled** by SUT. Unassigned funds: $19,200. However, the 4th PRC meeting **replaced** this deliverable by the new deliverable A2.4 (see below), with new budget allocation.

A2.12c) This deliverable was **reduced** to only one assignment for Prof. P. Barta. This assignment is on-going and will be completed in May, 1997. All other assignments were cancelled by SUT. The total expenses budgeted for this activity are reduced to $4,700. Unassigned funds: $27,300.

A2.12d) **Unchanged**. This deliverable will be completed in Dec. 1997. Total expenses budgeted: $12,800.

A2.21) All Ph.D. candidates from SUT have now been selected. This activity is now **complete**. Actual expenditures: $15,835.

RYERSON POLYTECHNIC UNIVERSITY
350 Victoria Street, Toronto, Ontario, Canada M5B 2K3 (416) 979-5052. Fax (416) 979-5280

New Approved Activities (RPC4, April 1997)

A2.4) Workshop for Postgraduate Engineering Programs Development and Quality Control: Seven Canadian Consultants, Nov. 1997.

Travel to and in Thailand	(7 × $3800)	$26,600
Accomodation	(7 × 10 × $120)	$8,400
Perdiem	(7 × 10 × $50)	$3,500
Consultants fees	(7 × 10 × $360)	$12,600
Total		$51,100

A2.5) Academic Research Exchange for Thai Faculty:
5 Thai faculty members, total 10 weeks. To be completed by Dec. 1997.

Travel to and in Canada	(5 × $3900)	$19,500
Living Allowance	(10 × $300)	$3,000
Program Planning by CUTC partners	(10 × $900)	$9,000
		$31,500
Total Funds Reassigned		$82,600

The remaining project deliverables will be completed within the 1997/98 fiscal year as indicated above, and the SUT/CUTC project (L-3004) will thus be completed on target as budgeted.

Thank you for your continued help and support.

Sincerely,

Dr. S.A. Boctor, P.Eng.
Program Manager

THAI CANADIAN HRD PROJECT
Linkage - CUTC and SUT
Project #L3004-91063
CIDA #906-14868

CIDA FUNDED EXPENDITURES
Deliverable Status
As at March 31, 1997

		Current Half Year			Project to Date			Estimated	
		Actual	Budget Exp.		Actual Exp.	Budget Exp.		Expenditures	Delivery
Deliverable		Oct-Mar/97	Oct-Mar/97	Variance	to Mar 31/97	to Mar 31/97	Variance	to Completion	Completed
1. Institutional Capacity Building Program									
A1.11a)	Training Academic Administrators (4)	0	0	0	36,789	36,789	0	0	Mar/95
A1.11b)	Training Academic Administrators (1)	0	0	0	5,276	5,276	0	0	May/95
A1.21	Training Faculty Members	0	0	0	50,524	50,524	0	0	May/95
A1.31	Training Support Personnel	0	0	0	81,557	93,164	11,607	0	Oct/96
A1.32	Institutional Support Services	0	0	0	8,936	14,949	6,013	0	Oct/96
A1.41	Evaluate ESL Needs	0	0	0	9,095	9,095	0	0	Dec/93
A1.42	Study Tour ESL	0	0	0	16,581	16,581	0	0	Feb/94
A1.5	CUTC Additional Mgt Activities	0	0	0	31,500	31,500	31,500	0	Apr/96
	Program 1 Sub-total	**0**	**0**	**0**	**240,258**	**257,878**	**49,120**	**0**	
2. International Academic Program									
A2.11a)	Academic Program Planning	0	0	0	24,172	37,512	13,340	0	Oct/96
A2.11b)	Academic Program Planning	16,709	0	(16,709)	16,709	0	(16,709)	0	Apr/97
A2.11c)	Academic Program Planning	0	0	0	0	0	0	21,681	
A2.12a)	Curriculum Implementation	0	19,200	19,200	21,840	25,600	3,760	0	Oct/96
A2.12b)	Curriculum Implementation	0	0	0	0	19,200	19,200	0	Cancelled
A2.12c)	Curriculum Implementation	1,695	0	(1,695)	1,695	0	(1,695)	3,005	
A2.12d)	Curriculum Implementation	0	0	0	0	0	0	12,800	
A2.21	Selection Supervisors/PHD	4,600	0	(4,600)	15,835	10,637	(5,198)	0	Apr/97
A2.23	Ph.D Research	0	0	0	0	0	0	6,900	
A2.25	Post Doct. Research Fellowships	8,338	20,000	11,662	25,038	20,000	(5,038)	34,762	
A2.26	Thai Advisors visit to Canada	8,073	5,000	(3,073)	8,073	5,000	(3,073)	0	Apr/97
A2.27	Collaboration co-supervisors		5,670	5,670		7,560	7,560	0	Cancelled
A2.31a)	Work Placements - Canada	8,000	8,000	0	16,000	8,000	(8,000)	0	Apr/97
A2.31b)	Work Placements - Canada	4,000	0	(4,000)	4,000	8,000	4,000	12,000	
A2.32a)	Work Placements - Thailand	0	16,000	16,000	16,000	16,000	0	0	Oct/96
A2.32b)	Work Placements - Thailand	8,000	0	(8,000)	8,000	16,000	8,000	12,000	
A2.4	Workshop-Post-grad. Eng Prog/Control	0	0	0	0	0	0	51,100	New
A2.5	Academic Research Ex. Thai Faculty	0	0	0	0	0	0	31,500	. New
	Program 2 Sub-total	**59,415**	**73,870**	**14,455**	**157,362**	**173,509**	**16,147**	**185,748**	
3. University-Industry Linkage Program									
A3.11	Training Co-op Program	0	0	0	7,234	7,234	0	0	May/95
A3.21	Industrial Training Framework	0	0	0	3,775	3,400	(375)	0	Oct/96
A3.22	Training Seminars by Canadian Consult.	0	0	0	33,225	31,350	(1,875)	0	Oct/96
A3.23	Additional Ind. Seminars in Thailand	0	0	0	0	0	0	19,600	
A3.31	Monitor Co-op Students	0	3,400	3,400	3,775	3,400	(375)	0	Oct/96
	Program 3 Sub-total	**0**	**3,400**	**3,400**	**48,009**	**45,384**	**(2,625)**	**19,600**	
4. Project Management									
A4.21a)	Canadian Management Team -yr 1	0	0	0	34,320	34,320	0	0	Mar/95
A4.21b)	Canadian Management Team -yr 2	0	0	0	35,759	35,759	0	0	Mar/95
A4.21c)	Canadian Management Team -yr 3	0	0	0	32,881	32,881	0	0	Mar/96
A4.21d)	Canadian Management Team -yr 4	16,848	18,105	1,257	34,416	36,210	1,794	0	Mar/97
A4.21e)	Canadian Management Team -yr 5	0	0	0	0	0	0	38,002	
A4.31	Project Review Committee - Thai	0	0	0	22,298	22,298	0	0	Dec /95
A4.311	Project Review Committee - Thai	0	0	0	0	0	0	25,560	
A4.32	Project Review Committee- Can	10,225	14,100	3,875	24,491	28,200	3,709	0	Apr/97
A4.33a)	Project Management	0	0	0	24,144	26,957	2,813	0	Oct/96
A4.33b)	Project Management	5,873	14,435	8,562	5,873	14,435	8,562	20,539	
A4.33c)	Project Management	0	0	0	0	0	0	25,000	
A4.41	Communication/Support	2,724	4,748	2,024	7,451	12,827	5,376	13,773	
	Program 4 Sub-total	**35,670**	**51,388**	**15,718**	**221,633**	**243,887**	**22,254**	**122,874**	
Total		**95,085**	**128,658**	**33,573**	**667,262**	**720,658**	**84,896**	**328,222**	

APPENDIX F

SUT CONTRIBUTION TO ANNUAL REPORT FOR THE PERIOD COVERING JULY TO DECEMBER 1996

THAILAND - CANADA HRD PROJECT
SUT-CUTC INSTITUTIONAL LINKAGE
AND TECHNICAL COOPERATION

QUARTERLY PROGRESS REPORT NO. 9

1 August 1996 - 31 December 1996

Submitted to :
Ryerson Polytechnic University

Prepared by

SURANAREE UNIVERSITY OF TECHNOLOGY
111 University Avenue
Amphur Muang
Nakhon Ratchasima 30000
Phone: (66-44) 216191-8 ext. 1154-6, 1159
Fax: (66-44) 216122

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SUT-CUTC Biannual Report for July-December 1996

I. REPORT SUMMARY

1. Program and Achievements to Date

Program 1. Institutional Capacity Building Program

Study tour was made in September 1996 by the Director of the Center for International Affairs (2 weeks) and of a Program Officer of the Center (4 weeks) to discuss the administration and management of the SUT-CUTC Project in Canada as well as to acquaint them of the activities of the Centers for International Relations / Affairs of the partner CUTC universities.

All activities of Program 1 have been completed.

Program 2 - International Academic Programs

2.1 International Applied Science and Engineering Undergraduate Programs

Two Canadian professors - Professors David MacKay and Gerry Schneider finished their 7 week assignments of teaching the 1995 IUP students (Mechanical Engineering).

The remaining five 1995 IUP students in the Mechanical Engineering program have been transferred to CUTC universities to start their second year in Canada. Three of them were admitted conditionally to TUNS while the other two were admitted to Conestoga College for remedial English course and would later enroll in the Engineering Program at the University of Waterloo.

There are currently 8 students remaining in the 1996 IUP Electrical Engineering Program.

2.2 Joint Research and Ph.D. Program

Two SUT faculty members have enrolled Ph.D Program at TUNS and two more will start in January and September, 1997 respectively. A fifth candidate is being considered for admission by TUNS. A sixth candidate is expected to start his Ph.D. Program in September of 1997 at the University of Guelph.

Two professors from the Institute of Industrial Technology visited some laboratories for mechanical and Electrical Engineering at the University of Waterloo.

2.3 Co-op Student Exchange Program

Two Thai students who have been working at the University of Guelph since June 1996 would finish their assignments in December 1996. Another two students started their co-op work terms at TUNS in September 1996.

Program 3 - University - Industry Linkage Program

Mr. Robert Eagle from TUNS visited SUT last October to discuss the possibility of additional industry-based workshops and seminars in Korat. It is expected that two or three seminars / workshops for industry will be organized by SUT's Technopolis in

II. PROGRESS REPORT ON PROJECT PROGRAMS, ACTIVITIES AND DELIVERABLES

1. Accomplishments

Program 1 - Institutional Capacity Building Program
1.3 Development of Academic Programs and Curricula at SUT

A1.31 Provision of customized training in Canada for SUT Academic Support Personnel

Visits to Canada of SUT's CIA Director and one program officer took place in September 1996. Prof. Dr. Ruben C. Umaly, CIA Director, visited the partner CUTC universities to discuss plans for the implementation of the remaining SUT-CUTC Project activities and future cooperation and also to examine the administration and management of the CUTC project in Canada. **(Attachment 1)**

Ms. Mantana Thammachoti - a Program Officer from The Center for International Affairs - attended a 4 week training course in September 1996 (during 1-27 September 1996) to familiarize herself with the strategic and operational management of Centers for International Relations/Affairs at each of the CUTC partner universities. **(Attachment 2)**

With these activities, all of Program 1 activities have now been completed.

Program 2 - International Academic Programs
2.1 International Applied Science and Engineering Undergraduate Programs

A2.11 Academic program planning and coordination

Two professors from the CUTC partner universities were at SUT for short-term assignments (7 weeks each) to help teach the International Undergraduate Program in Mechanical Engineering during the third trimester.

Prof. David MacKay from TUNS taught Engineering Practice, Ethics and Technical Communication, and ESL 300 from 1 June-19 July, 1996.

Prof. Gerry Schneider from University of Waterloo taught Engineering Graphics I and Fundamentals of Mechanical Engineering from 17 July-29 August, 1996.

A2.12 Curriculum Implementation of the International Applied Science and Engineering undergraduate programs.

a) Status of the 1995 IUP students (Mechanical Engineering)

After completing their first year in early September, the five remaining IUP mechanical engineering students transferred to Canadian universities. As the students did not meet the English language prerequisites, they were required to take remedial English language courses before being definitely admitted to the CUTC partner universities.

Two students were admitted for their remedial language courses at Conestoga College; one of them - Nattapon POOPIPAT, has now completed his English training and will enroll this coming winter term at the University of Waterloo. The second student is still in the English language program. The remaining three students were accepted by TUNS, but they also had to take English classes during October-December. They will be able to register in Engineering at TUNS in January 1997, but will first have to take a number of remedial courses at St. Mary or Dalhousie University before continuing in the engineering program at TUNS.

The sudden and unexpected decision to have the students continue their second year of studies in Canada caused some disruption and delay in the program.

As the students had not taken any TOEFL examination, the Canadian institutions found it difficult to assess their English language proficiency. As a consequence, one of the students, although qualified in the opinion of his instructors, could not obtain admission to Conestoga College. The students' departure for Canada was further delayed by about 4 weeks (and 8 weeks in one case) because of a lengthy visa application process.

Acceptance letters for 1995 IUP students by CUTC universities are given as **Attachment 3.**

b) Status of the 1996 IUP students (Electrical Engineering)

SUT only offered the Electrical Engineering Program for the 1996 academic year. After finishing the intensive courses during June - August 1996, 9 out of 13 students registered for the first trimester beginining September, 1996. Currently, there are 8 students remaining in the program. They were informed by the CIA Co-advisor of the transfer to the CUTC institutions for their second year studies.

2.2 Joint Research and Ph. D. Program

A2.21 Ph. D. Program

The second Ph.D student - Mr Anand Unsivilai from the Institute of Industrial Technology of SUT started his Ph.D program in electrical engineering at TUNS in September 1996. Another two faculty members - Ms. Ganthima Polprasert and Mr. Rangsan Wongsan were also admitted at TUNS for their Ph.D. programs. Ms. Polprasert is expected to start in January and Mr. Wongsan is expected to start in September 1997. A fifth candidate who is presently studying in USA has requested permission to transfer to TUNS.

Acceptance letters for Ph.D students from SUT by CUTC universities are given as **Attachment 4**

One Ph.D. candidate in Food Science anticipates to start his Ph.D. program at the University of Guelph as early as possible in 1997.

A2.25 Post-Doctoral Research Fellowship for Thai scholars

Three post-doctoral research proposals were approved. The recipients are Dr. Chongchin Polprasert, Dr. Sureelak Rodthong and Dr. Somprasong Suttayamully.

Dr. Chongchin Polprasert is expected to undertake his 12 month research in environmental engineering during January-December 1997.

Dr. Sureelak Rodthong has been accepted by the University of Guelph to pursue her research in Biology at the Agrofood Canada Lab for 5 months during 11 February-12 July, 1997.

Dr. Somprasong Suttayamully will undertake research in Transportation Engineering for 5 months at TUNS starting April 1997 and may extend it to one year if the necessary additional budget can be allocated.

Acceptance letters / contracts.for post-doctoral research fellowships of SUT professors in CUTC universities are given as **Attachment 5.**

A2.26 Thai Research Advisors

Two SUT professors from The Institute of Industrial Technology visited laboratories at the University of Waterloo to familiarize themselves with research facilities and projects. Dr. Kontorn Chamniprasart of the School of Mechanical Engineering visited Mechanical Engineering laboratories while Mr. Rawat Vipia of the School of Electrical Engineering, visited high voltage laboratories at the University of Waterloo during November 1-7, 1996.

2.3 Co-op Student Exchange Program

A2.31 Provision of work placement and supervision for Thai students in Canada by CUTC institutions

Since June 1996, two Thai students in food science, have been at Guelph University for their 16 week Co-op work terms. They will finish their assignment in December 1996.

Another two Thai students started their one term assignment in Mechanical Engineering and Chemical Engineering at TUNS in September 1996.

A2.32 Provision of work placement and supervision for Canadian students in Thailand by SUT

Four Canadian Co-op students from TUNS carried out their four - month assignment from May-August 1996. A fifth student started in September and finished his assignment in December, 1996.

Program 3 : University - Industry Linkage Program

3.2 Joint University-Industry Cooperation and Training Activities

A3.21 Development of a Framework for Industrial Training Seminars

It was agreed durjng the 3rd PRC Meeting held in Waterloo (September 26-27, 1996) that the development of a framework for industry-based seminar would be replaced by a planning and follow - up mission by Mr. Robert Eagle from TUNS in October 1996.

Mr. Robert Eagle visited SUT from 6 to 11 October, 1996 and met with SUT administrators and staff involved in the University Industry Linkage Program. and discussed the possibility of training / seminars with industry in Korat. **(Attachment 6)**

At least three seminars are being planned.

Program 4 : Project Management

A4.32 Third PRC Meeting in Canada

The third Project Review Committee Meeting was held in Waterloo during 26-27' September, 1996. Dr. Sam-arng Srinilta led the SUT delegation consisting of Dr. Prasart Suebkha, Dr.Tawit Jitsomboon, Prof. Dr. Ruben C. Umaly and Ms. Mantana Thammachoti.

During the meeting, both parties discussed the programs and issues of project implementation, readjusted some program activities, did a budget revision and discussed possible future cooperation among CUTC institutions after the SUT-CUTC Project termination. **(Attachment 7)**

It was agreed to hold the next meeting in Halifax in April 3-4,1997.

2. PLANNED ACTIVITIES

Program 1 : Development of Institutional Capacity

A1.32 Provision of Technical Services to SUT

Two additional activities were considered by the PRC.

1. Participation by CUTC Institutions in the Regional Colloquium on

Engineering and Technology Education for the 21st Century at SUT during 11-14 February, 1997. Four CUTC representatives will attend the colloquium with support allocated from activities A2.11 and A4.33.

2. The organization of a workshop on Continuing and Distance Education at SUT will be discussed at the next PRC meeting in Halifax.

Program 2 : International Academic Programs

A2.11 Academic Program Planning and Coordination

Dr. Stalin Boctor from Ryerson Polytechnic University will be involved in planning, coordination and monitoring of the program during his visit in February, 1997 to SUT. The 1996 IUP students' English competency and academic progress will also be assessed at that time.

A2.12 : Curriculum Implementation of International Engineering Program

Since the first year IUP mechanical engineering students have already been transferred to CUTC partner universities for their second year of study, the assignment of only four CUTC professors to teach the IUP students at SUT will be needed for 1996/1997.

Ryerson Polytechnic University sent the curriculum vitae and contracts of four professors to SUT for approval. Prof. Peter Barta, who will be teaching Electric Circuits I and Lab I in January 1997, has arrived at SUT. The other three professors will teach during the third trimester of 1997 beginning in May. Professor David MacKay from TUNS will come again to teach in the third trimester of 1997.

The remaining funds for CUTC expert assignments will be used to help SUT in the formulation, planning and development of graduate programs in engineering and applied science.

Dr. Goff and Dr. DeMann from the University of Guelph will visit SUT in September of 1997 to help the Institute of Agricultural Technology develop its undergraduate and graduate programs in Food Technology and to give seminar workshop in Food Technology.

A2.21 Selection of Thai Supervisors

A2.22 Provision of Ph.D Courses

A2.23 Jointly Supervised Research Work in Thailand

Some of the activities in this category were readjusted during the last PRC Meeting. Three Canadian professors from TUNS and Ryerson Polytechnic University will lead a 4 - week CUTC mission to SUT in 1997 to discuss and assist in the development of Post-Graduate Engineering Programs. The exact date and time will be announced later.

A2.25 Postdoctoral Research Fellowships

Two SUT faculty members will commence their research in January 1997. Dr. Chongchin Polprasert at TUNS and Dr. Sureelak Rodthong at Guelph. A third faculty member - Dr. Somprasong Sattayamully - will start his research at TUNS in April 1997. Additional post-doctoral research fellowships will be considered at the next PRC meeting.

A2.26 : Thai Research Advisors

The Director of the SUT Scientific and Technological Equipment Center - Assoc. Prof. Dr. Virul Mangalaviraj - will visit the CUTC institutions' laboratories in mid 1997. SUT will send his CV to Ryerson International to facilitate issuance of letters of invitation.

A2.26, A2.27 : Collaboration and Co-supervision in Canada

Some of the funds remaining from these two activities may be used to support additional postdoctoral fellowships and additional industrial seminar activities. This issue will be discussed at the next PRC meeting.

A2.31 Thai Co-op Students in Canada

Two SUT students will start their co-op terms at TUNS in January, 1997.

A2.32 Canadian Co-op Students in Thailand

TUNS will prepare plans for a final group of Canadian students to be sent to Thailand at the next PRC meeting.

Program 3 : University - Industry Linkage Program

A3.21 Technical Service by Canadian Consultants to provide Training Seminars in Thailand

During his assignment at SUT next September, Dr. Douglas Goff from the University of Guelph will arrange a seminar on Food Technology / Agribusiness.

A3.22 Delivery of Industrial Training Seminars in Thailand

Mr. Robert Eagle from TUNS visited SUT last October for discussions with SUT administrators. After an initial survey, topics for possible workshops were identified. It is expected that in the year 1997, two to three workshops will be organized by SUT's Technopolis in cooperation with CUTC.

Program 4 : Project Management

A4.32 Next PRC Meeting

The fourth PRC meeting is scheduled to be held at the Technical University of Nova Scotia, Halifax, Canada during April 3-4, 1997.

A4.33 Project Management

Dr. Claude Lajuenesse, President of Ryerson Polytechnic University, will visit SUT for discussions in July of 1997. He will also be a speaker at the international conference to be held at SUT in July 1997.

3. Budgetary Report

Budgetary report and requirements are included in the minutes of the PRC meeting.

III. Attachments

1. Report of a study tour of Prof. Dr. Ruben C. Umaly to Canada.
2. Training / study visit programme arranged by CUTC institutions for Ms. Mantana Thammachoti.
3. Acceptance Letters for 1995 IUP students by CUTC universities..
4. Acceptance letters for Ph.D students from SUT by CUTC universities.
5. Acceptance letters/contracts for Post-doctoral research by CUTC universities.
6. Trip report by Mr. Robert Eagle on the industrial seminars
7. Minutes of the third PRC Meeting

Industrial Seminars, Trip Report

Prepared for
SUT/CUTC Partnership

by
Robert Eagle

December 16, 1996

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Introduction

During the week of October 6,1996 and until October 17,1996, Robert Eagle visited the campus of Suranaree University of Technology in Nakhon Ratchasima in order to help establish a program of industrial seminars in which the Canadian Universities Technology Consortium would play a supportive role. The goals of the visit were to identify a process for selecting seminar topics, select a structure to give the seminars and to select the first few areas where CUTC could assist SUT with the seminar packages. The expected outputs of the visit were to be suggestions of specific topics, potential lectures, potential revenue, expected expenses and available resources.

Visit Schedule

The program schedule began in Nakhon Ratchasima on Monday October 7,1996 and finished in Bangkok with a wrap up meeting on Thursday October 17,1996. The program included meetings with senior SUT officials, industry representatives, executives of the Federation of Thai Industries, SUT Faculty members, Technopolis staff and Centre of International Affairs staff. The detailed program is attached in Appendix A.

Suranaree University of Technology

SUT has two departments that will be directly involved with organizing the seminar series. These being Technopolis and the Centre for International Affairs.

Technopolis is a science park established for technology innovation and fine tuning, technology transfer, and exhibition. Technopolis , an innovation in Thai higher education, has three directives:

1. Serving the industrial sector in research and development, individually or jointly with the University;

2. Promoting and supporting creative inventors; and

3. Offering service to both government and private sectors, to strengthen ties and cooperation between the University and those sectors for mutual benefit.

More specifically the facilities, resources and services which Technopolis offers are shown in Appendix B. Also in Appendix B is a list of Technopolis' Activities over its first 5 months. These activities included an industrial survey, the results of which are shown.

Under its mandate, Technopolis has been offering a series of seminars to industry and

There is a problem in the NE of attracting and keeping skilled labour. Labour has tended to move to the Central and Southern regions where wages are higher. A move to a better work environment with such benefits as affordable housing, good schooling, training, increased wages, etc., could help to reverse this trend.

Some of the training requirements that industry indicated an interested in participating in include:

- industrial safety
- a practical course in quality management
- industrial/environmental management-water related in particular
- management skills - in particular financial management/accounting
- computer management
- precision machinery

No industry specific courses were recognized in either the industry talks or the Technopolis questionnaire. More work needs to be done to identify these topics.

Technopolis is addressing many of the fundamental training requirements in the seminar program they have prepared for the coming year (Appendix C).

Course Criteria

Objective - The objective of the CUTC/SUT Industry Seminars is to assist industry in understanding and transferring new advanced technologies. The focus will be on local industry initially, however, topics for a broader participant base will also be sought.

Organization - Technopolis will be the main vehicle to deliver the courses, assisted by CIA, the SUT faculty and staff, and outside Thai expertise when necessary. CUTC will assist only where expertise is not available in Thailand.

Technopolis will be responsible for the organizing, administration and marketing of the seminars. CIA will assist when there is an international component to either the delivery or the audience.

Delivery - Technopolis will seek out the most appropriate speakers from SUT, CUTC, industry and government. A course director will be appointed to help bring together curriculum or course content, speakers, topics, etc. Each speaker will be asked to have a copy of their address in advance of the seminar. Technopolis will arrange for the translation of papers when necessary. Consideration should be given to having translation at the seminars.

Revenue/Expenses - The seminars will be set up to recover all costs including room rental, food, lodging, speakers fees, marketing costs, copies, supplies, telephone/communications, speakers living and travel costs, and some degree of overhead or profit. The early seminars should try to recover some of the CUTC cost so that they can be used to help bring in speakers for future seminars.

To save on costs, the seminars could be given in more than one location or country. This would allow for better use of resources. Travel cost would thus be written off over a larger number of participants.

Size & Duration - The seminars should try to be industry specific and applied in nature. This means a smaller participation but of more practical use.

Also the length of the seminars should be kept to 2 to 3 days so that industry can attend. Combining weekends or at least Saturday makes it more accessible to industry.

Topics

The topics that have been discussed for potential industry seminars are as follows:

1] Food Prooessing

Dr. Doug Goff from Guelph will be at SUT for the September to December term of 1997. He has agreed to offer one or two seminars in the food science area. The topics suggested are:

a] Food Technology for the Dairy Industry - This will be a 3 day course offered in the 3rd week of September 1997 [the week of the 15th]. It will emphasize advanced food processing processes. Three or four faculty members from SUT will assist in the giving of the material. It may be combined with a course offered by Germantown, an Australian Ice Cream Company that Doug has worked with in the past.

b] Food Quality and Safety - There have been a number of courses offered in this area but the emphasis has always been on the principles. This course will concentrate more on the application, process and documentation of the principles. It will be a two day course given either at the exam break in November 1997 [11th] or on a Friday/Saturday in that month.

Dr. Suwayd is the SUT contact person for these two courses. Robert Eagle has contacted Dr. Goff to express the changes to his program from the one he originally suggested.

2] Integrated Watershed Management of an Industrial Site

In July 1996, CUTC & SUT offered a seminar in water resources management. Although this was well received, there appeared to be a need for a more detailed hands-on workshop. Local industry are also concerned with how to dispose of or treat their industrial waste water. This course would address both of these needs. It would be 2 to 3 days in duration. It will be fit into the Technopolis schedule at a convenient time. The presenter from Canada would likely be Dr. William Hart. He would be assisted by SUT faculty he has already made contact with.

Prof. Manoo and Dr. Hart will exchange thoughts on this project with these two also being responsible for its implementation. Dr. Hart needs more information before he can proceed, thus Eagle to update him.

3] Community Based Environmental Resource Management

In January 1997, Technopolis will begin a series of meeting or workshops to discuss environmental resource based management. The first step would be a workshop in January [20 to 30] for Government, university and private sector organizations, to discuss the concepts surrounding CBERM. The second workshop, which would be held latter in the year , would develop an operational plan for CBERM of the North East Region. The third step would be to select pilot projects, one of which would be the establishment of a center of coordination at Technopolis.

The CUTC/SUT fund would be used to bring in a facilitator for the first workshop. It is likely that the speaker would come from either Guelph or Ryerson. Eagle is to get a name of someone to SUT. Prof. Manoo is to approach the Ministry of Science and Technology for support of this workshop.

The second workshop could be run at the same time as the SUT Anniversary [July 27 and the following week].

It is likely that this series of workshops will help identify other topic areas for technical seminars. Certainly technology gaps will be identified during the process.

4] Computer Technology In Industry

This could be a course aimed at showing the benefits of advanced computer technology to industry. It could address such topics as computer control systems, CAD/CAM, e-mail, internet, management control systems, robotics, etc. This concept needs more work and a more specific focus.

It will be integrated into the Technopolis program of computer courses. Technopolis already has computer courses planned in:

1] introduction to programmable logic controllers;
2] basic computer training, and
3] training for computer mapping, increased efficiency of library work with internet.

The two areas that SUTC can assist with are:

1] Integrated Manufacturing through Dr. Vorapot of Mechanical Engineering, and
2] something on computer aided management.

The first of these will take place in August 1997 after the new equipment is in place. Eagle will try to arrange an expert. The second will be explored with CUTC members and Technopolis.

Other Ideas

The remainder of these courses and workshops are ideas that need further exploration. Dr. Hueng is to prepare an industrial questionnaire to get more information about industrial needs. The process will be to interview a select number of industries to get detailed information and send the questionnaire out to the other firms in the area. Eagle to send a copy of the questionnaire TUNS is preparing for our manufacturing program.

1] Industrial Safety - This course would be aimed at showing the benefits of increased safety to local industry. The North East is losing its labour force to the more highly industrialized areas of Thailand. A cleaner/safer environment for workers would help to keep skilled labour in the area. The emphasize should be on industrial health and saftety. The local regulations lack enforcement.

2] Industry Specific Courses - The need exists to develop a series of industry specific course aimed at transferring to industry specific technologies. Technopolis needs to refine there contacts with industry to more clearly identify these opportunities. Some of the areas to be considered include;

a] Ceramics - The ceramics industry is made up of a large number of small producers, whose products are largely for the craft sector. Nova Scotia College of Art and Design has done some work with such industries in other countries in increasing the quality of their products with enhanced production techniques, new coatings, etc. Bill Caley has some expertise in this area.

b] Plastics/Polymers

c] Other industries - need information

3] Quality Assurance - Courses have been given in ISO 9000 and one is being planned in ISO 14000. What appears to be missing is a workshop that is more applied in nature. Again the concepts seem to be known but the process of application is weak.

Industry Trade Mission To Canada

The local branch of The Federation of Thai Industries is interested in taking a trade mission to Canada. This project would be self financing and would be arranged jointly by Technopolis and CUTC, support would be sought in Canada from CIDA. Industry Canada and the provincial economic development departments. Eagle had a meeting with Trade Officers in the Canadian Embassy on Thursday Oct. 17th. They would offer logistical; and administrative support.

Timing would be in the summer of 1997 and would be linked to a major industrial trade show in Canada. CUTC will be begin the process by identifying potential shows and communicating with FTI.

Technopolis Training

At the April meeting of PRC in Halifax, a proposal will be put forward to offer training in Canada to two or three Technpolis staff members in the areas of technology transfer, continuing education and industrial outreach. This will include visits to TUNS Continuing Education program, Waterloo Innovation Centre, Waterloo and Guelph's industrial parks, along with other components yet to be identified. The visit would be 3 weeks in length.

Appendix A

Visit Schedule

Tentative Program
Visit SUT of Mr. Robert Eagle

7 October 1996

08.20	Arrival at Nakhon Ratchasima Airport
09.00	Refreshment at hospitality house
11.00	Courtesy call on VR Planning, Dr. Pongchan Na-Lampang, Technopolis Coordinator, Dr. Neung Teaum voong, VR Development, Director, and Dr. Ruben Umaly, Director, CIA
12.00	Lunch with Director, CIA
13.00	Campus tour
19.00	Dinner with VR Planning, Director CIA, Dr. Prasart,VR Administrative Affairs, and Prof. Manoo, Director, Technopolis, O-makwbt

8 October 1996

09.30-11.00	Meeting with SUT executives/staff at Saranithas Conference Room, Admin. Bldg.
12.00	Lunch
Afternoon	Visit Technopolis - Ms. Panpimol (On)

9 October 1996

09.30	Visit Sa-nguanwong Industry Co. Ltd.- Mr. Eakarin Yanubol, Mr. Ded-anan, Labour Consultant, Wongkom Chan
11.00	Babcock Plant - Mr. Boontham Phaeprodit & TUNS Co-op Student, John Sole
12.00	Lunch
13.30	Visit S.W. Group Co. Ltd., Mr. Chaiya Wongprasert, Dr. Kiltisak, SUT

10 October 1996

14.00	Meeting with executives of the Federation of Thai Industries, Nakhon Ratchasima and SUT executives in FTI office. Chair - Mr. Chaiya Wongprasert

11 October 1996

09.30	Visit Chao Phraya Crop Co., Ltd. - Chol Anukulkitch, President
12.00	Lunch
13.30	Visit Chao Phraya Marble Co., Ltd. - Wong-A-Mart Amatyakul, Suvith Kruawan

12-13 October 1996

Toured local area

14 October 1996

a.m.	Prof. Manoo, Director of Technopolis
p.m.	Visit Suranaree Industrial Zone - Jimmy Panyarit Lawansirc

15 October 1996

09.00	Meeting with Dr. Terce, Dean, Institute of Agricultural Technology and Chair, Food Technology at Institute of Agricultural Technology, & Dr. Suwayd
12.00	Lunch
13.00	Final planning of seminars with SUT, Technopolis and CIA

16 October 1996

08.00-16.30	Wrote draft report
18.00	Transfer to Nakhon Ratchasima Airport for TG Flight to Bangkok

17 October 1996

10.00	Canadian Embassy - Thawee Thaiprasithiporn
18.00	Final Meeting - Dr. Ruben Umaly

Appendix B

Technopolis

TECHNOPOLIS
SURANAREE UNIVERSITY OF TECHNOLOGY (SUT)

SUT BACKGROUND

According to the Fifth National Social and Economic Development Plan prescribed among other things an increased distribution of opportunities for post-secondary education to rural areas as a major higher education development policy. Five new regional colleges were recommend to established by Ministry of University Affairs. Suranaree University of Technology (SUT) in Nakhon Ratchasima is one of those which chosen for serving the trends of national development needs and future direction of higher education management in country. Finally, His Majesty the King signed the Suranaree University of Technology BE 2533 Act on 27 July 1990, to conclude the process. Hence, SUT considers this auspicious date as her founding date.

SUT is a state University of Thailand, neither a government agency nor a government enterprise. It is a jurisdical body under the supervision of Minister of University Affairs and, hence, a state University supervised by government as defined in the 2533 BE SUT Royal Decree and in the Ministry of University Affairs operating Guidlines Act 2537 BE.

Supervised by the government, SUT has instituted its own administrative structure and system by concentrate in decentralizing authority using full automony. Thus, the University's administrative and management decision making is practically self-contained with the University Council being the highest authority. The organizational structure of SUT is compact as to ensure a high degree of flexibility and efficiency.

MISSION

SUT has a five-fold mission:

1. The training and production of highly qualified sciencetific and technological personels in response to national development needs.

2. Research and development for academic advancement and national development.

3. Adapting and disseminating suitable technologies for increased national and technological self-reliance.

4. Academic service to the public and various, both government and private.

5. National and Regional cultural preservation, especially that of the Northeast.

Technopolis, with a total area of 128 hectares, is an innovation in Thai higher education initiated by SUT with 3 directives:

Directive 1: Serving the industrial sector in research and development, individually or jointly with the University.

Directive 2 : Promoting and supporting creative inventors.

Directive 3 : Offering services to both government and private sectors, to strengthen ties and cooperation between the University and those sectors for mutual benefit.

Technopolis was constructed by the Royal Thai Government and assigned to be site of the World Agricultural and Industrial Exhibition 1995 (WORLDTECH'95 Thailand), held from 4 November to 16 December 1995. After the exhibition, the government handed over the land and various buildings of WORLDTECH'95 Thailand to the University. They were 10 permanent buildings, namely, Surapat 1, to house the Technopolis administrative office and incubation units, with 7,138 square meters of usable area; Surapat 2, to house the National Synchrotron Light Source Research Laboratory Center, with 9,907 square meters of usable area; Surapat 3, to house various exhibition, with 9,891 square meters: Surapat 4-5-6, to house various exhibitions and the Butterfly Park, with 5,264 square meters of usable area; Suranitat, a semicircular amphitheater for cultural events with a 3,000 seats capacity and 4,056 square meters of usable area; the Golden Jubilee Building, for Royal project exhibition, with 1,505 square meters; Suranapa Tower, the Technopolis symbolic tower from which SUT's campus may be viewed, 82.30 meters in height; and the Scientific and Technological Equipment Building, with a total of 8,232 square meters of usable area.

The University has also received buildings from exhibitors of WORLDTECH'95 Thailand to use in education, teaching, and research, including Exhibition Buildings 1-4. Exhibition building 1 was given to SUT by the Electrical Generating Authority of Thailand and the Metropolitan Electric Authority, with 5,600 square meters of usable area. Exhibition Building 2 was given by the Ministry of Science, Technology, and Environment, with 3,000 square meters of usable area. Exhibition Building 3 was given by the Laemthong Company,Ltd., with 1,200 square meters of usable area, and Exhibition Building 4 was given by the Charoen Pokapan Company, with 480 square meters of usable areas.

Technopolis serves as a University center for academic support, working as the central unit in the adaptation, transfer, and development of appropriate technology, as well as academic servicing to society. Technopolis and.the SUT campus will be refurbished to become;

1. A Technology Incubation Department, a place to generate support for research and development, with Surapat 1 serving as the technology incubation unit, Technopolis management office, and central business center.

2. An Innovation Department, a place for prototype projects under development, or new projects that need testing and fine tuning before being released for marketing, such as the High Tech Thai House.

3. A Technology Extension Department, to promote the transfer and adaptation of technology for maximum production efficiency, with the Scientific

and Technological Equipment Building being the main unit, along with laboratories to enable academic servicing.

4. An Exhibition Division, mainly with Surapat 2-5 and Exhibition Buildings 1-4 and the Butterfly Park.

5. Academic Services Division, to provide academic services to society on the local, national and international levels; such as expert speakers, presentation of project results and academic papers, project assessment and academic documentation expert and organizaticn of meetings/seminars/workshops.

Technopolis's Activities (March - July 1996)

1. Servey of status, problems and needs assessment in term of technology and management from government and private sectors in local area. The concluded data are as follow;

1.1 Government Sectors (106 departments)

<u>Percent of Ministry</u>

Departments from Ministry of Interior	33%
Departments from Ministry of Education	20%
Departments from Ministry of Agriculture and Cooperatives	16%
Departments from Ministry of Public Health	13%
Departments from other Ministries	18%

<u>Education status of officers</u>

- Higher than Bachelor's Degree	7.4%
- Bachelor's Degree	27.4%
- Lower than Bachelor's Degree	26.8%
- Temporary Empolyees	36.4%

<u>Problems and needs assessment</u>

1. Needs technology with related work and want SUT to be the center of technology transfer.
2. Needs improvement for officers quality.
3. Needs development of information and communication system.
4. Needs increasing of efficiency in administration and management system.
5. Needs more research and development

(1 = most needed   5 = less needed)

1.2 Private Sector (64 companies)

Status

* Type of industry

- Engineering Industry	40.3%
- Agricultural Industry	25.6%
- Manpower Industry	19.3%
- Electrical and Machinery Industry	8.1%
- Other industries	9.7%

* Size of capital outlay Expenditure

- 1-25 million baht	40%
- 26-50 million baht	27.5%
- 51-75 million baht	12.5%
- 76-100 million baht	10%
- more than 100 million baht	10%

* Employees according to work characterization

- Production	90.5%
- Administration	5.4%
- Quality control	3.3%
- Research and Development	0.8%

Problem and needs assessment

1. Development of products quality
2. Increasing the efficiency of production
3. Needs improvement of workers quality
4. Needs developments of processing system
5. Improve the quality of raw materials

(1 = most needs......5 = less needs)

R&D experiences

- Ever 19.6 %
- Never 80.4%

Problems with R&D establishment

- not enough expertees	41.7%
- not enough equipment	27.0%
- not enough knowledge	25.2%
- other	6.1%

2.High Tech Thai House

The High Tech Thai House, powered by solar energy, is a prototype project received by the Invention Unit from Thai Gypsum Products Company,Ltd. It was displayed at WORLDTECH'95 Thailand. The house design considered the environment, used high quality material, saved energy and insulated from heat, as well as brought energy of the sun into daily home use. There was also a water restoration system using natural methods and large numbers of fish.

To adapt, transfer, and develop technology, SUT has a cooperative research project with the private sector to develop the High Tech Thai House further by testing various system such as agricultural systems, water purifying systems, and energy conservation, eventually to form an "Eco-Village" consisting of such houses. Upon completion, this project will be the prototype of environmental care, using resources suitably, and improving the quality of agricultural personel.

3. Butterfly Park

The Butterfly Park is a project to instill into the public consciousness the values of nature conservation and appreciation, along the line of the plant and wild animal preservation used by Her Majesty the Queen. The Butterfly Park provides scientific knowledge about insects, biology, ecology, habits, agricultural and environmental impact, etc.,through exhibitions, creating natural aestheics, as well as providing a place for recreation.

The Butterfly Park is a large netted park in Surapat 6 building. Within the park are waterfalls, brooks, flowering plants, plant species, and plants which are food for the insects, with diverse kinds of butterflies.

4. The National Synchrotron Light Source Research Laboratory Center

The Synchrotron Light Source Generator is a high level instrument of technology useful in research in the fields of Physical Sciences, Material Sciences, Biological Sciences, Medicine and Industry, especially in the production of very small parts and telecommunications components. Industrially development countries such as the United States of America, Japan, South Korea, and China all use the Synchrotron Light Source Generator to support research impacting industrial development. As Thailand does not yet have such a Synchrotron Light Source Generator, the National Research Council appointed a committee of academics to perform a study involving Synchrotron feasibility and suitability for national research. As the study concluded that it was necessary for Thailand to have a synchrotron light source, the National Research Council Office was in the process of drafting a proposal to government showing details for the construction of a syncrotron light source, when it received news from scientists in Japan that the SORTEC Corporation and Japan, Ministry of Industries and Commerce were interested in giving a medium sized synchrotron light source generator (1 GeV in size) to Thailand, since the Corparation had finished their research projects by the end of 1996. A Group of Thai academics traveled to inspect the condition of the generator, and after careful analysis concluded that it was in excellent condition, with no less than twenty years of use remaining. Receiving the generator would save time and national resources, for building one from scratch take about 5 years and about 4,500 million baht

Since the Synchrotron light Source Generator is a high caliber instrument, and perhaps in the beginning, too advanced for the used of any one unit, the Prime Ministerial Cabinet Meeting on 5 March 1996 resolved to establish the "National Synchrotron light source Research Laboratory Center" under the supervision of the Ministry of Science, Technology, and the Environment, using an administrative system free from the civil service, with a Center Administrative Board to supervise. The Center will be located at Surapat 2, Technopolis, SUT, Nakhon Ratchasima Province, a technological university with a basic structure amenable to the support of the installation of the synchrotron light source generator as well as the operation of the National Synchrotron light Source Research Laboratory Center. Installation is expected to be completed and the Center open for operations in 1998.

The Synchrotron light source generator will be a national instrument, used to conduct scientific and technological research in various fields. Moreover in the research of faculty, researchers, graduate student from universities, institutes of higher education, and in industrial research and development projects both public and private will be further established. Thus Thailand has increased potential to be a leader and center of high level technology and research in the Southeast Asia region.

5. Academic Services

- **Organizing conferences/seminars/training session:**

  * ISO 9000 and techniques for quality Improvement

- **University personnel serve as special lecturers and speakers:**

  * Special lecture for science high school teachers
  * Special lecture for science primary school teachers
  * Special lecture for mathamatics high school teachers
  * Special English course for industry
  * Special English course for general

- **Consultation to project /research for outside units:**

  * Conservation of electrical energy for local industries
  * Product development of granite for local industries
  * Iron strength analysis for local industries

TECHNOPOLIS AND OPPORTUNITES

As the results indicated from survey of both government and private sectors problem and their needs assessment, those are correspond to our mission. From the requirement data obtained from government sector, transferring of technology from university is the most wanted item as well as the development of human resources particulary in their units. On the other hand, from industry sectors more technological needs is required rather than government sectors.

Thus, Technopolis has set up four important tools for these requirement and problem from them. First, **technological manpower**, mainly from Institutes (92 doctorate and 45 master's degree level) , center of scientific equipment of SUT (87 staffs) who able to support the technological needs from both biological and physical science as well as social sciences. Second, **science and technology infrastructure**, piece of land, seminar hall ,and building spaces for example with Surapat 1 building serving as the incubation unit and Technopolis administration. Surapat 1 initially can provided 30 small incubator units size ranged from 48 m^2-160 m^2/ unit) from total usable area 7,138 m^2. In addition, High Tech Thai House can be the place for innovate new research in term of high quality material for saving energy and insulated from heat, development of solar energy system and various system of agriculture etc. Third, **technological capability,** which mainly served from Scientific and Technological Equipment center and the National Synchrotron Light Source Research Centre in the near future. Fourth, **information technology and knowledge technology**, can be served by SUT's facilities such as satellite communication system, "SUTnet" network of type FDDI with a speed of 100 Mbps. and the subcomponents of the information system which are capable of Intregrated Hypermedia information services, consisting of Hypertext, Electronic mail, Internet, Applications, www, FTP, and two-way Teleconference etc.

Hehce, SUT is located in the area where easily conducted to various countries in Indochaina as well as these four tools as mentioned above togetherwith to construct the linkage between Universities, government and private sectors in local. Thus, rendering, Technopolis aims to make use of these opportunities to create strong production relationships among those concerns to open the gateway for business and development of country and the Indochina region. And further more expand economic and commercial which based upon technological development to international level.

Appendix C

Schedule at Technopolis
Academic Services Plans
1996-97

SCHEDULE OF TECHNOPOLIS ACADEMIC SERVICES PLANS (96-97)

TIME	TOPICS	ORGANIZED BY
NOV 96	1. "SCIENCETIFIC PLANING FOR PRIMARY SCHOOL TEACHER"	TECHNOPOLIS
	2. "AGRICULTURAL EXCURSION" : ADVANCEMENT FOR ECONOMICAL FLOWERS : ADVANCEMENT FOR ECONOMICAL FRUITS	TECHNOPOLIS
DEC 96	1. "AGRICULTURAL SEMINAR ON" : CUT FLOWERS	TECHNOPOLIS
	2. "AGRICULTURAL TRAINNING FOR" : MANAGEMENT TECHNOLOGY OF AGRICULTURAL MARKETING	TECHNOPOLIS
	3. "INDUSTRIAL TRANNING FOR": INTRODUCTION TO PROGRAMMABLE LOGIC CONTROLLERS (PLC)	TECHNOPOLIS - PRIVATE SECTOR
JAN 97	1. "WORKSHOP ON ALGEBARIC ANALYSIS"	TECHNOPOLIS+CIA(SUT)
	2. "ENVIRONMENTAL SEMINAR FOR": NATURAL RESOURCES MANAGEMENT IN THE NORTH-EASTERN PART OF THAILAND	TECHNOPOLIS
	3. "TRANNING FOR EVALUATION TECHNIQUE FOR QUALITY CONTROL IN PROJECT MANAGEMENT	TECHNOPOLIS
FEB 97	1. "AGRICULTURAL SEMINAR ON" : TECHNOLOGY FOR ORCHARDS	TECHNOPOLIS
	2. "AGRICULTURAL TRAINNING FOR" : TECHNOLOGY FOR ECONOMICAL FLOWERS PRODUCTION IN NORTH-EAST	TECHNOPOLIS
MAR 97	1. "INDUSTRIAL EXCURSION": IN TAIWAN	TECHNOPOLIS
	2. "BASIC COMPUTER TRAINNING"	TECHNOPOLIS + SUT - COMP.CENTRE
	3. "TRANNING FOR COMPUTER MAPPING"	TECHNOPOLIS

TIME	TOPICS	ORGANIZED BY
APR 97	1. "AGRICULTURAL SEMINAR ON" : FISHERIES TECHNOLOGY 2. "AGRICULTURAL EXCURSION ON" : ADVANCEMENT OF ECONOMICAL CUT FLOWERS	TECHNOPOLIS
APR- MAY 97	1. "TRAINNING FOR" : INCREASING EFFICIENCY OF LIBRARY WORK WITH INTERNET 2. "TECHNICAL TRANNING FOR" : BALLROOM DANCE FOR HEALTH	TECHNOPOLIS SUT-LIBRARY CENTRE TECHNOPOLIS+ SUT-SPORT CENTRE
APR- JUN 97	1. "SUT MEETS PEOPLE" (LOCAL SEMINAR, TRANNING, LOCAL PRODUCTS CONTEST)	TECHNOPOLIS+SUT -PR DIVISION
MAY 97	SEMINAR ON "MANDATE OF SCIENCETIFIC TEACHER" 1. "AGRICULTURAL TRANNING FOR" : PRODUCTION OFF-SEASON FRUITS	TECHNOPOLIS TECHNOPOLIS
JUN 97	1. "AGRICULTURAL SEMINAR FOR" : AGRICULTURAL MACHINERY	TECHNOPOLIS
JUN- AUG 97	1. "COMPUTER TRANNING PROGRAMMES"	TECHNOPOLIS+SUT- COMP.CENTRE
JUL 97	1. "SCIENCETIFIC PROJECT CONTEST" 2. "TRAINNING FOR COMPUTER MAPPING" 3. "TRAINNING FOR HIGH LEVEL BALLROOM DANCER"	TECHNOPOLIS TECHNOPOLIS TECHNOPOLIS
AUG 97	1. TRAINNING FOR SPORT TRAINNERS	TECHNOPOLIS+SUT- SPORT CENTRE

- All year round projects are as followed:

  A. Services for sciencetific analysis equipments

  B. Survey and study of electrical energy saving in industries

  C. Community English language courses

  D. Fitness test

  E. TECHNOPOLIS Tours

- The projects which have not been indicated the exact time are as followed:

  A. Short-term trainning (CIA-SUT&Vietnam national Univ. and ICEE)

  B. Industry-based seminar (CIA-SUT&CUTC)

  C. "Green conservation" (School of Biology)

Appendix D

Regional Economic Performance
The Northeast

REGIONAL ECONOMIC PERFORMANCE : The Northeast

In 1993, the Northeastern regional economy expanded at a satisfactory rate, somewhat higher than that in the previous year. Price stability, meanwhile, improved, with the inflation rate falling to a very low level. A growth-cum-stability economic situation in this region was in keeping with that of the entire country. Fuelling growth of the economy in the Northeast in 1993 were a number of factors, including principally the following. Manufacturing, construction and local and border trade expanded, while private sector investment recovered, thanks largely to the government policy of strongly promoting investment in zone 3. Consumption was, meanwhile, on the uptrend, driven by an increased purchasing power. Nonetheless, the 1993 pace of economic expansion failed to match that in the late eighties, having been reined in by a slowdown in the rate of growth of agriculture, which was affected by drought.

The Research Department, Bangkok Bank Public Co., Ltd., estimated the growth rate the Northeast's gross regional product (GRP) in 1993 at 6.2-6.5 per cent and the inflation rate at 2.5 per cent.

For 1994, a number of positive factors are at work (some continuing from prior year) to provide the impetus for further growth. Principal ones of these are growth in real estate, construction, personal consumption and border trade; continued recovery of investment; large government expenditure on infrastructure; strengthening prices of farm commodities and world economic recovery. But agriculture in this region continues to face drought, affecting overall economic expansion.

The Research Department expects the rate of increase of the Northeast's GRP to be 6.4-6.7 per cent in 1994. Inflation should hot up slightly, with the consumer price index (CPI) for the region advancing by an estimated 3.0-3.2 per cent.

Agriculture

This sector is the backbone of the Northeast's economy, accounting for an estimated 30 per cent of this region's GRP. Of the figure, production of crops, which are not numerous comprising principally rice, cassava, sugarcane, maize, kenaf and eucalyptus, makes up 20 per cent. The remaining 6 per cent and 4 per cent shares go to fishery and forestry production and simply agricultural processing respectively.

The Northeast grows more glutinous than the ordinary variety, with the ratio between the former and the latter being about 60 to 40 per cent. This region is famous for its jasmin fragrant high quality rice, which falls under the ordinary rice category and which constitutes a popular export item, commanding a high price. In 1993/94, rice cultivation was affected by a combination of a dry spell at the start of the planting season and the general low rainfall of this particular region. As a result, paddy output dropped 30 per cent to about 7.2 million tons. However, farmers were partially compensated, as they could fetch higher prices due to a 1.87 per cent fall in global paddy production, with China, Japan, South Korea and Taiwan suffering from inclement weather.

In 1992/93, production of cassava in the Northeast amounted 19.8 million tons, a drop of 2.7 per cent from 1991/92 and an equivalent of about 90 per cent of the country's total production of the crop. The price fetched by farmers averaged Baht 0.62 per kilogramme, down 7 per cent, due to

Key Economic Indicators of the Northeast

	1988	1989	1990	1991	1992	1993	1994
Regional economic growth (%)	11.9	8.1	6.7	6.4	5.7	6.3*	6.6*
Agriculture (%)	15.0	8.9	3.5	3.2	2.8	2.7*	2.8*
Non-agriculture (%)	10.6	7.7	8.1	7.8	7.2	7.7*	8.1*
Change in CPI (%)	3.9	3.1	4.4	5.8	6.6	2.5*	3.1*
Border trade with Laos (million baht)	1,896.9	2,872.2	2,976.0	3,496.3	3,982.5	5,897.8*	8,610.8*
- Exports	1,287.3	1,673.1	1,563.3	1,902.9	2,837.9	4,313.6*	6,642.9*
- Imports	609.6	1,199.1	1,412.7	1,593.4	1,144.6	1,584.2*	1,967.9*
Change in bank deposits (%)	13.5	19.0	24.7	18.1	21.9	19.0**	-
Change in bank credits (%)	25.6	25.6	25.7	16.4	23.0	29.2**	-
Change in credits for:							
- Personal consumption (%)	45.4	41.5	22.9	16.0	25.4	35.4**	-
- Construction (%)	18.0	9.2	33.4	14.1	21.2	49.0**	-
- Real estate business	3 0.2	48.3	44.6	-2.1	31.8	74.1**	-

Source: Bank of Thailand Northeastern Branch
** Estimated by the Research Department, Bangkok Bank Public Company Limited*
*** Jan.-Nov.*

the impact from the European Union's (EU's) agricultural reform policy implemented since July 1, 1993 and limited domestic usage of cassava. For 1993/94, cassava output of cassava in the Northeast is projected to stagnate at 19.8 million tons. Planted areas are expected to shrink somewhat on account of unattractive prices, which are weakened by exporters' refraining from buying the crop ahead of time. Thailand's exports of tapioca products, particularly pellets, are expected to continue to decline in the wake of a weakened demand in the EU market, where prices of animal feed fall leading to a drop in the use of tapioca pellets as a substitutes for other feed items. Moreover, the remaining amount of the quota for tapioca exports to the EU is only 4.3 million tons. However, exports of tapioca flour is foreseen to tend upwards on the heels of decreased competition from Indonesia, with principal markets being Taiwan, Japan and Hong Kong.

Area under sugarcane and output in the Northeast expanded, thanks to the relocating of a number of sugar mills from the Central Region where land is increasingly expensive and the supply of labour for cane cutting is unsufficient. It is expected that sugarcane will be planted more and more in the Northeast as a substitute for cassava, maize and kenaf. (Other crops also gaining in popularity include mulberry, eucalyptus and rubber, while those, the importance of which is on the wane, are cassava, kenaf, cotton and cashew nuts.)

Agro-industries in the Northeast with bright prospects are ready-to-drink milk and modified starch (made from cassava). The former has lately been growing, on an average, by 20 per cent annually. This has been thanks largely to the country's economic expansion, the successful official campaign to promote milk consumption and increased popularity of milk as a nutritious food item among the puplic. Principal types of ready-to-drink milk are pasteurized milk, sterilized milk, UHT milk and yogurts. Currently, sixty-odd ready-to-drink milk factories are operative throughout the country, the majority of them being located in Nakhon Ratchasima (in the Northeast), Saraburi and Ratchaburi, where the bulk of raw fresh milk is produced. Dairy farms in the Northeast account for 20-30 per cent of the country's total production of ready-to-drink milk, totalling 392,163 tons in 1993. Practically all of the ready-to-drink milk produced in the country is earmarked for domestic consumption, due mainly to the fact that Thailand's production costs of fresh milk are relatively high and domestic demand for dairy products is firm. The local market for ready-to-drink milk is worth about Baht 5,600 million a year, growing at an estimated 13-14 per cent annually. Of the market, UHT milk corners the largest share, followed by pasteurized and sterilized milk.

In regards to modified starch, which is a product made from cassava, a total of about 10 manufacturers with Board of Investment promotion are now operative in the country. Their combined production capacity totals roughly 300,000 tons per annum. Locally made modified starch consists of two grades, one being suitable for use as a feedstock for production of manufactured products, such as, textiles, paper, cosmetics, drugs, forged metals and mining, the other being processed into a raw material for a variety of food product industries. Both local and overseas demand for modified starch has been growing steadily and currently exceeds supply forthcoming from local factories. Thus, prospects for investment in this industry is promising and will help solve the problem of excess cassava production. Exports of modified starch amounted to 318,562 tons, worth Baht 1,840.4 million in 1992, compared to 295,140 tons, worth Baht 1,787.4 million in prior year, up 7.9 per cent and 3.0 per cent. In 1993, these exports are estimated at 200,000 tons, worth Baht 1,100.0 million. Principal markets are Japan, the USA, Australia, the Netherlands and Taiwan.

Manufacturing

The manufacturing sector contributes an estimated 9 per cent to the Northeast's GRP. Investment in industries in this region expanded satisfactorily in 1993, due mainly to the government's policy of giving high priority to the distribution of progress to the outlying provinces.

Industries that continued to grow well in 1993 included certain agro-industries and labour-intensive industries. The latter consisted of factories relocated to this region to take advantage of its abundant, inexpensive, easily trainable and reasonably disciplined labour. These are, for instance, garments, artificial flowers, fishing nets and seines. The former, meanwhile, make use of locally available raw materials to produce goods for both the local and overseas markets, with emphasis being placed increasingly on the latter. These include paper pulp, animal feed, silk canned vegetables and fruit and sugar. Concerning the last-mentioned, two large sugar mills were relocated from the Central Region to Nakhon Ratchasima in the Northeast. This has considerably increased output of sugar in this region and has helped promote sugarcane cultivation in the areas surrounding the factories.

Garments

Garment manufacture in the Northeast used to be a cottage industry, run by family members and supplying the local market. It has, however, expanded rapidly in the past few years, driven particularly by the relocation of the production base by entrepreneurs mainly from the capital area to this region. In the process, many garment factories have been established, with the highest concentration in Nakhon Ratchasima, followed by Udon Thani, Ubon Ratchathani, Maha Sarakham, Khon Kaen, Kalasin and Nong Khai. The vast majority of them are small and medium-sized concerns, with relatively low technology and very labour-intensive. They are, for the most part, subcontractors, taking orders from large-sized manufacturers in the capital area, who usually supply them with the raw materials needed. Important items produced in the Northeast are, for instance, sports wear, jeans and knitted shirts and blouses. They are destined either for local or overseas consumption, with however the actual marketing of the finished left in the hands of the large-sized firms in the capital area.

At end-1992, garment factories in the Northeast numbered 58, with a total investment of Baht 439.63 million and a combined workforce of 6,423. In the first half of 1993, roughly another 20 factories were set up, being located in Udon Thani, Nakhon Ratchasima and Ubon Ratchathani. The mushrooming of garment factories in the Northeast has lately been thanks to the fact that the Board of Investment no longer requires that garment production be totally export-oriented to qualify for its promotion given to a garment maker in the provinces. Moreover, Japanese and Taiwanese investors have been attracted by low labour costs and a trainable and sufficiently disciplined workforce to invest in garment manufacture in especially the Suranari Industrial Estate in Nakhon Ratchasima.

Promotion of Investment by Industry

	1992			1993 (Jan.-Sept.)		
	No. of factories	Invest-ment	Employ-ment	No. of factories	Invest-ment	Employ-ment
Garments	6	128.3	1,875	4	64.1	2,440
Canned food	2	52.7	332	-	-	-
Footwear	-	-	-	-	-	-
Sports equipment	-	-	-	1	130	75
Electronic products	2	239.5	1,570	2	20.0	238
Gems and jewellery	1	45.0	752	-	-	-
Toys	2	30.0	378	1	40.0	396
Spinning and weaving	-	-	-	4	332.3	1,409
Spare parts	2	352.2	359	5	406.8	406
Machinery	-	-	-	2	42.0	278
Glass and ceramic products	-	-	-	-	-	-
Plastic products	1	101.7	280	5	502.3	1,429
Leather products	1	15.0	118	1	40.0	418
Chemical products	1	89.0	104	-	-	-
Animal products	2	10.0	66	1	120.0	97
Agricultural products	2	388.8	286	5	355.7	271
Mining	1	7,514	1,260	5	461.5	611
Paper products	-	-	-	-	-	-
Wood products	-	-	-	-	-	-
Watches and clocks	-	-	-	-	-	-
Hotels and resorts	1	55.0	41	4	693.0	382
Hospitals	2	200.0	324	2	550.0	1,209
Others	2	2003.4	169	9	741.3	831
Total	20	11,254.3	7,914	49	4,107.7	10,490

Source: Board of Investment

From a survey, it was found that garment producers in Nakhon Ratchasima utilized only about a third of their total capacity in 1993, manufacturing only about 3,000 dozens per month. This was due mainly slackened world trade on account economic slowdown in major markets, namely the USA, the EU and Japan. Moreover, competition intensified further by increased sales of low-cost countries like China, Indonesia, Bangladesh and Vietnam. However, it is expected that production in Nakhon Ratchasima will rise to about 6,000 dozens a month in 1994, with prices strengthening and exports tending upwards, as importers' stocks were drawn down substantially in 1993.

Future prospects appear reasonably bright for the garment industry in the Northeast, which should as a base for export-oriented production for many more years to come. As it has turned out, certain garment makers in the Northeast, who moved to Laos, being attracted by the US GSP privileges given to that country, have encountered many grave problems particularly a lack of certain and clear-cut regulations and procedures and high transportation costs. In the meantime, the Northeast has a large supply of labour and the government has been active in training and enhancing the skills of workers in this region. The BOI is giving very generous incentives to investment in zone 3, which takes in all of the Northeast, and grants promotional privileges to R & D on garment manufacture. The garment has a policy of promoting sub-contracting by factories as well as households in the provinces. All these factors should help ensure a continued bright future of garment manufacture in the Northeast.

Industrial estates

Unfortunately, despite the decision of the Chatichai government set up 5 industrial estates in Nakhon Ratchasima, Khon Kaen, Udon Thani, Nong Khai and Ubon Ratchathani, the Northeast is still not in possession of any industrial estate operated by the public sector. However, the private sector has launched a number of projects to set up industrial estates as follows.

Suranari Industrial Estate. Located in Nakhon Ratchasima, this industrial estate has recorded the most progress. Its location is highly appropriate, as Nakhon Ratchasima serves as the gateway to the Northeast and is well linked up with Bangkok and the Eastern Seaboard through a well developed highway system. The Suranari Industrial Estate has been granted Board of Investment (BOI) promotional privileges and is situated in investment zone 3, which enjoys the most generous promotional privileges from the BOI. It encompasses a total of 2,800 rai. The first portion amounting to 530 rai has been developed and sold to investors. Application has been made to the BOI for its promotion for another 1,500 rai. Currently, a total of 31 factories have been approved for operations in this industrial estate, involving a combined investment of Baht 1.5 billion and hiring a total workforce of 5,000. Investment in the factories in this industrial estate has been mostly by Thais, who have relocated their production bases from Bangkok to this Northeastern province. There is also a number of foreign investors, the most numerous being Taiwanese, followed Americans, Japanese and Pakistanis. Topping the list of industries established there is agro-processing, followed by engineering industry, computers and parts, metals, plastics, carpets (for cars), household textiles and sports equipment. Most of the industries are small-sized, with investment ranging from Baht 10 to 60 million.

Udon Thani Industrial Estate. This is the first industrial estate project to be implemented by the private sector in the Upper Northeast. Udon Thani has the advantage of being a major urban centre in the Northeast. It also borders on Nong Khai, which is located on the Mekong River opposite Vientiane, the capital of Laos. A total of 2,000 rai has been set aside for the project. Currently, development of utilities to serve this industrial estate is in progress, with about 80 per cent of the work having been undertaken. It is expected that utility development will be fully carried out by mid-1994.

Needless to say, the establishment of both private and public sector industrial estates in the Northeast should be given high priority by the government, as this region has abundant labour with a high degree of stamina, relatively inexpensive and easily tramable. Moreover, the Northeast possesses considerably potential of being a gateway to Indochina and perhaps also South China.

Investment

Investment in the Northeast, all of which lies in investment zone 3, picked up perceptibly since April

1, the date on which the government zone 3 promotional measure became effective. According to BOI statistics, in the first three quarters of 1993, applications for promotional privileges for projects in the Northeast numbered 110, proposing to invest Baht 11.7 billion, increases of 3.6 times and 1.3 times over the same period of prior year. Roughly half of these projects are in Nakhon Ratchasima. During this period, 49 projects were approved for promotion, up 1.3 times, with a combined investment of Baht 4.11 billion, up 1.8 times, and a combined workforce of 10,559, up 80 per cent. The majority of these projects were medium-sized. Topping the list were projects to manufacture garments, followed by agro-industrial projects and those to make machinery and parts. Twenty-nine were proposed to be set up in Nakhon Ratchasima, nine in Khon Kaen with the remainder being distributed among several other provinces.

An interview with businessmen in the Northeast revealed that there was still considerably potential for growth in investment there, particularly in medium and small-sized industries. There is strong likelihood that industries will be set up to do sub-contracting work, especially for major manufacturers in the Capital area. Many local entrepreneurs are expected to enter joint-ventures with big-time Thai investors and foreign investors. It is also expected that the Northeast will be as a base for production of goods earmarked for Indochina.

Construction

Public and private sector construction in this region expanded briskly in the first seven months of 1993. Municipal areas given permission to construct totalled 86,731 sq.m., an increase of 22.7 per cent over the same period of prior year. Areas given permission to build homes and commercial buildings grew at relatively faster rates of 28.6 per cent and 34.4 per cent respectively. This was due to strong demand for low and medium-price housing facilities and stepped up construction of commercial buildings in keeping with high economic growth. By province, Chaiyaphum topped the rest with the highest percentage growth in the areas given construction permits, followed by Sakon Nakhon and Roi Et. On the public sector front, construction to lay down infrastructure is being undertaken in many parts of the region, for instance, expansion of highway construction in Khon Kaen province.

The real estate business expanded satisfactorily. In the first half of 1993, land transacted in this province was worth Baht 7,675 million, more than doubling

Investment Indicators

	1991	%+-	1992	%+-	1993	%+-
Private sector investment						
No. of new plants	554	-17.8	138	-75.1	n.a.	n.a.
Expansion	100	35.1	55	-45.0	n.a.	n.a.
Construction area (1,000 sq.ms.)	105.7	-10.6	128.1	21.2	86.7 1/	22.7
Investment promotion						
No. of applications	63	-24.1	38	-39.7	110 2/	358
Investment (billion baht)	10	-10.7	8.2	-18.0	11.69 2/	132
Applications approved	65	22.6	31	-52.31	49 2/	178
Investment (billion baht)	8.5	23.5	11.5	35.29	4.11 2/	-63
Promotion certificate granted	31	-25.0	26	-16.13	27 2/	35
Investment (billion baht)	3.2	-65.6	3.3	0.31	1.93 2/	-36
Firms starting operations	9	125.0	17	88.89	8 2/	-27
Investment (billion baht)	0.9	50.0	1.6	77.78	0.44 2/	-41
Commercial bank credits (million baht)						
Manufacturing	14,941.2	11.19	17,530.7	17.33	9,512.9 3/	21.94
Construction	4,359.5	14.36	5,284.0	21.10	6,692.5 3/	33.32
Real estate business	1,482.3	-1.98	1,953.9	35.71	3,223.5 3/	86.97

Source: Bank of Thailand Northeastern Branch

1. Jan.-Jul.
2. Jan.-Sept.
3. Jan.-Aug.

that in the same period in prior year, and the number of transactions was 4,627, an increase of 42.2 per cent. The province with the highest transaction value was Nakhon Ratchasima, followed by Khon Kaen, Surin and Buriram. Credits granted to real estate-related businesses in the Northeast rose by as steeply as 86.9 per cent, with Nakhon Ratchasima being provinces with the highest amounts of this type of credit.

Factors fuelling growth in the real estate business included strong housing demand and land speculation on the expectation that the Northeast will become a gateway to Indochina.

Consumption

Consumption expenditure particularly in urban centres in this region expanded at a rather high rate. This was thanks to continued economic expansion, which became more evident in 1993. The situation is reflected particularly by the fact that in the first eleven months of 1993 commercial bank credits for consumption purposes grew by slighly over 35 per cent over the corresponding period in prior year. Another factor driving consumption was the sales promotional compaigns by department stores and shopping centres, which have mushroomed throughout the region. Remittances by overseas workers moreover put more money in the pockets of consumers, who spent more as a consequence.

In 1994, it is expected that consumption expenditure in the Northeast will continue on the uptrend as the positive factors will continue to be at play. In addition, the value of agricultural production in this region will rebound in 1994.

Car sales

The car market in the Northeast is the Kingdom's second largest after Bangkok, with car sales in this region accounting for roughly 15 per cent of the country's total. Pick-up trucks dominate the market, with a ratio between their sales and those of passenger cars being roughly 85:15 per cent. In 1993, car sales rose by about 17 per cent on the back of overall economic growth, expansion of commerce and border trade and strengthened purchasing power of those who had become suddenly wealthy due to their sales of real estate especially land.

Broken down, sales of commercial vehicles in 1993 rose 15 per cent, a slight drop from the rate of increase in 1992. This was due largely to weak prices of cassava and affected crop production in drought stricken areas. Moreover, the market for large trucks and buses had become saturated, due to a sharp rise in their sales in 1990-1992.

In contrast, sales of passenger cars soared by about 40 per cent. This was thanks to strong demand by consumers in the non-agricultural sector. Furthermore, distributors waged strong campaigns to promote car sales, which proved very enticing and effective. Hire-purchases accounted for an estimated 60 per cent of passenger car sales, 70 per cent of the sales of pick-ups and 85-90 per cent of the sales of large trucks and buses.

It is expected that a similar pattern of car sales will prevail in 1994, i.e., a smaller growth in sales of commercial vehicles compared to that in sales of passenger cars. This is due to the fact that a similar set of factors remains to affect the car market in 1994.

Tourism

In 1993, tourism in the Northeast was much affected by the collapse of a hotel building in Nakhon Ratchasima. The building mishap, which occurred in August, nudged the tourism sector into the doldrums in the three subsequent months. This, it is estimated that visitors to the six major tourism provinces (namely, Nakhon Ratchasima, Khon Kaen, Udon Thani, Ubon Ratchathani, Buriram and Nakhon Phanom) in 1993 numbered 4,651.5 thousand, up 3.7 per cent on 4,486.4 thousand in the preceding year. Of the total, 97.5 per cent or 4,535.0 thousand were Thais and the remaining 2.5 per cent or 116.5 thousand foreigners. Most popular provinces were, in order of importance, Nakhon Ratchasima (with a 33.1 per cent share), Khon Kaen (21.7 per cent), Udon Thani (18.3 per cent), Ubon Ratchathani (14.8 per cent), Buriram (6.3 per cent) and Nakhon Phanom (5.8 per cent). Hotel occupancy was satisfactory, averaging 70-90 per cent.

In terms of spending in 1992, Udon Thani and Ubon Ratchathani, with their numerous entertainment places, headed the list, recording an average tourist expenditure of Baht 897.51 and Baht 886.26 per person per day, followed by Khon Kaen (Baht 816.15), Nakhon Ratchasima (Baht 797.89), Nakhon Phanom (Baht 711.32) and Buriram (Baht 443.05). For 1993, the average tourist expenditure is estimated to increase by about 20 per cent. The average tourist spending is kept low by the fact that many Thai vacationers stay in the homes of their relatives while sojourning in the region.

It is expected that the number of tourists visiting the Northeast will rise by 6.1 per cent in 1994. Future prospects for tourism in the North-east are promising as the region holds considerable potential as the gateway to Indochina. Moreover, its transportation and telecommunication systems are pretty well developed.

Thai-Lao trade

Total bilateral Thai-Lao trade, comprising border trade and tran-shipments from third countries through Thailand to Laos, should exceed the milestone Baht 10 billion for the first time in 1996. Available statistics show that in the first eight months of 1996, the total bilateral trade grew dramatically by 52.1 per cent over the same period of prior year to Baht 6,980.7 million. Of the amount, border trade accounted for Baht 3,576.4 million, up 41.8 per cent, and tran-shipments through Thailand to Laos another Baht 3,404.3 million, up 64.8 per cent.

Border trade between Thailand and Laos is being undertaken through six check points, namely those at Nong Khai, Mukdahan, Nakhon Phanom, Phiboonmungsaharn and Khemmarat in Ubon Ratchathani and Loey. Of these, Nong Khai is the most important, with the lion's share or 63 per cent of total border trade, followed by Mukdahan with an 18 per cent share. Major export goods in the Thai-Lao border trade include cars, motorcycles and parts and electrical appliances. Rice, which used to be a leading Thai export to Laos, has lately declined in importance, with Laos becoming more self-sufficient in the staple. Capital goods and raw materials accounted for 14.4 per cent and 2.6 per cent of exports to Laos. In particular, construction materials shipped to Laos have grown satisfactorily, with Laos expanding its utilities and enjoying brisk economic expansion. On the import front, sawn wood is the most important import commodity from Laos, making up 90.1 per cent of imports from that country, and metal scrap. making up another 1.3 per cent.

In regards to goods in transit through Thailand to Laos, machinery and parts account for a major portion, originating from Singapore, Hong Kong and Japan. They are followed by textiles from Singapore and Hong Kong, and oil products from Singapore. Leading products in transit from Laos through Thailand to third countries and garments to France, Italy, Canada, the USA and Holland and sawn wood to Japan, Hong Kong and Taiwan.

The Structure of Thai-Lao Trade (Jan.-Aug. 93)

	Share (%)	Value (million baht)
Total exports	100	2,518.6
Consumer goods	29.1	732.8
- Rice	0	0.4
- Vehicles and parts	6.3	157.7
- Electrical appliances	6.4	161.2
- Others	16.4	413.5
Raw materials	2.6	64.2
Capital goods	14.4	362.3
- Construction materials	8.8	221.3
- Machinery and parts	2.5	63.9
- Others	3.1	77.1
Others	12.1	305.7
Unclassified goods	41.8	1,053.6
Total imports	100	1,057.8
Timber	90.1	953.0
Metal scraps	1.3	13.7
Others	8.6	90.9

Source: Bank of Thailand Northeastern Branch

Thai-Lao Trade

(Million baht)

	1992	+-%	1993e	+-%	1994e	+-%
Border trade	3,982.5	13.9	5,897.8	48.1	8,610.8	46.0
Exports	2,837.9	49.1	4,313.6	52.0	6,642.9	54.0
Imports	1,14.6	-28.2	1,584.2	38.4	1,967.9	24.2
Balance	1,693.3	447.1	2,729.4	61.2	4,675.0	71.2
Goods in transit	3,418.0	18.3	5,800.0	69.7	8,004.0	48.2
From Laos	1,153.3	31.1	2,133.0	85.0	3,071.5	44.0
To Laos	2,264.7	12.8	3,667.0	61.9	4,932.5	34.5
Total	7,400.5	15.9	11,697.8	58.0	16,614.8	42.0

Source: Bank of Thailand Northeastern Branch

e : Estimated by the Research Department, Bangkok Bank Public Company Limited

Throughout 1993, border trade is estimated at Baht 5,897.8 million, up 48.1 per cent. Exports amounted to Baht 4,313.6 million and imports Baht 1,584.2 million, with the surplus being Baht 2,729.4 million in Thailand's favour.

In 1994, prospects for growth in Thai-Lao bilateral trade are promising, as the Thai-Lao Friendship Bridge are open to traffic further facilitating trade between the two countries. It is expected that the bilateral trade will total Baht 16,614.8 million, up 42 per cent. Of the figure, border trade amounts to an estimated Baht 8,610.8 million and transhipments of goods through Thailand another Baht 8,004 million.

Banking and finance

Deposits outstanding at end-August 1993 at commercial banks and the Government Savings in the Northeast amounted to Baht 143,865.4 million, an increase of 18.7 per cent or Baht 22,680.2 million over end-August 1992. Commercial banks accounted for 91.2 per cent or Baht 131,216.7 million and the Government Savings Bank the remaining 8.8 per cent or Baht 12,648.7 million.

At end-August 1993, commercial bank branches in this region numbered 402 (of which 23 were sub-branches), an increase of 17 branches. A total of 132 ATMs were installed, up 16 machines. Deposits at commercial banks in the Northeast rose 19.8 per cent, compared to 21.8 per cent in prior year and the country's average growth figure of 17.7 per cent. Nakhon Ratchasima, Khon Kaen, Udon Thani and Ubon Ratchathani topped the list as the provinces with the largest amount of deposits, with shares of respectively 21.3 per cent, 15.1 per cent, 12.1 per cent and 9.8 per cent.

At end-August 1993, the Government Savings Bank operated 122 branches in the Northeast, up 6 branches. Its outstanding deposits stood at Baht 12,648.8 million, up 8.1 per cent.

Outstanding credits at commercial banks and the Bank for Agriculture and Agricultural Cooperatives in the Northeast totalled Baht 148,682.1 million, an increase of 32.3 per cent or Baht 36,268.3 million over end-August 1992. Commercial banks accounted for 82.2 per cent of the total and the Bank for Agriculture and Agricultural Cooperatives the remaining 17.8 per cent.

Commercial bank credits in the Northeast rose 30.7 per cent to Baht 122,193.2 million at end-August 1993, compared to 18.2 per cent in prior year and the country's average figure of 21.1 per cent. Similarly, Nakhon Ratchasima, Khon Kaen, Udon Thani and Ubon Ratchathani were provinces with the largest amount of credits, boasting percentage share figures of respectively 20.2 per cent, 16.6 per cent, 11.8 per cent and 9.8 per cent.

At end-August, the Bank for Agriculture and Agricultural Cooperatives' outstanding credits amounted to Baht 21,848.3 million, up 41.6 per cent.

At end-1993, the number of securities trading offices in the Northeast was 33, up 7 over prior year. Securities turnover at these offices amounted to Baht 37,198.4 million, down 10.6 per cent.

APPENDIX G

ACTIVITY A 4.32
PRC MEETING, HALIFAX, APRIL 1997 - MINUTES

THAI-HRD CUTC-SUT PROJECT
Fourth PRC Meeting, April 3, 4, 1997
Dalhousie University Polytechnic (formerly TUNS)
MINUTES

CUTC: Dr. Stalin Boctor, Ms.Mary Jane Curtis, Dr. Gerry Schneider, Dr. Feridun Hamdullahpur, Dr. William Caley, Mr. Robert Eagle, Dr. James Shute

SUT: Dr. Tavee Lertpanyavit, Dr. Pongchan Na-Lampang, Ms Mantana Thammachoti

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1. Welcome, Introductory Remarks

Bill Caley welcomed SUT partners. Dr. Tavee thanked hosts and hoped for fruitful discussions.

2. Selection of Chair for the Fourth PRC Meeting

Motion: Bill Caley and Dr. Tavee as co-chairs. Moved by Stalin. Seconded by J. Shute. Carried.

Approval of agenda: Dr. Tavee noted additional items for #8 from SUT.
R. Eagle - spelling correction to INNOVACorp

3. Review and Approval of Third PRC and Mini-PRC Meetings' Minutes (September 1996, University of Waterloo and Thailand, February 1997)

- correction A2.26, under action Prof. Virul
Motion to approve minutes of PRC Meeting, September 26-27. Moved by: J. Shute; Seconded by: F. Hamdullahpur. Carried.

Motion to approve Mini-PRC Feb'97: Moved by: J. Shute seconded by: S. Boctor. carried
- spelling correction to DeMan, and *'Al'* Taweel

Review of completed/ongoing activities since the 3rd PRC meeting:

a) *A 2.11: CUTC representatives' contribution to the S.E. Asia Deans of Engineering Conference at SUT, February 1997/Mini-PRC report*

Stalin summarized activities since October 97:
- Eng. Conference Feb'97 + Mini PRC
- IUP Program: third trimester cancelled, 4 teaching assignments in EE cancelled.

The above assignments were approved in 3rd PRC and are now cancelled.
- R. Eagle requested discussion and review of the Mini-PRC February to clarify what happended at SUT from the 3rd PRC leading to the cancellation of a number of key project activities. Dr. Tavee explained that SUT did not retain sufficient numbers of students in the IUP Program in the third trimester for its continuation. Because Ponsiri is staying in Canada, there is no need for her Canadian Supervisor to come to Thailand. Graduate students and Post-Doctoral programs will continue as planned. Budget constraints at SUT - government has made general cutbacks; a 15% cutback was made for the current fiscal year ; Dr. Tavee hopes that in the next year the financial situation will improve.

b) *A2.12: IUP Electrical Engineering, Prof. P. Barta's assignment, and status of the remaining students. Availability of study program at Ryerson and transferability of eligible students.*

- 2 SUT students have requested transfer to Ryerson (Mr. Gal Samanmoo, Ms. Oei Chantarasombat). Stalin made enquires about available courses in Summer'97. English Dept. at Ryerson running intensive English courses commencing June'97 June 23-Aug 14'97 Condensed program 9 am-3 pm and an evening program in Oral Communication from 6:30 pm-9:30 pm. Other make up courses will be offered in Fall'97 (language, liberal arts, 2nd yr. math). By January 1998 students will be enrolled in regular stream program, 2nd semester. Require official transcripts (after conclusion of second trimester) and other documentation from SUT as soon as possible in order to enrol students in Summer'97 programs. SUT students also must obtain visa and medical clearance. Robert Eagle noted that there are changes soon to be made to the system which will shorten the visa/medical clearance.

c) *A 2.21: Selection of Ph.D. candidates. Status of present and expected candidates at TUNS. Activity Completed*

Status report from F. Hamdullahpur: 3 students currently registered (Ms. Pornsiri Jongkol, Mr. Anand Unsivilai, Ms. Kanthima Polprasert) 4th candidate will arrive in September 1997, Mr. Rangsan Wongsan, Electrical Engineering. Dr.

Chongchin requested another candidate in environmental engineering (TBA) but no fellowships received to date. Post Doctoral fellow Dr. Chongchin and all Ph.D. candidates are making excellent progress.

d) *A 2.25: Two-term assignments in Environmental Engineering started January 1997 at TUNS. One single-term assignment in Biology started February 1997 at Guelph. One term Assignment in Transportation Engineering will start in June 1997 at TUNS.*

2 started: one at TUNS- environmental engineering, in January'97. (Dr. Chongchin Polprasert). Dr. Sureelak Rodthong started at Guelph in February, 1 at TUNS in Transportation Engineering: start date has been revised and confirmed to June '97. (Dr. Somprasong Sattayamully)

e) *A 2.31: Co-op work placements. Canadian students completed 5 assignments, one on-going and three assignments (1 TUNS, 2 Guelph) to start in April/May 1997. Thai students completed 4 assignments, two on-going at TUNS and two to start in May at Guelph, thus completing the program.*

Canadian Co-op students:
- five completed as of December. One ongoing from Guelph. 3 more assignments - 2 Guelph, 1 TUNS commencing May. Total 9 Co-op (Canadian) students to Thailand. Activity will be completed.

Thai Co-op students:
4 completed, 2 at TUNS, 2 expected at Guelph TBA
A total of 8 Thai students to Canada when program completed

5. *Status of the planned project activities:*

A 2.12: Cancellation of the third trimester of the IUP Electrical Engineering, and the four Canadian professors' assignments planned for June 1997.
- Status of the two assignments in "Food Technology" planned for September 1997;
- Latest developments regarding the new IUP student intake for June 1997;
- Cancellation of the three Canadian Consultants' assignments at SUT to develop post-graduate degree programs in Engineering, planned for June 1997.

4 Cdn. professors planned for June, cancelled due to lack of students; 2 prof. from Guelph (DeMan, Goff) contracts were left at Mini-PRC Feb'97 for SUT to sign. Dr. Tavee will have the contracts signed (informally approved by Dr. Terd) and returned to Ryerson. Guelph conducting briefing and orientation for Co-op students and professor Goff and wife.

IUP intake: Program may not run if less than 30 students/program are registered. Need to wait until end of April to determine status of each programs SUT has created a Task Force to promote program. Stalin enquired about what CUTC could do to assist. SUT want 30 students each in Mechanical, Electrical, Chemical and Food Technology programs. Tutition structure compared with Thammasat: SUT slightly more expensive.

Stalin asked what the status is at SUT to plan graduate programming. Some engineering post-graduate programs have been postponed for one year. The graduate Program in Chemical Engineering will start next year, June 1998. Stalin proposed a one or two week workshop at SUT, by CUTC professors, to discussion planning and administration of graduate programs in engineering.

A 2.23: Ph.D collaboration: Assignment for Professor Al Taweel regarding the Chemical Engineering Ph.D. candidate, to be determined.

Planned activity :
Prof. Al Taweel will travel to SUT in October 1997. (to be confirmed)
(Co-supervisors: Dr. Kasem and Dr. Chaiyot)

A 3.23: Plans for the proposed new additional Industrial Seminars requested by SUT in Construction Management (September 1997), Watershed Management and Industrial Safety and Health.

Increased project funding was allocated to support SUT request for this activity. Three consultants to go to SUT. SUT will choose which seminars will be offered. Bill Hart, TUNS is available re: Watershed Mgmt.; Construction Management - maximum 2 persons (Ryerson/Waterloo) but requires more input from SUT (topics, structure, dates etc.) Robert Eagle and Bill Hart will be in touch with Mr. Manu and directly organize the seminar. Construction Management: Robert Eagle will follow through. Topics will be confirmed by SUT. Seminar to be organized by SUT. Project funding will support 3 Canadian participants in total. Activities must be confirmed by December 1997 and completed by March 31, 1998.

6. Project sustainability after the completion of CIDA funding:
- Areas to explore: IUP, Ph.D. and Research collaboration, Industrial Seminars, etc.
- Lessons learned from the project's implementation to date

a) Dr. Tavee stated that the Ministry of University Affairs will support the following in the field of engineering :

- One-term student exchanges for academic credit, fees waiver requested.
- 6 months to one year research assignments: funding for transportation , per diems and living allowance for Thai faculty to Canada

Short term assignments for Canadian professionals to Thailand: The Ministry will support transportation, accommodation and fees for professional services. (lecture/seminars).

b) SUT is interest in exploring other exchanges such as Co-op.

c) IUP Program: Question raised about further exploration of admitting undergraduate Thai students in Canadian universities as this was a focal point in the development of the project. SUT indicated recruiting students is a challenge and CUTC should give students more incentive to come to Canada. The tuition fees, TOEFL level, documentation (visa) and admission requirements for foreign students present some problem. TUNS and other CUTC partners have reduced the level of TOEFL requirement for SUT students to ease the difficulty. Additional English support at no additional cost (tutorials) has been offered by TUNS. SUT faculty at TUNS have shown great improvement in English (written/oral). Students must have English language certification before they can be accepted into programs. A testing method could be instituted at SUT acceptable to the CUTC member institutions, such as CANTEST. CUTC want students to succeed in programs - without acceptable English standards the potential to fail is great and would be damaging to the success of the project.

7. *Status of Project Funding and Budget Review*

A March 27, 1997 budget summary was attached to Agenda package. Stalin Boctor and Sam Mikhail met with ARA to review status of the project budget. Other ARA-administered Thai projects have experienced similar challenges in not being able to deliver on some of the program areas. ARA has agreed to be flexible on the funding allocation. The project can put additional funds towards key activities jointly approved.

Funds remaining after the cancelled activities are approximately $130,000.

8. *Other requested activities and their relationship to the project's goals:*

a) One additional post-doctoral assignment (Dr. Arjuna Chaiyasena, SUT).

This has been approved by *CUTC* ; dates to be confirmed by Dr. Langford/Guelph. Funds can cover a 4 month assignment.

b) Two new assignments in Multimedia (Dr. Krich and Dr. Umaly from SUT)

CUTC cannot approve funding for these activities (Mass Communications and Multi-Media) as they are beyond the scope of the project and do not meet the sustainability objectives.

c) Visit in Nuclear Engineering (Prof. Virul from SUT)

The request was reviewed. Nuclear Eng. is not available within CUTC group. Dr. Tavee would like Prof. Virul to review graduate and teaching lab equipment. CUTC require a more specific proposal. The request is pending.

d) Visit to explore technology transfer and industry outreach
(Dr. Neung and Mr. Manu from Technopolis at SUT)

A 2-week visit can be supported by U. of Waterloo, Guelph and TUNS. Approve 2 assignments: one week at TUNS and a couple of days at each of Waterloo and Guelph. Robert Eagle will prepare the proposed program and sent to SUT.

e) Additional CUTC Proposal:

A three-day workshop in planning/administration of post-graduate programs was proposed. Dr. Tavee wanted as well to address the issue of accreditation/quality assurance and the participation of other universities. Approval was given but the content is to be negotiated with SUT based on proposal from CUTC.
Possible date: November 10-12/97

f) SUT additional requests:
Chair of Mathematics, Dr. Pairote Sattayatham, 2 weeks at Waterloo, Faculty of Mathematics

Pending review by U. of Waterloo, Gerry Schneider. Dr. Boctor will advise Dr. Tavee.

Assistant Rector Academic, Dr. Tasanee Sukosol: 3 weeks at U of Guelph, Depts. of Food Science and Veterinary Microbiology

Pending: Jim Shute will review with Doug Goff. Dates requested: May-June 2-3 weeks
Stalin Boctor to confirm program with Dr. Tavee

9. *Status of proposed visit to SUT by Dr. Claude Lajeunesse, President, Ryerson Polytechnic University, July 1997.*

Date confirmed Thursday, July 24, 1997. Dr. Lajeunesse will give an address at the 7th Anniversary of SUT and attend an evening formal reception. CUTC would like the President to make mention of the CUTC-SUT project and its accomplishments.
Speech topic is open.

10. *Need for 5th PRC meeting in Thailand? If yes, when? (originally proposed for Dec. '97) Agenda items to be included.*

CUTC and SUT confirmed the need for the meeting in order to ensure continuity and sustainability. Dates: January 12-13, 1998 arrival in Korat 11th evening.

11. *Review of the draft of the minutes - 4th PRC meeting*

Dr. Boctor moved to approve the revised draft of the minutes.
Seconded by Robert Eagle. Carried.

12. *Closing Remarks*

Bill Caley thanked the CUTC-SUT group for their contribution to the 4th PRC. Acknowledgement and thanks were given to Mary Jane Curtis for handling the minutes. Dr. Tavee thanked the partners and indicated that SUT would be looking forward to seeing everyone at the 5th PRC meeting to be held at SUT in January, 1998.

CUTC-SUT offered their gratitude and thanks for all the arrangements for the 4th PRC.

13. *Adjournment*