Ten Years Review Report
(1974 - 1984)

Bilateral Collaboration in Biochemical Engineering
between
Indian Institute of Technology, Delhi
and
Swiss Federal Institute of Technology, Zurich

OCTOBER 1984

BIOCHEMICAL ENGINEERING RESEARCH CENTRE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
HAUZ KHAS, NEW DELHI-110016, INDIA

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CONTENTS

		Page No.
Introduction	...	1
Objective	...	2
Plan structure and budget	...	2
Facilities	...	3
Operation	...	9
Exchange of visits	...	10
Fulfilling the objectives		
Education and training	...	11
Research and development	...	24
Transfer of knowledge through symposia, workshops and advanced level courses	...	36
Industrial collaboration	...	41
Continuing and Future Programme	...	44
Conclusion	...	50
Acknowledgement	...	55

INTRODUCTION:

The Indian Institute of Technology, Delhi (IIT-D) and the Swiss Federal Institute of Technology, Zurich (SFIT-Z) are two Federal Institutes of stature and excellence for imparting technological education at advanced academic level. Both the institutions are engaged in education, research and developmental endeavours including industrial collaboration of significance to their countries. A collaboration in biochemical engineering which began in 1974 between the two institutes was possible because in late sixties programmes in applied microbiology and biochemical engineering sciences were already initiated at the SFIT-Z and IITD respectively. The two groups began working on a long term joint collaboration in biochemical engineering since early seventies. Based on the initial negotiations an agreement was signed by the governments of India and Switzerland in September 1974. The programme was initially approved for a period of five years (in two phases), Phase-I (1974-77) and Phase-II (1977-79) for fiscal reasons. The collaboration was further extended for a period of five years (1979-84) on the basis of the Expert Committee recommendations discussed at IV Joint Review Committee meeting in 1978. At the Ninth Annual Joint Review Committee meeting held in June 1983, it was decided to have a consolidated review report on the work done during the entire collaboration period of a decade (1974-84) which should be discussed and considered for further recommendation by the next Joint Review Committee meeting to be held in 1984.

OBJECTIVE:

The principal objective of collaboration was to foster the growth of biochemical engineering sciences in India and Switzerland through

- education and training
- research and development
- symposia, workshop and advanced level courses
- industrial collaboration

PLAN STRUCTURE AND BUDGET:

At the initial period of collaboration the purpose was to meet the requirements of extension and consolidation of post-graduate education in biochemical engineering in India and to achieve rapid progress to bring up the scientific level of the entire programme to the highest international standards. With this in view, a two phased programme was envisaged. In its initial phase (1974-77), rapid development of service facilities and supply of equipment, chemicals and training of some technical supporting cadre were undertaken. A sum of SFr.800,000 was made available for this phase. The second phase of programme (1977-79) was to consolidate and utilize the facilities created in the R&D activities of bioconversion of cellulosic substances into energy, chemicals and microbial proteins and the training of some junior faculty members. A sum of SFr.500,000 was available for utilization in the II Phase. At the IV Joint Review Committee meeting the Swiss Government offer for the Third Phase (1979-84) amounting to SFr.12.5 Lakh with a matching rupee component of Rs.47.9 Lakh was discussed and approved. The facilities and research activities were further consolidated during the third phase. Amounts of funds available and utilized by BERC during the period 1974-79 and 1979-84 are shown in Table-1 and Table-2.

The additional support received from the Department of Science and Technology (subsequently transferred to Department of Non-Conventional Energy Sources) during 1979-84 is also shown in Table-3.

FACILITIES:

During the operation of the programme, substantial experimental facilities were created with Swiss and Indian funds which include the following:

Budget and Expenditure of the Project (1974-84)

	Budget	Expenditure
IIT Delhi (Rs.)	70,00,400	78,62,284
SFIT, Zurich (SFr.)	25,50,000	26,40,181

The rupee expenditure figures do not include sponsored project funds amounting to Rs.19.8 Lacs, and also students scholarships and annual service facilities. The ad-hoc grant of Rs.40 Lacs received from the Ministry of Education is also not included here

Table-1 **Budget and Expenditure (Swiss Funding) in SFr.**

Head	Budget 1974-79	Expen-diture 1974-79	Budget 1979-84	Expenditure 1979-80	1980-81	1981-82	1982-83	1983-84	Total 1979-84
Equipment & supplies	7,60,000	10,36,301	7,00,000	3,34,878	1,89,423	1,95,020*	77,483	1,06,522	9,03,332
Visits from India	4,50,000	1,96,366	5,50,000	6,296	46,177	29,683	-	-	82,156
Visits from Switzerland		1,93,451		11,687	7,100	3,812	3,865	7,089**	33,553
Project Administrative expenses at Zurich				31,025	36,063	41,242	44,396	44,401	1,97,127
Unforeseen	90,000	-	-	-	-	-	-	-	-
Course-cum-Symposium II	-	-	-	-	-	(-)1,706	(-) 399	-	(-)2,105
Total	13,00,000	14,26,118	12,50,000	3,83,886	2,79,763	2,68,051	1,25,350	1,58,012	12,14,063

*includes SFr.35,974 in equivalent rupees as cost of proceedings of 1980 symposium

**This amount is equivalent to two visits while only one visit by Prof. Fiechter was made in 1983

Table-2 Budget and Expenditure (Indian Funding, IIT Delhi) in Rupees

Head	Budget 1974-79	Expenditure 1974-79	Budget 1979-84	Expenditure 1979-84					Total 1979-84
				1979-80	1980-81	1981-82	1982-83	1983-84	
Core facilities									
a) Equipment b) Service units	5,10,000	8,78,000	9,00,000	1,77,400	1,25,692	85,450	66,483	86,262	5,41,287
c) Building	2,15,000	-	2,15,000	-	-	10,05,000	-	-	10,05,000
Faculty, research and support staff salaries*	10,53,800	5,87,000	32,76,600	6,16,000	7,36,841	7,16,986	4,41,560	6,03,130	31,14,517
Operational cost**	4,30,000	6,07,000	6,15,000	2,55,200	2,66,243	2,15,922	1,78,618	2,13,497	11,29,480
Total	22,08,800	20,72,000	47,91,600	10,48,600	11,28,776	20,23,358	6,86,661	9,02,889	57,90,284

* This does not include scholarships of M.Tech and Ph.D. students of the Centre as this pertains to the general head "scholarships" of the institute. The figures (which amounts to approx. Rs.3.0 Lacs per year) are not available separately.

**This does not include the expenditure incurred towards service facilities of the Centre (approx. 1.0 Lac per year)

Note: The expenditure figures do not include Rs.6.02 Lacs spent during 1983-84 out of the Ministry of Education ad-hoc grant of Rs.40 Lacs for the period 1982-85 to strengthen biochemical engineering activities of the Centre.

Table-3 Budget and Expenditure of DNES Sponsored Projects

	Approved Budget (Rs.)	Expenditure (Rs.)				
		1979-80	1980-81	1981-82	1982-83	1983-84
Project-I (1979-85)	6,34,400	27,472	69,381	1,96,060	1,40,284	1,01,578
Project-II (1979-85)	7,38,600	31,127	78,179	2,19,627	1,05,677	68,283
Project-III (1981-84)	4,04,000	-	-	-	35,973	1,80,286

Project-I : Bioconversion of Cellulosic Wastes into Ethanol

Project-II : Microbial Production of Methanol from Methane

Project-III : Bioconversion of Agroresidues for Improved Animal Feed

- Bioreactors (300, 150, 100, 60, 30, 5 and 2 litres) with various monitoring and control system are in operation and can be hooked up with the Institute's recently installed IC 2960 series computer terminal
- Laminar flow chamber
- INGOLD steam sterilizable pH, pO_2 and ion selective electrodes and controllers
- Automatic analysers for gaseous and dissolved components
- Paper, thin layer, column* and HPLC chromatographic systems
- Amicon ultrafiltration systems
- Leitz Universal microscopes with camera attachment
- Vibro energy grinding mill, Wiley mill
- Anaerobic cabinet
- LKB isoelectric focussing column
- Roller culture apparatus
- Pneumatic pulse column reactor
- Peristaltic pumps of various capacities
- Automatic dispensers
- LKB Uvicord fraction collector and analyser systems
- Lyophilizer*
- Orbital incubators
- Visible and UV Spectrophotometers
- Hewlett-Packard 9820 mini-computer with interface, DA converters and X-Y plotter

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*Procured with Indian funding

- Hermes Toptronic 51 Typewriter
- Collection of a large number of useful microbial cultures

(Note : Facilities procured through Indo-French collaboration are not included in the list)

In addition, the Centre has infrastructural facilities like 88 KW diesel generating set, 100 kg/hr steam boiler, automatic steam sterilizers, chilled water supply unit, constant temperature (37°C) and cold room (4°C) facilities, air compressor and modern audio-visual aids, duplicating facilities and mutation unit outfits.

One of the important supports being developed is its documentation unit where current literature in the area of biochemical engineering, biotechnology, bioenergy, bioconversion and genetic engineering are available for the faculty, research staff and students. The unit is maintained by a documentation assistant and it houses about 910 books and 18 titles of periodicals. The unit maintains serial documentation numbers of all publications, reports and reviews emerging from BERC. It also undertakes collation, retrieval of information and exchange of publications with a number of centres around the world, active in the field.

Space:

Total available built-up space in the Centre is 1,525 sq.m. of which 521 sq.m. is air-conditioned.

OPERATION:

A Standing Joint Review Committee composed of representatives from several departments of both the governments and the two project leaders reviews the results of the past year on the basis of approved plans and finalise the programme of the immediate future. Until June 1983 nine meetings were held since October 1975. The project leaders have been responsible for proper and efficient execution of the annually revised programmes on year to year basis. Necessary administrative support to assist in the expeditious approval of the requirements has been provided by both SFIT-Z and IIT-D with annual administrative expenses at the rate of nearly 16% have been debited from the Swiss end. Equipment and consumables including rare chemicals required in the training and research which are not available in India are procured by SFIT-Zurich and delivered to IIT Delhi through normal channels.

The Swiss fund is operated by the Swiss Project Leader himself in accordance with the established accounting procedures of the Federal Institute of Technology, Zurich. This arrangement offered a number of advantages like:

- least involvement by officials and administrators not connected with the project,

- optimal man-hour association in the execution of the programme
- at Delhi end the project funding has been approved and set aside for the entire collaboration period,
- minimum delay occured in the approval and procurement of requirements by BERC, IIT Delhi,
- maximum utilization of the available fund for the training, education, research and development work.

EXCHANGE OF VISITS:

Some IIT-D faculty staff and technicians engaged in Biochemical Engineering and Biotechnology activities have received training at the SFIT-Zurich; Lund University, Sweden; Osaka University, Japan; Rutgers University, USA and Institute of Biotechnology, Julich, FRG in areas of microbial biochemistry, culture maintenance and management, analyses and control of bioprocesses, modelling and design of bioreactors and enzyme engineering. From the Swiss end one post-doctoral and two doctoral students from the SFIT-Zurich spent more than 25 man-months to participate in the research programme at the BERC. Prof. Ghose visited SFIT-Zurich initially in connection with equipment procurement and later as a Visiting Professor for four months in summer 1976 and four months in US University during summer 1980. Prof. Fiechter visited IIT Delhi once every year to attend Joint Review Committee meetings, to give seminars and to participate at the International Symposium (1977 and 1980). He made in all twelve trips to Delhi in connection with the project work. BERC faculty and support staff spent in all 57 man-months abroad under the collaboration programme till December 1981. From Delhi end no further visit took place since that time.

FULFILLING THE OBJECTIVES:

I. Education and Training:

The Centre's faculty staff has been offering several courses in the Department of Chemical Engineering at the undergraduate level and supervising UG projects. Generally, very bright students opt for biochemical engineering related projects at the UG level.

The most important academic function of the Centre has been to impart adequate and balanced education and training at the post-graduate level such that they will be able to provide professional leadership in research and development activities and promotion of biochemical industries. Centre's academic programme, framed and modified whenever necessary has always been associated with active R&D work. The total number of projects completed are given below. The year-wise break-up of graduating students (M.Tech. Ph.D.) is shown in Tables 4 and 5.

Education and Training

The Centre has supervisied 28 B.Tech. Projects, 45 M.Tech and 21 Ph.D. Theses.

6 M.Tech and 22 Ph.D. theses are in progress

Table-4 Completed and Continuing Ph.D. Projects since 1974

I. Completed:

1.	Studies on the biological treatment of tannery wastes by oxidative fermentation technique	R.N.Chakraborty	1974
2.	Kinetic studies on citric acid fermentation from cane sugar and cane molasses	A.H.Khan	1974
3.	Studies on immobilized enzyme catalyzed reaction system : glucose-glucose oxidase	Vinod Bihari	1976
4.	Studies on kinetic of cellulase production	A.N.Pathak	1976
5.	Kinetic and oxygen transfer studies on gluconic acid fermentation in stirred tank bioreactor	P.Ghosh	1976
6.	Studies on the kinetics of gluconic acid fermentation and assessment of volumetric oxygen transfer coefficient in HRF	S.N.Mukhopadhyay	1976
7.	Kinetic studies on microbial conversion of naphthalene to salicylic acid	S.K.Tangnu	1976
8.	Studies on the mechanism of hydrolysis of cellulosic substances by cellulase enzymes	V.S.Bisaria	1977
9.	Kinetic studies on the production of cellulases in batch and continuous culture systems	Vikram Sahai	1978
10.	Isomerization of cellulose hydrolyzate to glucose fructose mixture by immobilized whole cells	Subhash Chand	1978

11.	Continuous production of ethyl alcohol from cellulose hydrolyzate	R.D.Tyagi	1978
12.	Pretreatment and saccharification of various cellulosic waste materials	C.P.Dwivedi	1978
13.	Single cell protein from deglucosed bagasse hydrolyzate	P.S.Vishnoi	1980
14.	Immobilization of whole cells on inert support for bioconversion of urea	V.Kannan	1980
15.	Isolation and purification of β -glucosidase and its immobilization on solid supports	R.K.Sachdeva	1981
16.	Continuous alcohol production using immobilized whole cells	K.K.Bandyopadhyay	1981
17.	Rate studies of cellobiose hydrolysis using immobilized whole cells	Deepak Jain	1982
18.	Analysis of multi-reactor degradation of solid substances into acids and methane	A.Bhadra	1983
19.	Microbial conversion of cellulose to ethanol using Clostridium sp.	S.Kundu	1983
20.	Pretreatment of cellulosic residues for enzymatic hydrolysis	P.V.Pannir Selvam	1983
21.	Physiological studies on biosynthesis of cellulases from Trichoderma reesei QM 9414	Meera Nanda	1984

II. Continuing:

1.	Microbial conversion of cellulose to acetone-butanol (thesis submitted)	B.K.Soni*	
2.	Kinetics and mechanism of enzymatic hydrolysis of cellulose (synopsis submitted)	S.K.Srivastava*	

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*These are likely to be completed by December, 1984

3.	Optimization of methane production from agricultural wastes (synopsis submitted)	D.Das*
4.	Biological fixation of nitrogen through immobilized cells (synopsis submitted)	K.K.Raina*
5.	Simultaneous saccharification and fermentation of lignocellulosic residues to ethanol (synopsis submitted)	P.K.Roychoudhury*
6.	Ethanol separation by sorption-desorption technique (synopsis submitted)	R.K.Malik*
7.	Bioconversion of xylose to xylitol using immobilized yeast cells	Gyan Prakash*
8.	Mass transfer studies in pulse column bioreactor	V.V.P.S.Murthy*
9.	Optimization of ethanol production from pentoses	Maitreyee Banerjee*
10.	Mixed culture fermentation for the production of cellulases and hemicellulases	T.Panda*
11.	Separation of ethanol from ethanol-water system by membrane technique	J.P.Choudhury
12.	Microbial oxidation of paraffins	P.K.Mehta
13.	Transient studies on ethanol production by immobilized whole cells	S.K.Gupta
14.	Modelling and optimization of cellulase production by a mutant of <u>T.reesei</u>	S.K.Rakshit
15.	Studies on fungal bioconversion of lignocellulosic residues	S.K.Saxena
16.	Studies on production of stability of restriction endonuclease Bam H1	A.K.Dubey
17.	Search for cellulolytic organisms for conversion of cellulose to cells	A.K.Srivastava

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*These are likely to be completed by December, 1984

18.	Kinetic and oxygen transfer studies studies with immobilized osmophilic yeast in fluidized bioreactor	D.K.Sahoo
19.	Effect of oxygen limitation on the shift of cell formation to the biosynthesis of 2-3, butanediol by *Klebsiella pneumoniae*	Meenakshi Nigam
20.	Regulation and transport of substrate and product on the biosynthesis of lysine by *Brevibacterium lactofermentum*	Nandani Seshadri
21.	Energetics and regulation of mixed anaerobic acid fermentation to accumulate propionic acid	Rana Khan
22.	Modelling of immobilized yeast cell system with respect to increased efficiency, productivity and decreased growth	A.K.Srivastava

Table-5 Completed and Continuing M.Tech Projects since 1974*

I. Completed

1.	Studies on the enzymatic saccharification of agrocultural residues	N.P.Ghildyal	1970
2.	Biosynthesis of lactic acid from cheese whey	B.S.Sampath	1970
3.	Studies on microbiological leaching of copper from chalcopyrite minerals	Desh Deepak	1971
4.	Improvement in the design of sterilizer for air filtration	O.P.Bhardwaj	1972
5.	Improvement in the oxygen transfer characteristics of fermentors	B.S.Suri	1972
6.	Studies on immobilized enzyme reactor for cellulose-cellulase system	V.S.Bisaria	1973
7.	Dynamics of mixed culture of yeast and Azotobacter in chemostat	K.R.Malhotra	1974
8.	Dispersion model in STR under imperfect mixing conditions	R.K.Bhargava	1974
9.	Kinetic studies on adsorption of cellulase on non-reactive supports	S.Ramaswami	1974
10.	Studies on enzyme immobilization	V.Sahai	1974
11.	Studies on purification of glucose oxidase from *A.niger*	M.Rama Rao	1974
12.	Growth of SCP on bagasse hydrolyzate	P.G.K.Murthy	1977
13.	Purification of sugars through microbial rejection	B.S.M.Rao	1977
14.	Microbial reduction of carbon dioxide to methane	B.P.Misra	1977
15.	Vapour-liquid equilibrium studies on CO_2-EtOH-water system under reduced pressure	Deepak Jain	1977

*The first six projects were completed before 1974

16.	Separation and recovery of ethanol produced from cellulose hydrolyzate under reduced pressure	P.S.Vishwa-nathan	1978
17.	Growth and oxygen tranfer studies in HRF	A.C.Manchan-da	1978
18.	Increased productivity of methane in biogas	Amar Singh	1979
19.	Inversion of sucrose to glucose-fructose and conversion of glucose to gluconic acid and separation as calcium gluconate	Aloka Cha-kraborty	1979
20.	Studies on increased production of methane in biogas from different indigenous resources	N.K.Nigam	1979
21.	Analysis of growth and cellulase production in <u>T.reesei</u> with pH cycling in HRF and STR	R.K.Malik	1979
22.	Microbial separation of glucose from glucose-fructose mixture	V.K.Gupta	1980
23.	Maintenance coefficient of microbial culture	A.K.Gupta	1980
24.	Simultaneous saccharification and fermen tation of cellulosic materials	P.K.Roy-choudhury	1980
25.	Fermentation of inverted molasses by thermotolerant yeast	A.Mukho-padhyay	1980
26.	Ethanol concentration by membrane tech-nique	J.P.Chou-dhury	1980
27.	On-line assay of substrate and products	P.K.Mukhhe-rjee	1980
28.	Rapid vinegar production using immobilized cells	P.Chatto-padhyay	1980
29.	Enzymatic saccharification of delignified cellulosic wastes in high concentrations with enzyme recovery and cycling	A.K.Sri-vastava	1980
30.	Microbial isomerization of glucose to fructose using immobilized <u>Actinoplanes</u> cells	E.S.Venkata-ramani	1980

31.	Scale-up studies on bioconversion of straw for improved fodder production	D.Adhikari	1981
32.	Media optimization for increased production of cellulase from *T.reesei*	D.Gopal	1981
33.	Studies on energetic aspects of growth of *Aspergillus wentii*	S.Nene	1981
34.	Production of lysine from immobilized *Brevibacterium* sp.	S.Mukhopadhyay	1981
35.	Rapid hydrolysis of tapioca starch	M.Sivanadane	1981
36.	Cellulase production using agricultural residues	U.C.Banerjee	1982
37.	Optimum pH and temperature profiling for cellulase production	R.B.Manihar	1982
38.	Studies on immobilized column reactor for ethanol production to reduce CO_2 hold-up	J.S.Rajan	1982
39.	Kinetics of enzymatic hydrolysis of agricultural residues	S.C.Goel	1982
40.	Kinetics of solvent delignification of agricultural residues	S.K.Gupta	1982
41.	Cellulase enzyme recovery and reuse by ultrafiltration	T.K.Bandopadhyay	1982
42.	Ethanol recovery by preferential adsorption of water using agricultural residues	S.K.Rakshit	1982
43.	Separation of fructose from glucose through oxidation of glucose to gluconic acid using *A.niger* spores	A.K.Gupta	1982
44.	Continuous production of cellulase by *T.reesei* C-5 on soluble sugars	B.K.Choudhury	1983
45.	Purification and characterization of cellulases of *T.reesei* D-1/6	C.S.Tripathi	1983

46.	Scale-up studies on solvent delignification process	A.Prakash	1983
47.	Glycerol production from cellulose hydrolyzate using osmophillic yeast	P.K.Jain	1983
48.	Growth and kinetics of glycerol production and inhibitions using osmophilic yeast on molasses	A.Chattopadhyay	1984
49.	Production of cellulase by <u>Trichoderma</u> <u>reesei</u> strain E-12 on rice straw	S.Suryanarayan	1984
50.	Isolation and characterization of lignin produced by solvent delignification from rice straw	Meenakshi Nigam	1984
51.	Studies on biosynthesis of cellulase on sorbose by <u>Trichoderma</u> <u>reesei</u> C-5	D.K.Sahoo	1984

II. <u>Continuing</u>

1.	Kinetics of thermal inactivation of cellulase	A.K.Dutta
2.	Evaluation of different treatment methods for enzymatic hydrolysis of rice straw	M.Patel
3.	On-line analysis of cellulase using HP system	V.Sahai
4.	Glycerol separation from soap lye	Mamta Agarwal
5.	Studies on oxygen absorption in the cultivation broth of <u>Bacillus</u> <u>stereothermophilus</u> in thermophilic temperature range	T.R.Sreekrishnan
6.	Carbon and energy efficiency of bacterial and mold fermentations	N.G.Angal

Supervision of Projects/Thesis done during 1974-84

B.Tech (Projects)	: 28 (45 since 1969)
M.Tech (Thesis)	: 45 (51 since 1970)
Ph.D. (Thesis)	: 21 (22 since 1970)

Continuing Projects/Thesis (1984-85)

B.Tech	: 6 (II Sem. 1984-85)
M.Tech	: 5
Ph.D.	:22

Out of the current 22 Ph.D. projects eleven are likely to be completed by March 1985. The status of projects is shown in Table 4 and 5.

It can be seen that BERC's contribution to the man-power development at various levels, like projects supervision at B.Tech (Chem. Engg.), academic programme leading to M.Tech in Biochemical Engg. and Biotechnology, and Ph.D. which began in 1971 resulted in substantial number of trained personnel (Tables 4 and 5). Rough estimates reveal that about 25% of M.Techs and 40% Ph.Ds produced by BERC are either studying or working abroad and the rest are engaged in the country in gainful employment. The Centre is constantly asked to supply manpower for academic and R&D functions in Universities and industries and it has not been possible to meet this requirement.

So that the East Central and South East Asian countries get the benefit of the training facilities at the IITD the institute has submitted a proposal to the Ministry of Education for the Establishment of a 'Centre for Advanced Studies in Biomass Refining and Bioconversion' to seek assistance from the UNDP. If approved, this will create facilities for additional training namely 20 M.Techs every year and 16 Ph.Ds over a period of five years.

Course and Curriculum Development:

The title of the M.Tech programme in Biochemical Engineering was changed to include Biotechnology in the academic session 1979-80. Since then it is open to both graduates of Chemical Engineering/ Biochemical Engineering and high ranking graduates of Microbiology/ Biochemistry/Chemistry. This measure was taken in view of the academic needs and opportunities of trained personnel in the industries/R&D Centres. etc. Before 1979, the programme was in Biochemical Engineering with intake of engineering graduates only. The course curricula undergoes continuous review and revision in the light of advances taking place in the field. Whereas at the time of the initiation of the collaboration BERC offered courses equivalent to 31 credits, it has now been increased to 49 credits. These are listed in Table.6.

Table-6 M.Tech, Pre-Ph.D. and B.Tech courses offered by BERC since 1974

Academic year (1974-75) Course title & No.	Credits	Academic year (1984-85) Course title & No.	Credits
PG Courses		PG Courses	
Microbiological Engg. (2-0-3)	3	Biological waste treatment CH-682 (2-0-0)	2
Enzyme Engg. (2-0-3)	3	Principles of Biochemistry CH-665 (2-0-0)	2
Biochemistry-I (2-0-3)	3	Advanced Food Engg. CH-684 (2-0-0)	2
Biochemistry-II (2-0-3)	3	Microbiological Engg. CH-661 (2-0-0)	2
Microbiology (2-0-3)	3	Enzyme Engg. CH-662 (2-0-0)	2
Waste Engg. (2-0-0)	2	Instrumentation and control in fermentation and enzyme processes CH-672 (3-0-0)	3
Adv. Food Engg. (2-0-0)	2		
UG Courses:		General Microbiology CH-667 (2-0-0)	2
Technology of process wastes (2-1-0)	3	Microbial Biochemistry CH-666 (2-0-0)	2
Introduction to Biochemical Engg. (2-1-0)	3	Bioreactor design and analysis, CH-674 (2-0-0)	2
Environmental Engg. (2-1-0)	3	Microbial Process Principles, CH-671 (3-0-0)	3
Biochemical Technology (2-1-0)	3	Introduction to Enzyme Science CH-685 (2-0-0)	2
		Bioconversion CH-687 (2-0-0)	2

Laboratory techniques in genetic engg., CH-686 (0-0-4)	2
Mini Projects, CH-688, (0-0-6)	3
Microbial Engg. Lab., CH-663 (0-0-4)	2
Enzyme Engg. Lab., CH-664 (0-0-4)	2
Microbiology Laboratory, CH-669 (0-0-4)	2
Microbial Biochemistry Lab., CH-668 (0-0-4)	2

<u>UG Courses (B.Tech in Chem. Engg.)</u>

Introduction to Biochemical Engg., CH-496 (2-1-0)	3
Biochemical Technology CH-598 (2-1-0)	3
Engg. Biology, CH-391 (3-1-0)	4

II. Research and Development:

It is clear that BERC's R&D activities are integrated with the process of training students at post-graduate and doctoral levels. Most of the problems analysed and solved are confined to fundamental engineering analysis of microbiological and enzymatic systems to find direct and relevant industrial applications. Broadly speaking these are drawn from the general areas of bioconversion of lignocellulosic materials and industrial agro-residues into chemicals including organic building blocks, liquid and gaseous fuels and microbial proteins. With a few very highly qualified biologists trained in the USA recently recruited BERC is expected to have a base for genetic engineering studies to tacle questions also related to the same area. The current research activities of the Centre are divided into three major areas.

A - bioconversion systems - feedstock and fuels

B - microbial and enzyme reactor and process analyses, and

C - microbial biochemistry and genetics

A. Bioconversion Systems - Feedstocks and Fuels

The research activities under this area are concerned with utilization of renewable resources like cellulosic and starchy materials and their by-products into sugars, fuels (ethanol,

Research and Development

R&D activities resulted in publication of 150 papers almost all in accredited international journals

Significant results of R&D activities are summarized in Table-7 methane), solvents (acetone, butanol), chemicals like fatty acids, amino acids, sugars and microbial feed. Pretreatment of lignocellulosics, production of high activity cellulase for cellulose saccharification, ethanol fermentation via novel routes and separation processes are being studied in this area.

B. Microbial and Enzyme Reactor and Process Analyses

(i) Kinetics, Modelling and Reactor Design

This area is concerned with parameter estimation, development of rate expressions, growth modelling, and reactor configuration of both microbial and immobilized enzyme processes for various bio-conversion routes. Studies on CSTR, PFR, pulsed column and fluidized bed reactor for a number of bio-processes are underway.

(ii) Instrumentation and Process Control

Conventional as well as microprocessor coupled fermentation and process simulation form subject of research in this area. Collaboration studies in this area with Electrical Engg. Dept. are very actively pursued.

C. Microbial Biochemistry and Genetics:

Studies on the biochemical and physiological aspects of micro-organisms associated with cellulose-cellulase systems are being made. Genetic improvement of industrial microorganisms via molecular and cellular approaches is also being carried out.

Highlights of R&D Activities since 1974:

BERC's R&D efforts on biomass conversion approaches began at a time when a few highly developed industrial nations just started shifting emphasis on to renewable energy resources from non-renewables. Today, it has become almost an inescapable route for meeting future needs of non-commercial energy, feed, food, pharmaceuticals and some chemicals etc. and nearly all developing countries including ours have launched ambitious plans in bio-technological education, research and development.

The activities aim at developing integrated bioconversion processes leading to the total utilization of lignocellulosic biomass residues like bagasse, rice straw etc. by conversion to ethanol and co-products. The cellulose to ethanol route as developed involves integration of operations like delignification, cellulase production, saccharification, improved technology of converting sugars to ethanol, mixed feed production and ethanol separation. Based on the accumulated knowledge in these areas an integrated demonstration unit for biomass refining of agricultural residues to ethanol and co-products such as lignin and animal feed is proposed to be set-up at the Centre. Since 1974

BERC's efforts resulted in distinct opportunities for a few new cultures, bioreactor control and processes. These include:

1. Development of hyper-cellulase producing mutants of *Trichoderma reesei*: Starting from *Trichoderma reesei* QM 9414, the Centre has developed two powerful strains viz. D-1/6 and E-12 which are among the best known so far and one constitutve mutant named C-5. Studies on physiological aspects of *T.reesei* revealed the nature of induction of cellulase enzyme and also the localization of enzyme synthesis sites in the cell. While endo-glucanases are truely extracellular in nature, β-glucosidase is cell-wall bound and can be released by incorporating chitin or sorbose in the growth medium or by treating with cell-wall lytic enzymes.

2. Control strategies of extracellular cellulase enzyme synthesis in batch, fed batch and continuous cultures employing improved *T.reesei* strains, low cost nutrients, soluble and in-soluble substrates, cell recycle and dynamic control of some important environmental parameters have been optimized. With improved hyper-cellulase producing strains, it is now possible to get the most out of it in terms of active extracellular cellulase (120 IU/l/hr). This development includes built-in continuous recycle system of solid components of the medium in constant uniform concentration to the reactor. Using *Aspergillus wentii*,

a potent producer of β-glucosidase, optimization led to synthesis of as high as 400 IU/l/hr of productivity. Studies have also been done on combined synthesis of both cellulases and hemicellulases using mixed cultures of various fungal strains. A mixed culture fermentation of _T.reesei_ D-1/6 and _A.wentii_ is seen to be superior to either of the two strains in pure culture fermentation for cellulase synthesis. Also the biochemical mechanism of cellulose hydrolysis has been explained on the basis of selective adsorption-desorption phenomenon of cellulase components. These results suggest more effective use of mixed cellulase and hemicellulase enzyme in the hydrolysis of native cellulosic residues such as bagasse. Mathematical models incorporating these processes have been developed which describe hydrolysis kinetics of native cellulosic employing mixed enzymes.

3. A two stage _catalytic solvent (butanol or ethanol) delignification_ process at lower temperatures (120°C) for the pretreatment of agricultural residues has been developed by the Centre. The process enables delignification to the extent of 90%. The treated residue on being subjected to enzyme hydrolysis yielded 90% saccharification in 16 hours. The opportunity of obtaining polymer grade lignin and free hemicellulose derived sugars as co-products is a positive feature of the process.

4. Production of ethanol from cellulose hydrolyzate in batch and continuous system employing free cells, recycled cells and immobilized cells have been extensively studied and in details. The Centre is the first to publish data and analysis on ethanol production from enzymatically hydrolyzed cellulose. The results include development of a yeast strain which is tolerant to high concentration of glucose and ethanol with nearly 90% conversion achieved in about six hour. Productivity under high cell density activity a level of 32 g/l/h., about 7.5 times higher than the normal continuous process without cell recycle.

A novel technique of fixing yeast cells on inert supports and using these in the continuous production of ethanol at various dilution rates has also been developed. It has been successfully applied to both bagasse and rice straw hydrolyzates as well as cane molasses. Simultaneous saccharification and fermentation of cellulose to ethanol with vacuum recycling and intermittent substrate feeding again constitutes the original contribution of this Centre. Using this technique, it has been possible to achieve rapid yield of alcohol with very high conversion efficiency (>98%) and about 16% v/v ethanol concentration in the product stream employing such reduced consumption of cellulase and β-glucosidase enzymes.

Direct conversion of cellulose into ethanol using anaerobe Clostridium thermocellum under vacuum cycling has also been studied. To avoid substrate inhibition, fed batch system with vacuum cycling gave substantially increased ethanol in the product. More than half the total process energy in the production of ethanol by fermentation goes to separation of ethanol from water by conventional distillation. In view of this, intensive studies are in progress on a few alternative energy effective approaches for ethanol separation. These are ethanol dehydration by preferential adsorption of water on lignocellulosic adsorbents, selective sorption of ethanol on polymer based adsorbents and membrane permeation and ultrafiltration. From 10 % ethanol in feed, distillation followed by adsorption yielded more than 98% ethanol; this process uses per mole of EtOH nearly one/half of the energy compared to the conventional distillation process. In another approach, a two stage process using polymer based resins results in 99% ethanol from 10% initial feed. Using modified cellulose acetate based membrane it is possible to achieve separation efficiency of the order of 90% and above from aqueous ethanol solution (5-20% v/v). Further studies on the development of resins and membranes are in progress.

5. Cellulose hydrolyzate contains mixture of sugars such as glucose, xylose and cellobiose. The organism Clostridium saccharoperbutylacetonicum has the capability to utilize all the

sugars in the hydrolyzate. It was possible to utilize the intermediates accumulated in ethanol fermentation by Cl. thermocellum under anaerobic condition to produce solvents. Using vacuum fermentation a mixture of 6% solvents was obtained in the receiver. It has been possible to utilize high sugar concentration, upto 9%, by incorporating recycling the products of adsorbent column to the bioreactor.

6. Studies on the isomerization of glucose obtained as hydrolyzate of cellulosic residues by enzymatic route followed by the use of immobilized microbial cells has resulted in a process yielding glucose-fructose syrup containing 70% total sugars. The process mainly involves cultivation of Actinoplanes cells containing glucose isomerase activity (460 IU/g) and heat treatment followed by immobilization and use of these cells in packed bed reactor for isomerization of cellulose or starch hydrolyzates. The isomerization reactors are operated with programmed feed policy (residence time varying from 2 to 4 hrs), so as to yield an uniform product. The immobilized cells exhibit an operational half life of 13 days under reaction conditions. An yeast like fungus, Trichosporon melibiosaccrum has also been used for bioconversion of xylose to xylitol in view of its high xylose reductase activity. The NADP(H) dependent reduction of xylose to xylitol by the system has been shown to require glucose as an associated substrate, which is catabolized to regenerate

NADPH via HMP pathway. In nitrogen limited non-aerated culture, the cells were able to yield 90% conversion efficiency in presence of stoichiometric quantities of glucose and result in an overall productivity of 2 $g.l^{-1} h^{-1}$.

Other areas in which important contributions have been made by the Centre include:

(a) an integrated process of biogas production using mixed solids containing animal dung and a number of aquatic biomass like waterhyacinth, algae etc. The mixed slurry yields nearly 80% methane in the biogas in the same period of time and involving equivalent total volatile matter as that of dung. Rigorous kinetic analysis of the results of methanogenesis of the mixed acid in multireactor system has also been done. Considering various mechanism of methanogenesis of acetic acid based on available pathways, rate models have been developed. This mechanism predicted that of the total methane produced 72% comes from acetic acid directly and 28% via CO_2 reduction route. The thermodynamic feasibility of the proposed mechanism and the stoichiometric calculations show that reaction proceed in the direction of the methane formation spontaneously with adequate decrease in free energy. Arising out of the results of these studies a two stage system of distillery waste treatment to obtain high methane yield and significant reduction of BOD has been successfully developed. A demonstration plant has been in operation in the laboratory since March 1984 to establish confidence of Indian distillers in the process.

b) a continuous process for quantitative removal of urea from fertilizer effluent employing fibre entrapped whole microbial cells providing high urease activity and recovering 100% NH_3 released in the system by a subsequent ion-exchange operation. It has been possible to hydrolyse 95% of the urea present in the effluent (3000 ppm) in a two stage process during a cycle time of 150 minutes. Operational stability of this technique is nearly 400 hours, while the immobilized half life of the cells exposed to continuous use is not less than 7 days.

c) generalized growth equations incorporating O_2 as the second substrate and applying the same for *Pseudomonas ovalis* in the oxidation of glucose to gluconic acid.

d) mathematical models for oxygen transfer and biochemical reaction rates in the case of glucose oxidation to gluconic acid in horizontal rotary bioreactor. The reactor developed in the course of the studies has since been scaled up.

e) nitrogen fixation by free and immobilized *Azotobacter vinelandii* cells have yielded interesting results on the cell growth and nitrogen fixation in a chemostat as well as in cells supported on inert materials such as soil and lignocellulosic residues. Studies on nitrogen fixation associated with enzymatic saccharification of lignocellulosic materials in two stages resulted in a productivity of 0.21 $g.l^{-1} h^{-1}$ compared to 0.66 $g.l^{-1} h^{-1}$ in a batch culture.

(f) techniques for immobilization of enzymes on abundantly available and less expensive carriers (lignocellulosic residues) and microbial spores and cells on to pumicestone have resulted potential catalytic materials for their application in continuous biotransformations. In the former case, the cellulosic residue is activated and converted into its amino-hexyl derivative which can be used for covalent coupling of enzymes.

The significant results of BERC's R&D activities are highlighted in Table-7.

Substantive results of various research and developments activities of the Centre are regularly reviewed and published in reputed international journals. Since 1974, the Centre has published about 150 papers in accredited international journals. Some of the important research and development activities mentioned above are continuing. These activities are mentioned under "Continuing and Future Programme" alongwith the time frame within

Table-7 Significant Results of BERC's R&D Activities

Process	BERC Data	Others
- Delignification (rice straw)	80%	NA (for rice straw)
- Cellulase activity	15 $IU.ml^{-1}$ (*T.reesei* E12)	15 $IU.ml^{-1}$ (*T.reesei* C 30)
- β-glucosidase activity	20 $IU.ml^{-1}$ (*A.wentii*)	14 $IU.ml^{-1}$ (*A.phoenicis*)
- Ethanol productivity (based on saccharification and fermentation time)		
Cell recycle	3.3 $g.l^{-1}h^{-1}$	-
Immobilized column reactor	3.2 $g.l^{-1}h^{-1}$	-
SSF with vac. cycling	5.8 $g.l^{-1}h^{-1}$	-
- Ethanol separation (adsorption-desorption)	10-98% (3-4 MJ/l EtOH)	8-99% (3.8 MJ/l EtOH)
- Effluent treatment		
Residence time	7 days	12 days
BOD reduction	87%	70-90%
Biogas l/l effluent	40	30

The Centre has organized three International Courses/Symposia and six national Courses/ Workshops which they are expected to be completed.

III. Transfer of Knowledge through Symposia, Workshops and Advanced Level Courses

The development of any new academic discipline largely depends on the organized dissemination of the knowledge generated in research through seminars and workshops. In pursuit of this a number of professional activities have already been successfully organized, namely:

- First International Course-cum-Symposium on Biochemical Engineering and Bioconversion of Cellulosic Substances into Energy, Chemicals and Microbial Proteins, Feb. 1977
- Joint Workshop on Twenty Years of Biochemical Engineering Education and Research in India (IIT Delhi and Jadavpur University) January 1979
- Second International Course-cum-Symposium on Biochemical Engineering and Bioconversion, February-March, 1980
- QIP Course on Microbial Engineering, July 1981
- Refresher Course on Recent Advances in Enzyme Engineering and Technology, December 1982
- Indo-French Workshop-I : Fundamental of Genetic Engineering, November 1983

- Indo-French Workshop-II : Genetic Engineering and Technology of Yeasts, Nov-Dec 1983
- Workshop on Cultivation of Edible Mushrooms, February-March 1984.

Some special features of the two International Courses and Symposia organised by the Centre and supported by Indo-Swiss project , UNESCO & that of VII International Biotechnology Symposium held in February 1984 are given in Table-8.

VII International Biotechnology Symposium, February 19-25, 1984

The VII International Biotechnology Symposium 1984, sponsored by Commission on Biotechnology (IUPAC), Indian National Science Academy and a number of national and international agencies, industries and professional societies was successfully conducted under the Chairmanship of Prof. T.K.Ghose. Moreover practically all faculty members of the Centre were involved very actively in the organisation of this important international event which took place for the first time outside the developed world.

The scientific programme consisted of four Key Lectures, two on the day of inauguration (February 19) and two on the concluding day (February 25), twenty Plenary Lectures and twentyfour

Table-8 Salient Features of 1977, 1980 International Course-cum-symposium and 1984 International Biotechnology Symposium

	1977	1980	1984
I. Course			
- Total experts (foreign)	17(13)	31(18)	
- Lectures from invited experts including Indians	23	24	
- Total attendees (overseas)	65(8)	80(12)	
- Regular laboratory experiments	9	10	
- Demonstration experiments	3	5	
- Panel Discussion	1	1	
- Key Lectures	2	2	
II. Symposium			
- Plenary Lecture	3	5	20
- Papers presented	37	60	324
- Total participants (foreign)	138(44)	250(100)	881(352)
- Key Lecture	-	-	4
- Position Papers	-	-	24

Proceedings of both the 1977 and 1980 Symposia were edited by Prof. T.K.Ghose and printed in addition to the plenary lectures delivered by him at the symposia. The printing and publication of the Key, Plenary and Position Papers addresses given at the VII-IBS 1984 are currently in progress.

plenary Lectures and twenty four Position Papers presented in four panel sessions. In addition 334 poster papers were also presented. The inaugural key lectures were delivered by Dr. Jonas Salk, Director, Salk Institute for Biological Studies, California on "Contribution of Biosciences to Biotechnology" and Dr. Elmer L.Gaden, Jr., Dept. of Chemical and Biochemical Engg., University of Virginia, on "Engineering and Biotechnology : Accomplishment and Challenges". The two concluding session key lectures were delivered by Prof. Werner Arber, Nobel Laureate, Biozentrum, Universität der Basel on "Future of Recombinant DNA Technology" and Prof. A.E.Humphrey, Vice-President and Provost, Lehigh University on "Biotechnology - The Future". While Professors Salk and Arber emphasized the great and revolutionary role that molecular biology would play in shaping the future of biotechnology, Gaden and Humphrey's approach clearly indicated with many examples that adequate and substantive engineering inputs are the king pins of biotechnology in the use of molecular biology and microbiology. India, they hoped, in appreciation of this need, will make correct balance with proper emphasis because its significant contributions in biochemical engineering are well known.

Twenty plenary lectures broadly covered the areas of r-DNA technology, hybridomas, plant and animal cell cultures, secondary metabolites, algal technology, gaseous and liquid fuels from biomass, immobilized biocatalysts, microbial transformations, analysis of chemical and biochemical routes for production of organic feedstocks, microbial insecticides, biometallurgy, down-stream processing, design and computer control of bioreactors, mass transfer and optimization of integrated biological systems etc.

The poster sessions provided the most important complimentary contributions to the plenary sessions in the form of original presentations, these were previously reviewed critically. The subject closely followed the areas already delineated in the plenary sessions. Three hundred and thirtyfour papers were presented in twenty one sessions including one miscellaneous session. The presentations made over a period of a full week were received with great satisfaction and enquiry. The largest number of papers from one single laboratory was from BERC, IIT Delhi (16) followed by the second highest presented by the University of Miami, USA (5) and University of Hannover (5).

The four panel sessions running parallel were heavily attended, particularly the one on "Biotechnology - The Global Priorities". In all twenty four position papers presentations made by eminent biotechnologists of the world, six in each as planned originally. Discussants of each session reviewed all these papers and prepared the respective panel papers.

The exhibition held as a part of the symposium was organised at the conference venue and its impact, according to most visitors, was outstanding. Once again the idea was to provide atleast glimpses of hardware needs of biotechnological processes including computer software for control. The BERC, IIT Delhi presented some such softwares developed at the Centre; it also displayed a scale model (1:33) of the pilot facility based on its studies for the production of ethanol and coproducts from agro-residues. Thirtyone stalls were set-up by firms from Europe, United States, Japan and India.

The symposium was attended by 881 participants from 37 countries, out of which nearly 60% were from India.

Centre's faculty members and research staff also participate in advanced level courses/seminars/symposia which were held in or outside India to exchange scientific information with others. Prof. Ghose is quite frequently invited to deliver key note addresses or participate in panel discussions in many major international and national scientific meetings and conferences on biochemical engineering and biotechnological education, biomass conversion, bioenergy etc.

IV <u>Industrial Collaboration:</u>

The Centre has been active in providing advice to various

The Centre undertook sponsored research projects worth Rs.19.8 lakhs and consultancy projects worth Rs.1.5 Lakhs industrial firms, who come quite frequently to seek help and assistance from the staff on various projects in biochemical engineering and biotechnology. There has been a special interest of industries in BERC R&D results on cellulose to ethanol process. Lists of such industrial firm who sought BERC'c advice on various biotechnological processes are given in the Status Report of previous years. Inspite of interest shown by numerous firms, there has been very little initiative taken by most of them; it can be attributed to various factors. By any standard, the biotechnological industries in India are still in their infancy because both concept and process wise, a lot more effort has to go into this area to accelerate the pace of its growth. Quite frequently the industrial houses are just interested in knowing what has not been available in the country and go for foreign collaboration after having relevant information from the R&D Centres. Lack of industrial collaboration with indigenous process is also because of rather liberal import policy of Govt. of India and industrial houses take advantage of this to enter into foreign collaboration. Inspite of this lack of culture on the part of many industries to entrust Indian R&D Centres, biotechnology being no exception, BERC has been able to provide consultancy to some big industries - one, Indian Drugs and Pharmaceuticals Ltd., Rishikesh (the biggest national antibiotic plant), the other M/S Chemaux Pvt. Ltd. on providing technical guidance on their research and development activities, and the third M/S Ranbaxy Ltd. on production and scale-up studies on 6-amino penicillanic acid, a vital life saving drug intermediate. A project on "Microbial production of lipids" sponsored by TOMCO, Bombay is presently underway at the Centre. In addition to these our process on the treatment of distillery effluent has been taken by a distillery for pilot scale trials.

CONTINUING AND FUTURE PROGRAMME:

1. Continuing Programme:

As per the agreement between Indo-Swiss Scientific and Technical collaboration between IIT Delhi and SFIT-Zurich (Ref. letter of Education Secretary, Govt. of India No.J12012/6/77 T-6 dated October 11, 1977 to the Ambassador of Swiss Embassy in India), the objectives of the collaboration were to strengthen BERC for the following activities:

a) to train personnel and to provide expertise for meeting the needs of the biochemical industries and applied research institutions in India,

b) to develop useful fermentation processes and to carry out engineering analysis of microbial and enzymatic systems in bioreactors of various configurations, with a view to suggest economically feasible solutions for helping the biochemical industries to improve their productivity and to enter new areas of social needs,

c) to provide consultancy to industries and to disseminate the knowledge generated at the BERC through seminars and symposia.

While BERC has successfully met the objective (a) and (c) pertaining to training of personnel as well as organizing international and national symposia, the objective (b) still remains partly fulfilled. Several important research and developmental activities initiated at BERC during the first two phases (1974-77 and 1977-79) of collaboration have yielded significant achievements. However, some of the programmes are still continuing and are expected to be completed in the time frame indicated against each incompleted task as follows:

1. Dynamics of mixed culture (March 1986)

- mechanism of enzyme biosynthesis by mixed fungal cultures
- upgradation of agro-residues for animal feed by mixed cultures

2. Mechanism of cellulase synthesis and inhibition of regulation in constitutive mutants (March 1987)

3. Isolation of powerful cellulase producing mutants (March 1987)

4. Simultaneous reaction and separation systems (March 1987)

- cellulose to ethanol conversion by simultaneous saccharification and fermentation under vacuum cycling.
- starch to ethanol conversion by two stage and simultaneous saccharification and fermentation
- cellulose to fructose conversion by simultaneous saccharification and isomerization
- cellulose to gluconic acid by simultaneous saccharification and oxidation.

5. Recombination of cellulase producing fungus into yeast cells by cell protoplast fusion technique as well as recombinant DNA technique (March 1989)

So that major part of the unfulfilled tasks can be completed a nominal Swiss assistance amounting to SFr.225,000 is envisaged till March 1987 which will primarily be utilized for procurement of some spare-parts, books/journals/reprints and for consumables and rare chemicals. Only one visit from BERC to Switzerland for a year and two visits by Prof. A. Fiechter to India are envisaged. The year-wise break-up of the funds requirement is shown in Table-9.

Table-9 Budget estimates for 1985-87 (Swiss Funding)

Head	1985-86	1986-87	Total(1985-87)
- Spare parts/accessories of existing equipment	40,000	20,000	60,000
- Books/journals/reprints etc.	20,000	15,000	35,000
- Consumables/chemicals	30,000	20,000	50,000
- Visits (India-Switzerland)	-	32,000	32,000
(Switzerland-India)	4,000	4,000	8,000
- Administrative expenses	20,000	20,000	40,000
Total SFr.	114,000	111,000	225,000

Note: 1. Since nothing is known about the status of Swiss Funding during 1984-85 figures are not included in this table.

2. The Indo-Swiss collaboration in biochemical engineering may terminate with effect from April 1, 1987

The Indian counter-part fund likely to be available from Ministry of Education for the period 1985-87 is shown in Table-10 , in addition to approx. 12 Lacs available from IIT Delhi per year.

Table-10 Budget Estimates for 1985-87 (Indian Funding) (for continuing programme)

Head	1985-86	1986-87	1985-87	1985-90
- New equipment	500,000	200,000	700,000	
- Supplies (chemicals/ consumables etc.)	100,000	100,000	200,000	
- Miscellaneous	50,000	50,000	100,000	
Total Rs.	650,000	350,000	10,00,000	25,00,000

2. Future Programme

From the later part of the academic session 1984-85, some major questions that the Centre will be concerned with in seeking appropriate solutions are given below:

1. Interpretation of the fermentation status by amalgamating information obtained directly and indirectly that is through sensors and material energy balances respectively.

2. On-line control of the fermentation process for maximization of productivity. Advaptive control algorithms will be developed

involving on-line parameter estimation and exercise of control.

3. Separation of ethanol from ethanol : water system by vapor-phase dehydration.

4. Effect of chemical association of lignin on the hydrolysis of cellulose

5. Inactivation of thermophillic Clostridium sp. in presence of oxygen related to ethanol production.

6. Effects of environmental fluctuations inherent in inadequately agitated system (pulse column, fluidized bed reactor) on the kinetics of growth and product formation by microorganisms.

7. Relationship between cell density and ratio of DNA/RNA in a turbidostat.

8. Regulation of TCA cycle on the overproduction of glycerol by osmophilic yeasts.

9. Problamatique of monitoring D.O. concentration in a complex media involving cells with high oxygen demand.

10. Interrelationship between energy charge and the mode of sucrose assimilation in Leuconostoc sp.

11. Effect of shear and temperature on cellulase adsorbed on specified cellulose particles.

12. Quantification of the effects of entrapment of cells on specific growth rate, product formation rates and conversion efficiency.

involving on-line parameter estimation and exercise of control.

3. Separation of ethanol from ethanol : water system by vapor-phase dehydration.

4. Effect of chemical association of lignin on the hydrolysis of cellulose

5. Inactivation of thermophillic Clostridium sp. in presence of oxygen related to ethanol production.

6. Effects of environmental fluctuations inherent in inadequately agitated system (pulse column, fluidized bed reactor) on the kinetics of growth and product formation by microorganisms.

7. Relationship between cell density and ratio of DNA/RNA in a turbidostat.

8. Regulation of TCA cycle on the overproduction of glycerol by osmophilic yeasts.

9. Problamatique of monitoring D.O. concentration in a complex media involving cells with high oxygen demand.

10. Interrelationship between energy charge and the mode of sucrose assimilation in Leuconostoc sp.

11. Effect of shear and temperature on cellulase adsorbed on specified cellulose particles.

12. Quantification of the effects of entrapment of cells on specific growth rate, product formation rates and conversion efficiency.

13. Mechanism of transport of gases produced in immobilized cell system.

14. Identification of the factors influencing the cycling rate and stability of cofactors in biotransformation reactions.

If the UNDP project referred to in the report earlier receives approval additional training of 20 M.Tech (now 10 only) and 16 Ph.D. in the course of next five years will be possible with new staff being made available.

Also, based on BERC's R&D results, a proposal for establishment of an integrated demonstration facility for cellulose to ethanol and chemicals is under active consideration of Department of Non-Conventional Energy Sources, Ministry of Energy, Govt. of India. If approved, this facility will result in the demonstration set-up for production of 50 l/day of ethanol by simultaneous saccharification and fermentation process. It will, for the first time anywhere, enable to demonstrate the lab. scale results of ethanol production based on cellulosic residues by some exciting process steps incorporating new biological inputs all developed at BERC during the past decade.

CONCLUSION:

An exciting era of useful Indo-Swiss bilateral collaboration in biochemical engineering has completed a decade. In the light of the objectives of the collaboration and as per IIT Delhi Board of Governors' decision, teaching and R&D have been the main functions of the Centre. The training in biochemical engineering and biotechnology at M.Tech and Ph.D. levels provided by the Centre has been widely acclaimed to be of very good standard essential for proper growth of biotechnology in the country. The revised and updated courses being offered now are equivalent to 49 credits compared to 31 credits ten years ago. IIT Delhi is the only place where quality education in biochemical engineering comparable to international standards is available in India. This could not have been fulfilled through separate training in biology and chemical engineering. This gap has been adequately filled by this Centre during the last decade.

Concepts and practices of the recent advances in biotechnology and genetic engineering are also covered in the training and this area will be improved further with most recently recruited staff. Because of the emerging interest in this thrust area, the Centre has started offering a course on "engineering biology" to UG students of the institute from the current academic session 1984-85.

In the field of R&D, the Centre, has over the years, consolidated four closely integrated research groups, outlined earlier which interact with one another for overall development of all R&D projects. Although there is no yard stick to evaluate the gains, the progress made by the Centre in the development of cellulose to ethanol process, hypercellulase production, fructose syrup from cellulose and development of a few reactor concepts etc. are some unique and outstanding. Further, what is perhaps not directly evident is the effect the Centre has been able to create in catalysing and initiating the concept of microbiological solution of problems related to energy, chemical feedstock, human and cattle nutrients, solvents etc. The leadership that the BERC, IIT Delhi has provided with strong and effective support received from both IIT Delhi as well as the Ministry of Education in imbibing the spirit in this endeavour has been bearing fruits. The Indo-Swiss project has been to a large extent responsible to provide the base.

Based on BERC's R&D results, a proposal for establishment of an integrated demonstration facility for cellulose to ethanol and chemicals has been under review by the Department of Non-Conventional Energy Sources (DNES), Govt. of India. A scale down feasibility report of the process is under preparation and will be submitted to DNES soon for consideration for funding. In the field of transfer and exchange of information generated worldwide, the Centre has been able to achieve this adequately through organization of VII International Biotechnology Symposium 1984, two International Courses and Symposia and six national courses/workshops during the ten years' period.

In view of the importance of biotechnology in the future development needs in the area of energy, chemicals and food and feed from renewable resources and the successful performance of BERC in meeting some of its objectives, BERC has been established as one of the Centres of Excellence in India.

The assistance received from Indo-Swiss collaboration has yielded fruitful results based on Centre's objectives. The facilities created are being extensively used in training students and conducting R&D work and executing consultation jobs assigned to the Centre. None of the facilities created is lying idle without being properly utilized. Training received by several members of faculty, research and support staff in various laboratories of the world has been very useful in achieving the goals.

It is also pertinent to record here the growth of the Centre in terms of its faculty, staff and students since start of the collaboration as summarised under:

	Approved	
	March 1974	Sept. 1984
<u>Faculty</u>		
Professor	1	5
Asstt. Prof.	-	6
Lecturer	-	3
<u>Research Staff</u>		
Sr. Sci. Officer-I	-	2
Sr. Sci. Officer-II	-	3
Res. Assoc.	-	5
Res. Assoc. (CSIR)	-	5
SSO-II (DNES Projects)	-	1
Sr. Res. Asstt.	-	4
Sr. Res. Asstt. (DNES projects)	-	5
<u>Support staff</u>	1	27
<u>Students</u>		
Ph.D.	7	32 (16 full time)
M.Tech	-	20

The Centre will continue with the projects mentioned on page 45-46 under Indo-Swiss collaboration until March 1987. The new projects will be funded from other sources.

ACKNOWLEDGEMENT:

This review covering the most fruitful relevant activities of a decade of collaboration between IIT Delhi and SFIT Zurich will remain incomplete if it does not include acknowledgement of the support that the project received from various agencies and officials. It is, therefore, appropriate to place on record the continued assistance received from the following sources and officials.

(A) India

Indian Institute of Technology, Delhi

1.	Shri G.K.Chandiramani	Chairman, BOG
2.	Dr. B.D.Nagchaudhuri	Former Chairman, BOG
3.	Prof. R.N.Dogra	-do-
4.	Shri Dharma Vira	-do-
5.	Air Marshal Arjan Singh	-do-
6.	Prof. N.M.Swani	Director
7.	Prof. O.P.Jain	Former Director

Ministry of Education and Culture

1.	Dr. Ashoke Chandra	Education Adviser (Technical)
2.	Prof. C.S.Jha	Former Education Adv.(Tech.)
3.	Shri V.R.Reddy	Former Dy. Edn. Adviser
4.	Dr. K.Gopalan	-do-
4.	Dr. S.Muthukumaran	-do-
6.	Shri H.D.Gulati	-do-
7.	Shri S.Vedantham	Dy. Edn. Adviser
8.	Shri M.L.Gilautra	Education Officer

Department of Economic Affairs, Ministry of Finance

1. Dr. M.Natarajan
2. Mr. A.R.Krishnaswamy
3. Smt. P.Sen Vyas
4. Shri B.Jai Shankar
5. Shri Ajay Choudhury

Experts

1. Prof. K.S.Gopalkrishnan
2. Mr. R.N.Ghatak
3. Prof. C.V.Seshadri
4. Prof. P.K.Maitra
5. Mr. S.R.Sen

Prof. K.S.Goaplkrishnan who joined BERC from M/S Hindustan Antibiotics Ltd., Pimpri, on successful completion of his academic assignments has retired on 30th June 1984. His participation in the Indo-Swiss project has been immensely constructive and valuable. We acknowledge his many contributions made to the success of this endeavour.

(B) Switzerland

Embassy of Switzerland in India

1. H.E.Fritz Real, Ambassador in India
2. H.E.Eteinne Suter, Ambassador in India
3. H.E.Peter Erni, Ambassador in India
4. Madam Catherine Kriege, Charge d'Affaire
5. Mr. J.S.Giovanini
6. Mr. H.Ph.Cart
7. Dr. R.Dannecker
8. Mr. S.Chappatte
9. Dr. G.Pfister
10. Dr. A.Kohler

SFIT, Zurich

1. Prof. A.Fiechter
2. Mr. A.Binder
3. Dr. W.Beyeler
4. Dr. J.R.Mor
5. Dr. U.Baier
6. Mrs. Erika Bush

T.K. Ghose
(T.K.Ghose) Oct 5, 1984