Minimum Energy Design for Industrial Processes

Presented to

WB Energy Efficiency Thematic Group
Washington D C

by

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DSCL ENERGY SERVICES CO LTD, INDIA

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To Begin with a Poser

Driving a car-only 1% is used for the job-70% is wasted in conversion & another 20% in transporting the transporter*

What if this usage could be doubled/tripled?

*Natural Capitalism-RMI

Presentation Structure

- Brief introduction to the DSCL Group & DSCL Energy Services
- Minimum Energy Design-Concept
- MED-Historical perspectives
- Applications
- Case studies-Conceptual
- Case studies-Practical
- MED-Looking ahead

DSCL : Business Portfolio

Rs. 3000 Crs Conglomerate

MANUFACTURING PLATFORM

AGRI BUSINESS	PLASTICS	CHEMICALS
•Fertiliser •Agri-Marketing •Sugar	Commodity Speciality	Commodity Speciality/ Value Added

SERVICE PLATFORM

Agri-Retail

Haryali Kisan Bazaar

Fenesta

U PVC Window system

ENERGY SERVICES

DSCLES 1999

Power (>230 MW) (RE >70 MW) (Export >25 MW)

DSCLES - Overview

- Established in 1999
- Largest ESCO in India with over 40 professionals and fully networked offices in Delhi & Ahmedabad
- Energy Efficiency & Renewable Energy-over 150 Projects-net contribution of over 525 MW in India and other countries in Asia and Africa
- GHG Reduction of over 2 MNT/year

DSCLES
POWER PLANTS
ALTERNATE ENERGY
CDM
ENERGY EFFICIENCY

Winner of PCRA Award for four Of lat five years

DSCL ENERGY SERVICES

Minimum Energy Design-Concept

- Energy need analysis
  - Movement of material/mass transfer
  - Heat transfer
  - Energy transformation/transportation
  - Computation
- Need fulfillment processes
  - Law of physics and chemistry
  - Bio-sciences

MED-Brief Historical Perspective

- Early research in UK and Russia in 1930s for optimization of steam distillation processes
- Flurry of activities in the 80s post publication of report on pioneering work done by B Linhoff and others on HEN & 'Pinch'
- Currently standard practice in some of the industries like refineries and petrochemicals. Very little information on action in other industries
- MED concept developing to encompass all energy related activities

MED-Applications

- Industry (Process synthesis, HEN etc)
- Buildings (LEED etc)
- Transportation (Power technologies, Ultra light material technologies)
- Computation

Minimum Energy Design-Industry

- Process synthesis
  - Mass exchange/transfer
  - Mixing
  - Separation
  - Reactions

- Synthesis of heat exchanger network (HEN)
  - Maximum heat recovery
  - Most cost effective engineering

- Synthesis of control system

Designing a system from fundamental considerations

Process Synthesis – An Example

Minimum energy consumption in sugar production by cooling crystallization of concentrated raw juice

M Grabowski (Warsaw University of Technology); J Klemes (University of Manchester); K Urbaniec, G Vaccari (University of Ferrera, Italy) and X. X Zhu

The sugar manufacturing process based on cooling crystallization of concentrated raw juice is considered. Micro-filtration and softening of raw juice makes it possible to obtain white sugar by three or four stage cooling crystallization. Prior to Crystallization raw juice should be concentrated by multi stage evaporation in a pressure range below the atmospheric pressure. The preferred evaporator arrangement is backward feed. As the temperature of vapors and condensates leaving the evaporator station is low, the opportunities for heat recovery is limited. In order to save energy, vapor compression can be applied.

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HEN

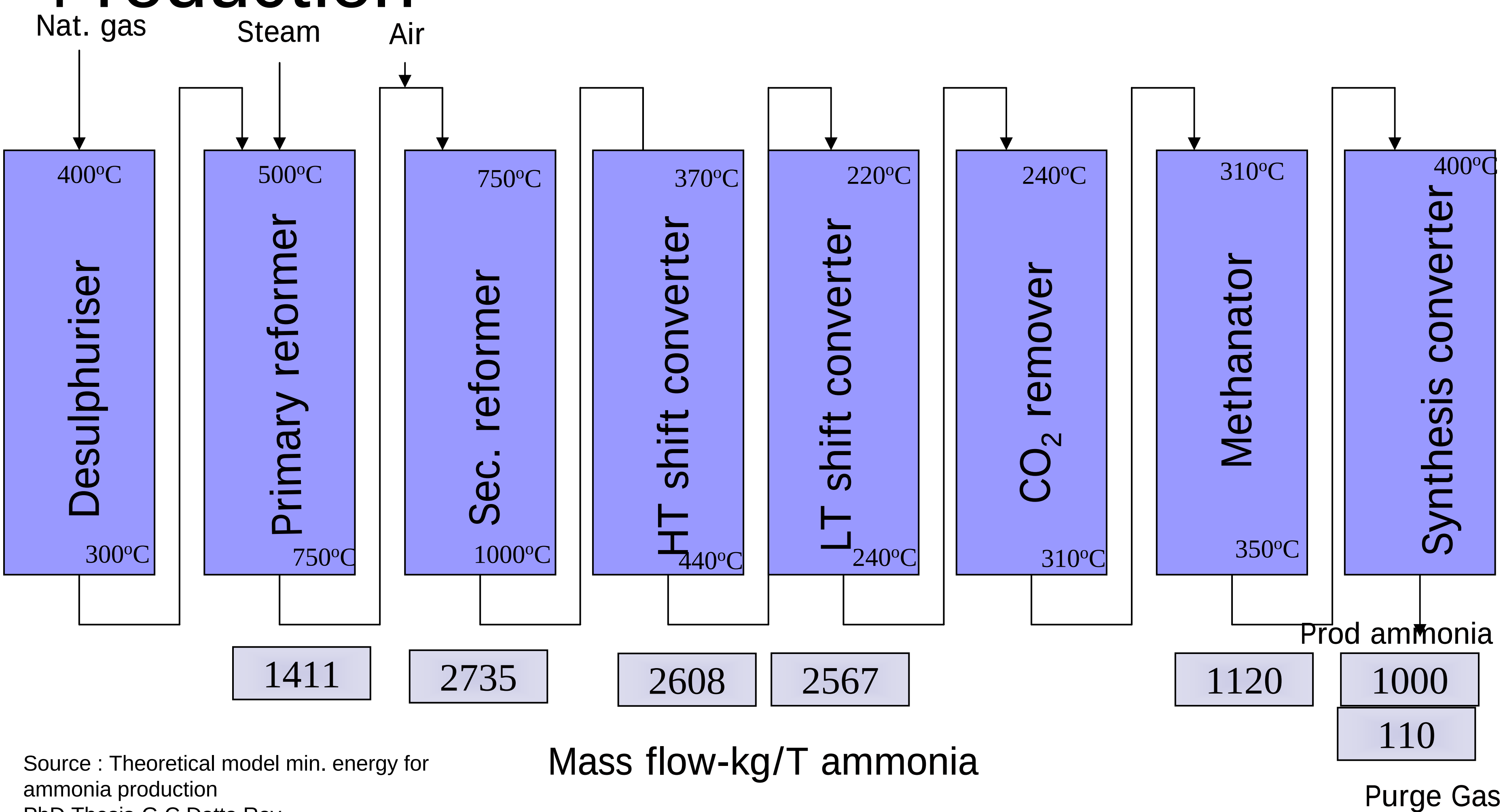
- Process cold streams
  - (All streams where heat is being added)
- Process hot streams
  - (All streams undergoing cooling)
- Cold composite curve (CCC)
- Hot composite curve (HCC)
- Grand composite curve (GCC)
- Pinch
- Heat exchange on either side of the 'Pinch' yields maximum energy savings
- Heat exchange across the 'Pinch' causes double waste

Use of 'Pinch' for audit can dramatically improve process energy efficiency

MED
Conceptual Analysis-
Case Study

Ammonia Process

Minimum Energy Design-NH_3 Production



Mass flow-kg/T ammonia

Source : Theoretical model min. energy for ammonia production
PhD Thesis-G C Datta Roy

SNW Heat Flow

SNW No.	SNW Temp. °C	Cp-cold stream-K Cal/C/T				Dt 20°C	SNW Hot °C	Cp-hot stream K Cal/C/T				Diff	SNW rate	SNW Temp Diff	SNW Heat flow Th.K Cal/t	Cumulative flow Th.K Cal/T	Corrected heat flow
		C1	C2	C3	Total			H1	H2	H3	H4	Total					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
-	-	-	-	-	C+D+E	/// ///	-	-	-	-	-	I+J+K+L	M-F	_	N x O x 10³	P	-
I	980 450			-		/// /// ///	1000 470					1560	1560	530	837.4	837.4	-
II	420				-	/// ///	440	1560				2311	2311	30	69.3	906.7	-
III	400					/// ///	420					3793	3723	20	74.5	981.2	-
IV	350			965	1337	/// ///	370		1482			3893	2456	50	122.8	1104.0	-
V	310				372	/// ///	330					2213	1841	40	73.6	1177.6	-
VI	220				1367	/// ///	240				731	2213	846	90	76.1	1253.7	-
VII	200	372	995		1367	/// //	220					2232	865	20	17.3	1271.0	-
VIII	100				1367	/// ///	120			1501		2232	865	100	86.5	1357.5	-
IX	80				372	/// ///	100					2232	1960	20	39.2	1396.7	-
X	30				372	/// ///	50					731	356	50	17.7	1414.4	-
XI	20					/// ///	40					731	731	10	7.3	1414.4	-

Energy Required for 1 MT of NH_3 Production

5.56 million kCal/T against the then prevailing benchmark of 7.0

- Heat of Combustion
  - Methane – 13265 kCal/kg
  - Ethane – 12400 kCal/kg
- Mass Flow Rate
  - Methane – 388.95 kg/h
  - Ethane – 32.4 kg/h
- Energy Required
  - 388.95 x 13265 + 32.4 x 12400 = 5.56 million kCal/T of ammonia
- The above estimate
  - Includes 20% hydrogen gas loss in the process
  - Excludes energy requirement for compressors, pumps, refrigeration and utilization of 1 T of surplus steam/ ton of ammonia

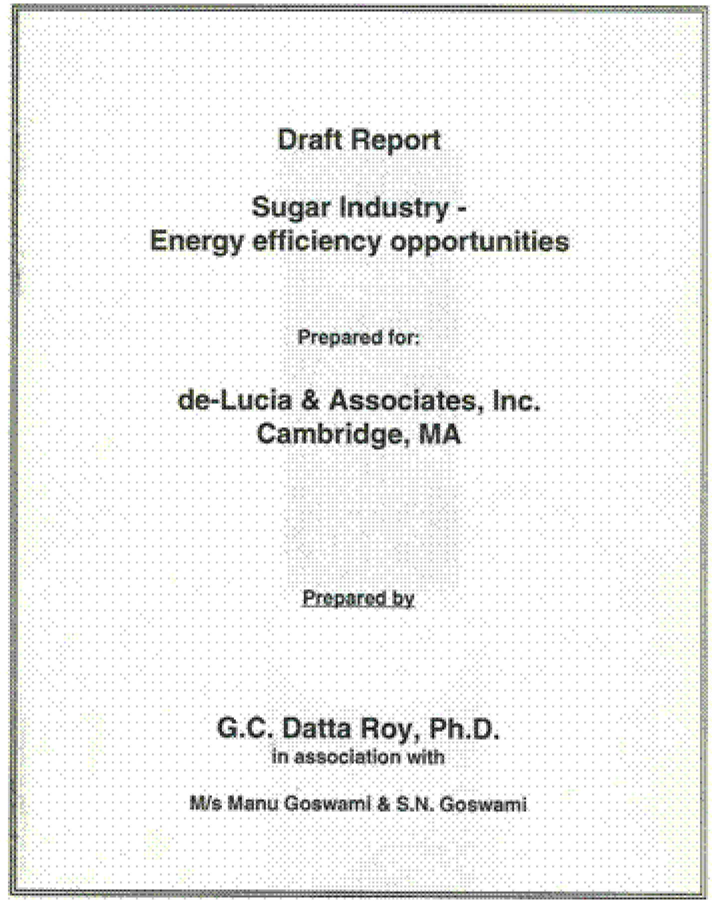
MED
Conceptual Analysis

Sugar Process

Specific steam consumption-White Cane Sugar Process

- Steam is required in different processes like evaporation, crystallization etc.

- MED concept was applied for determination of the minimum steam need against the then prevailing consumption of about 0.50 T/T of cane crushing (expressed as % cane).



Draft Report

Sugar Industry -
Energy efficiency opportunities

Prepared for:

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Cambridge, MA

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M/s Manu Goswami & S.N. Goswami

Comparison of various options for Evaporation in Sugar Industry :

Particulars	Units	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
		w/o grid supply	with grid supply	With Th.comp	With steam saving	With Power saving	With PLC	With bagasse dryer	Extr. press. 0.9 K	Extr. press. 1.1 K
A. Quintuple Effect : (ENFNES)										
- Live steam press.	K(g)	62	62	Not reqd. due to very low flow thru' PRV	62	62	62	62	62	62
- Live steam temp.	C	450	450		450	450	450	450	450	450
- Exhaust steam press.	K(g)	1	1		1	1	1	1	.9	1.1
- Th. comp. steam press.	..	N/A	N/A		N/A	N/A	N/A	N/A	N/A	N/A
- Steam to heaters	T/hr	.00	.00		.00	.00	.00	.00	.00	.00
- Vapour to heaters	..	14.63	14.63		14.63	14.63	14.63	14.63	14.61	14.65
- Steam to evaporators	..	34.51	34.48		34.60	34.53	34.51	34.51	34.25	34.77
- Steam to vac. pans	..	.00	.00		.00	.00	.00	.00	.00	.00
- Vapour to vac. pans	..	17.85	17.85		17.85	17.85	17.85	17.85	17.85	17.85
- Steam for feed heat.	..	.00	.00		.00	.00	.00	.00	.00	.00
- Total process steam	..	34.51	34.48		33.91	34.53	34.51	34.51	34.25	34.77
- Steam to Th. comp.	..	.00	.00		.00	.00	.00	.00	.00	.00
- Steam to PRV	..	1.65	.00		1.05	2.77	1.65	1.65	1.77	1.53
- % steam saved	%	0	0		2	0	0	0	0	0
- Live steam load	T/hr	31.84	31.99		31.25	31.74	31.84	31.84	31.61	32.08
- % Steam		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
- % power saved	%	0	0		0	1	0	0	0	0
- Internal power cons.	KW	3150	3150		3150	3045	3150	3150	3150	3150
- Power to grid	..	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0
- Realisation f[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	162.6	159.4
- Realisa[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0
- Tota[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	159.4
- [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. Q[illegible]										
- Live s[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62	62
- Live steam [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	450	450
- Exhaust steam pr[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	.9	1.1
- Th. comp. steam press.	..	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	N/A	N/A	N/A
- Steam to heaters	T/hr	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.89	1.90
- Vapour to heaters	..	13.72	13.72	13.72	13.72	13.72	13.72	13.72	13.70	13.74
- Steam to evaporators	..	39.90	39.93	32.83	39.08	39.90	39.90	39.90	39.64	40.13
- Steam to vac. pans	..	.00	.00	.00	.00	.00	.00	.00	.00	.00
- Vapour to vac. pans	..	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85
- Steam for feed heat.	..	.00	.00	.00	.00	.00	.00	.00	.00	.00
- Total process steam	..	41.73	41.82	34.73	40.94	41.73	41.73	41.72	41.53	42.03
- Steam to Th. comp.	..	.00	.00	5.00	.00	.00	.00	.00	.00	.00
- Steam to PRV	..	8.93	.00	1.87	8.08	10.03	8.93	8.93	9.05	8.79
- % steam saved	%	0	0	0	2	0	0	0	0	0
- Live steam load	T/hr	37.81	38.80	36.26	37.11	37.69	37.81	37.81	37.57	38.04
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
- % power saved	%	0	0	0	0	1	0	0	0	0
- Internal power cons.	KW	3150	3150	3150	3150	3045	3150	3150	3150	3150
- Power to grid	..	0	859	0	0	0	0	0	0	0
- Realisation from bagasse	Rs.lacs	120.2	113.4	130.8	125	121	124	130.6	121.9	118.7
- Realisation from power	..	0	61.9	0	0	0	0	0	0	0
- Total realisation	..	120.2	175.3	130.8	125	121	124	130.6	121.9	118.7

- 13 -

Summary result from model for a 105 TCH process factory

13 August 2007

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Recent development-2006-07

- Two factories have achieved steam consumption close to calculated figures
  - GMR Sugar, AP-35% on cane
  - DSCL Sugar, Ajbapur-38% on cane

- Recent proposal from a sugar consultant-32% on cane

- Bulk of the 400 factories still operating at 45 to 50% on cane

Conclusion

- 40 to 50% savings can be achieved by application of MED in many types of process industry
- In India, Sugar industry alone can save about 7.5 million T of bagasse-power generation from the same would result in GHG saving of over 5 million T/year
- Newer application of MED likely to result in revolutionary changes in the energy-scope in the industries

MED
Retrofit Applications

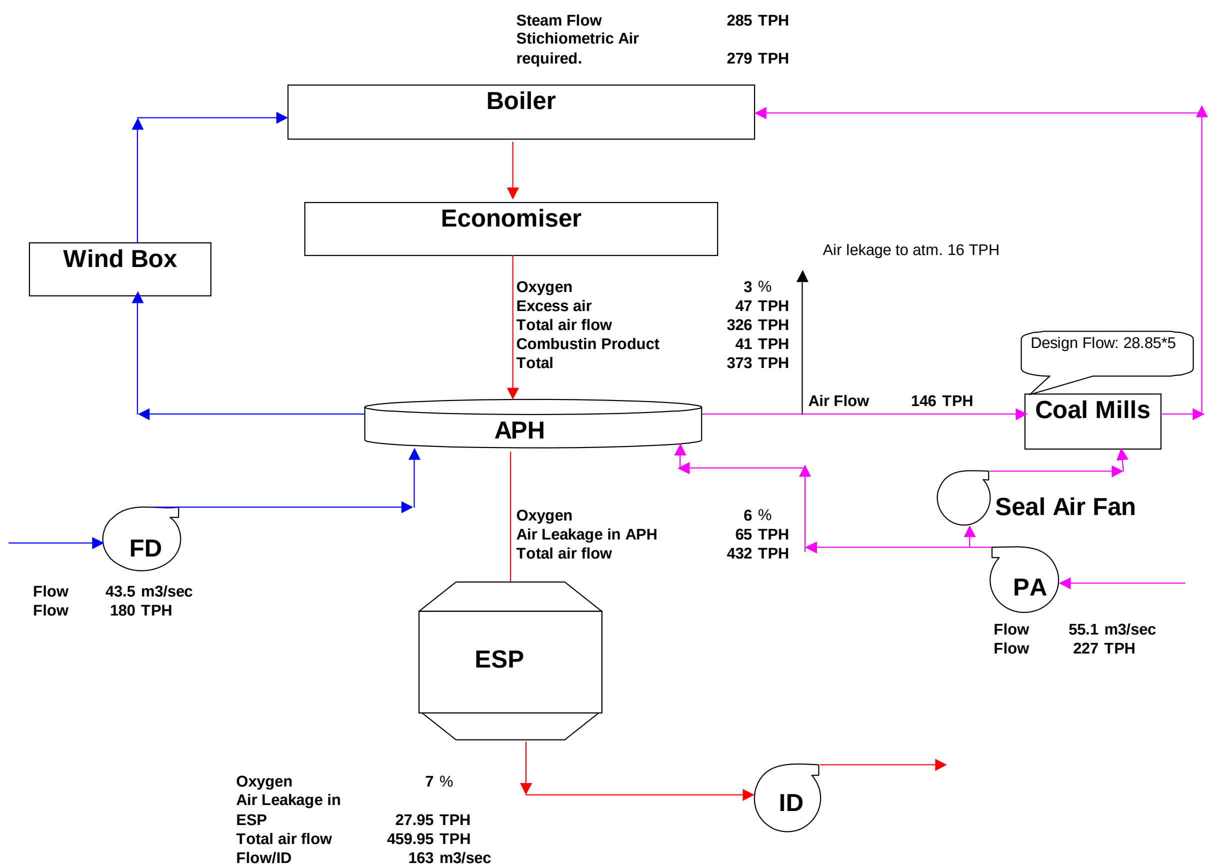
Retrofit Methodologies-Comparative Evaluation

Methodology	Guiding Principle
Conventional energy audit	Mainly evaluation of efficiency of the existing operating system, used only for retrofit
Benchmarking	Comparing against the existing best-Gap analysis-Project design
MED	Challenging the existing best and setting new targets based on fundamentals. Can be used for new design as well as retrofit

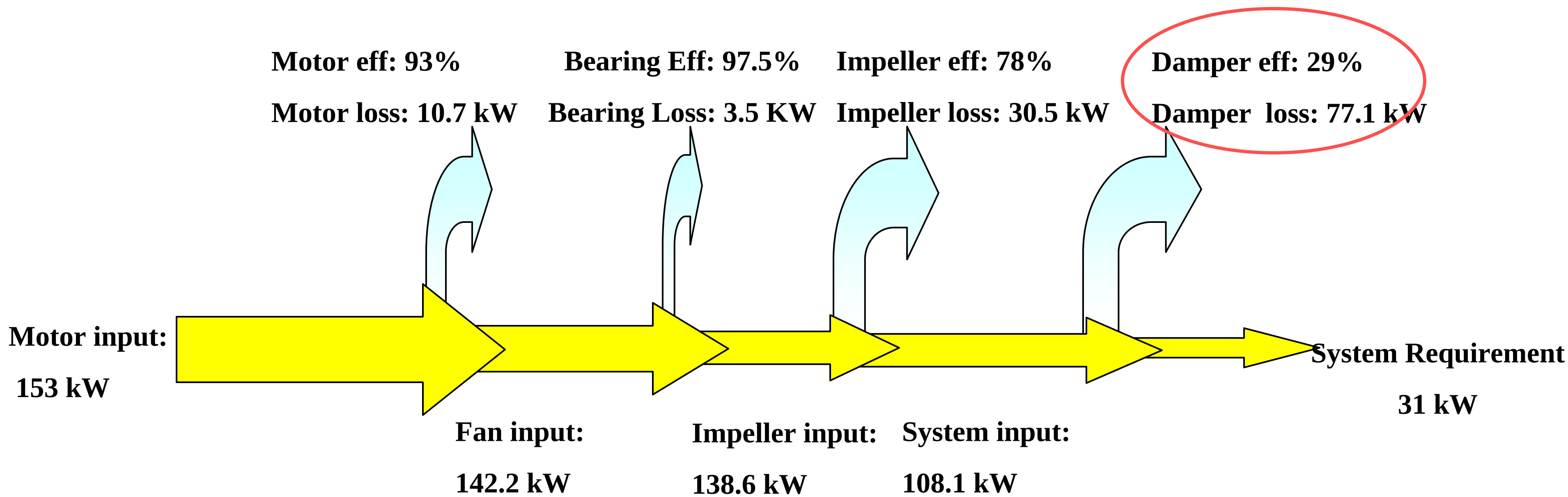
Case study

Power Plant

Boiler Auxiliary – Gas Balance



Sankey of FD Fan – Present System



Present system eff: 20%

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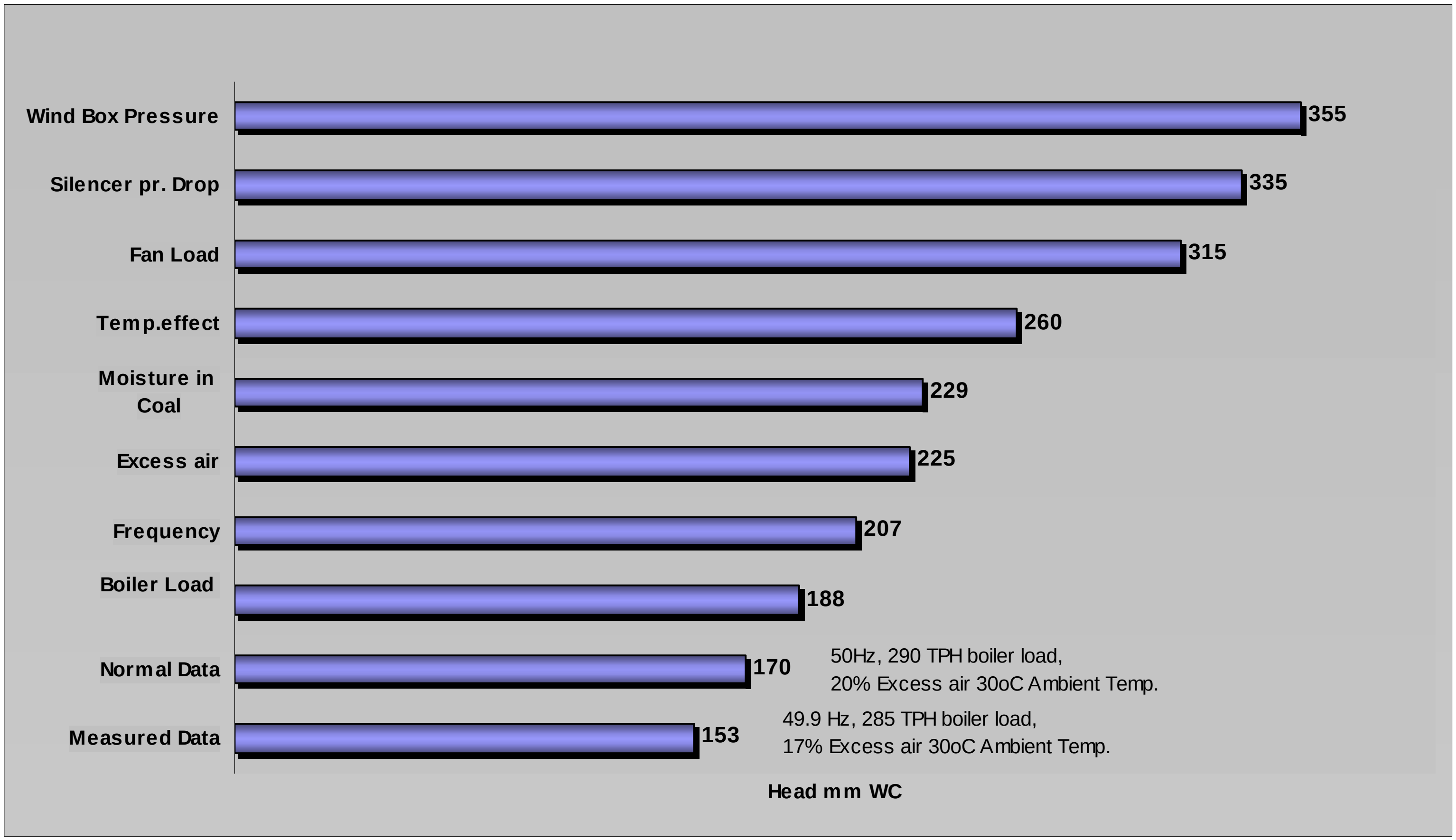
Constraint on Pressure : Normalized Condition



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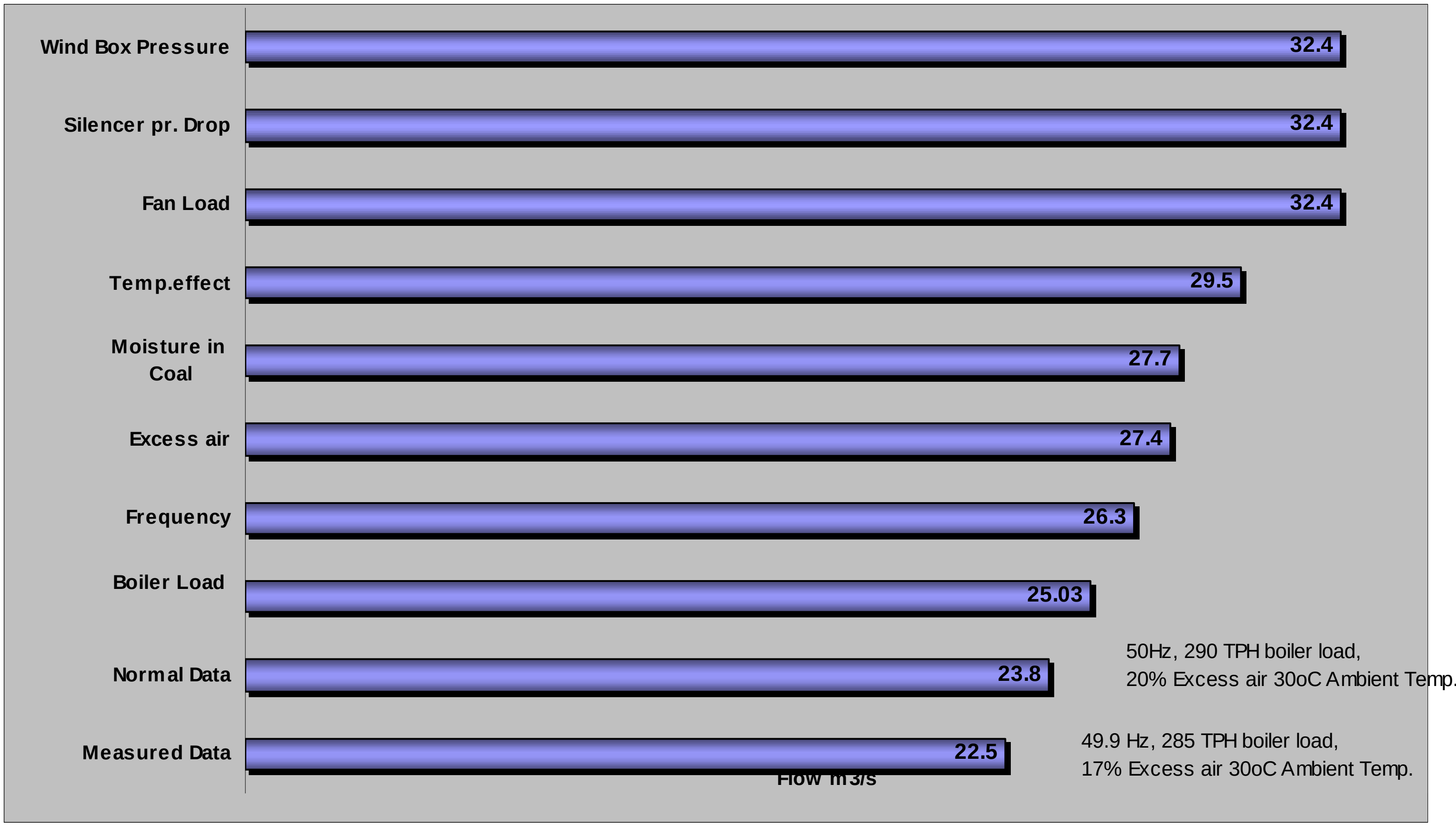
Constraint on Flow: Normalized Condition



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Screening of Options : Constraint Screen

S.No	Options	Result	Remarks
FD Fan			
1	Existing fans + VFD with LT/HT motor	√	Passes the Contraint
2	Two new fans with new LT motor & VSD	√	Passes the Contraint
3	Existing fans with lower RPM motor(740 rpm)	X	Will not be adequate for low frequency when boiler load is 305 TPH. - Does not pass the technical constraint screen
4	New smaller size fans with existing motor	X	Does not pass the constraint screen as margins will be reduced
5	Gear Box	X	Does not pass the constraint screen as margins will be reduced
6	Slip ring motor with GRR	X	Not a normal practice in power plants. Need further study
7	New single fan	X	Does not pass the constraint screen as margins will be reduced

Screening of Options: Economic Screen

S.No	Options	Savings	Investment	Result	Remark
FD Fan		KW	Rs Lac		
1	Existing fans + VFD with LT/HT motor	184	74.1	√	Most economical option
2	Single fan + VFD with LT motor (One stand by fan)	187	163	X	As compared to one eff. gain is less but the cost is high

In addition to the above shortlisted option, single fan option for the existing boiler is evaluated considering reduced margins.

Case study

Edible oil processing

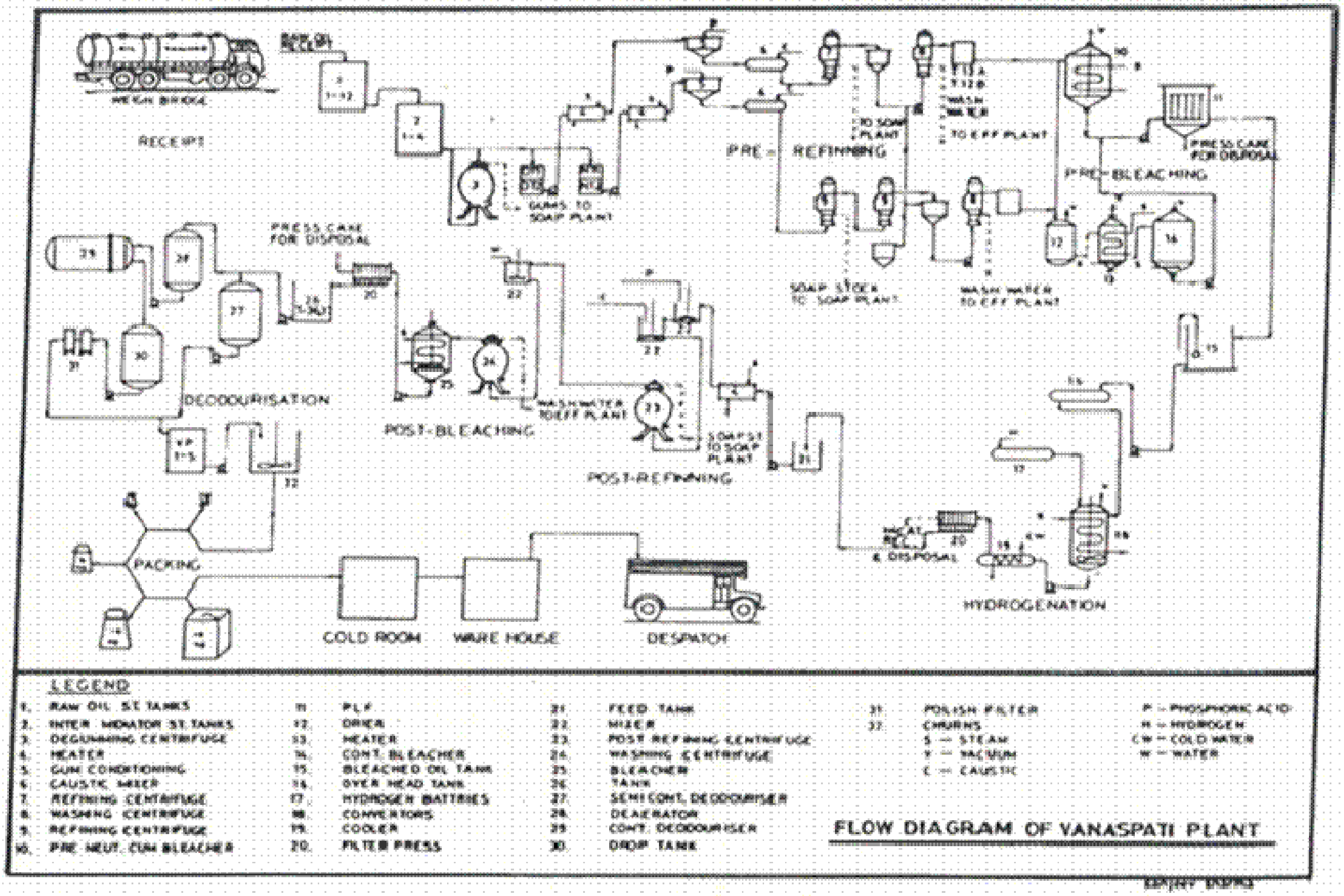


Fig. 5.2 Flow Diagram of Vanaspati Plant

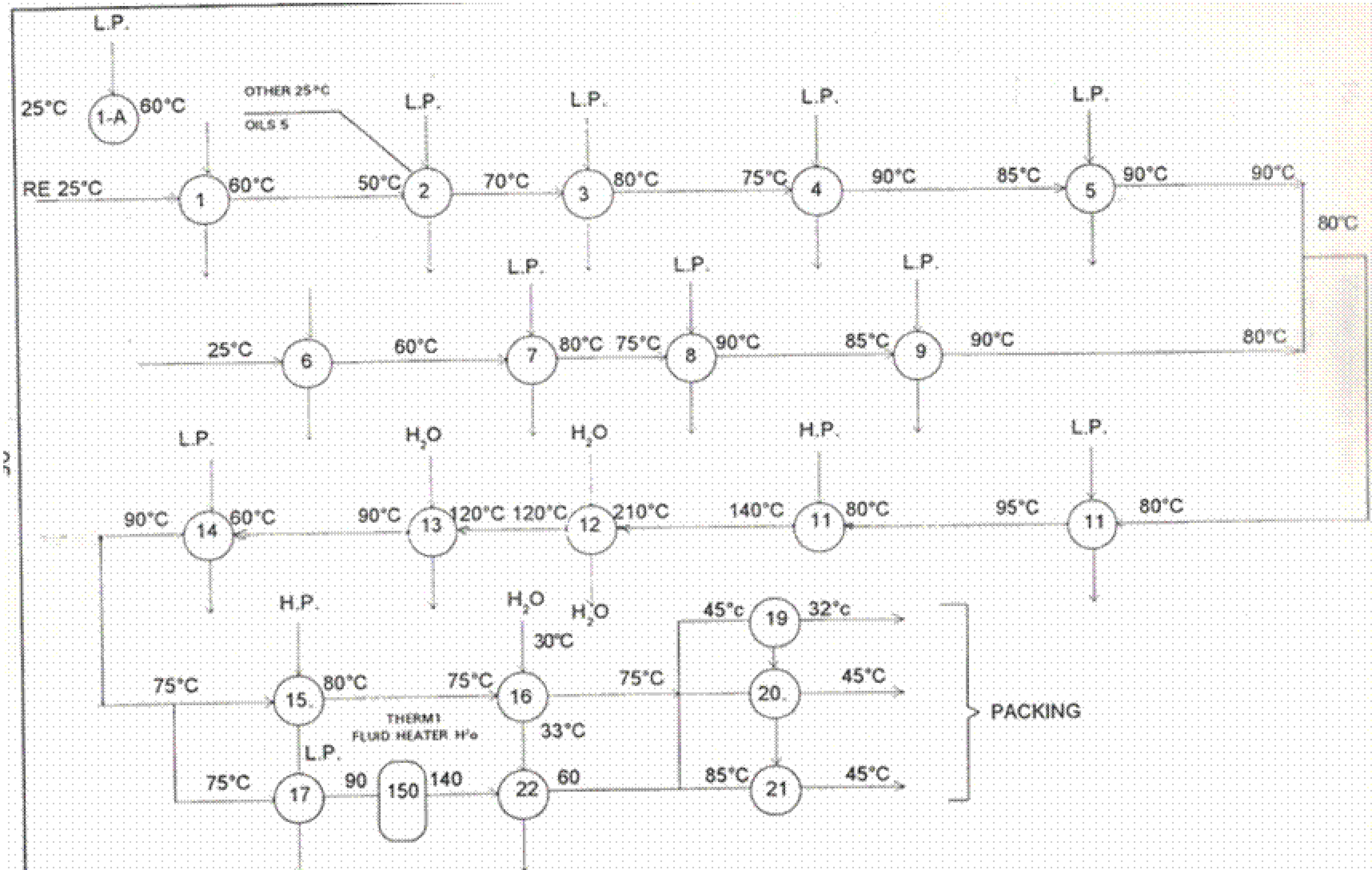


Fig. 5.6. Heating cooling system

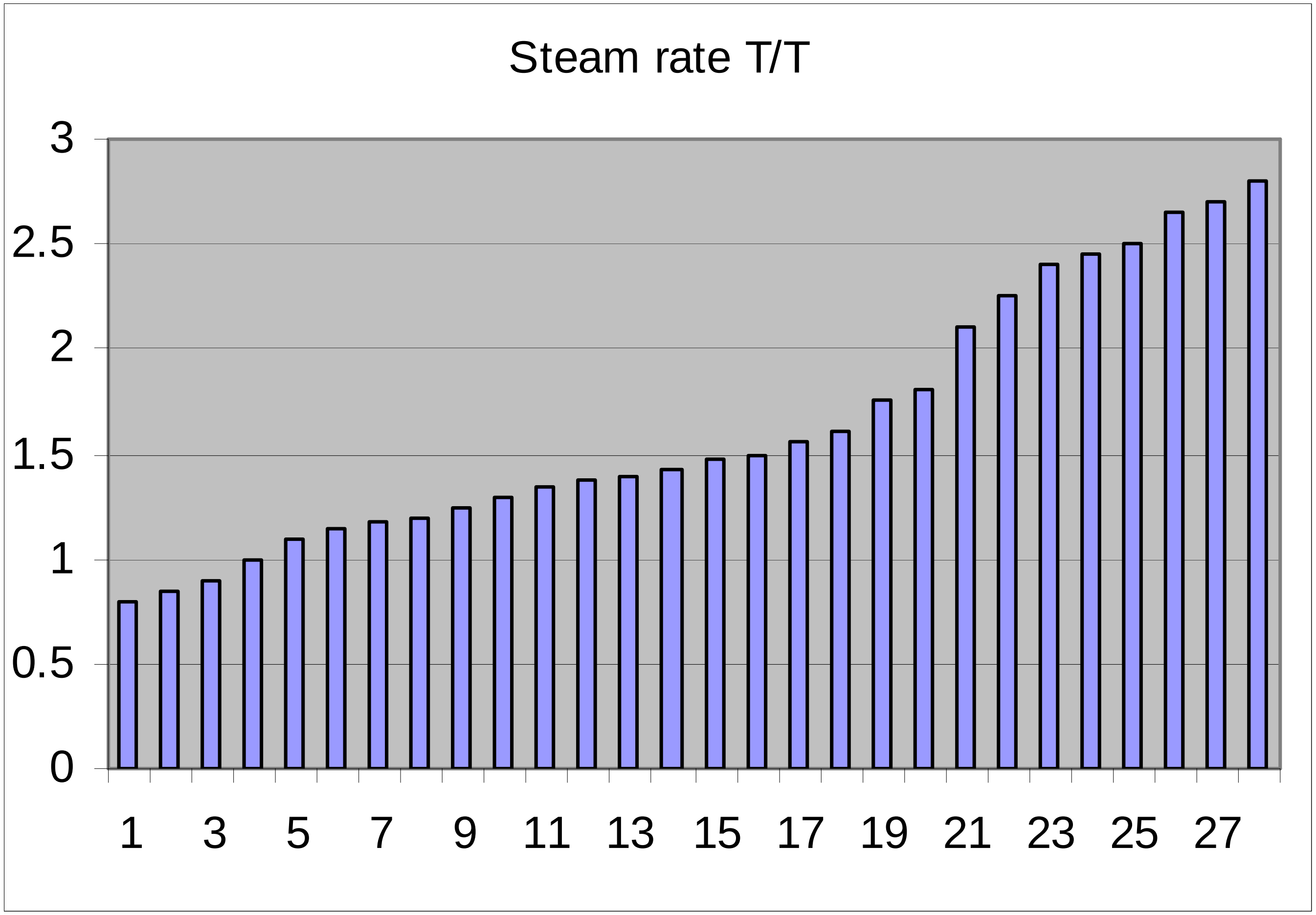
Table 5.7 - Steam usage in heating system

Heat exchanger No.	Flow-rate T/Hr	Temperature -'C			Heat Gain KCal/Hr
		Inlet	Outlet	Rise	
1 A	2.5	25	60	35	43,750
1	4	40	60	20	40,000
2	4	50	70	20	40,000
3	4	70	80	10	20,000
4	4	75	90	15	30,000
5	4	85	90	5	10,000
6,7	7	25	80	55	1,92,000
8	7	75	90	15	52,500
9	7	85	90	5	17,500
10	10	80	95	15	75,000
14	10	70	90	20	1,00,000
17	4	75	90	15	30,000
				Total L.P.	6,51,250
11	10	80	140	60	3,00,000
15	6	75	190	115	3,45,000
				Total H.P.	6,45,000

Theoretical need

Particulars	Units	Quantity
LP steam	Kcal/Hr	651250
HP steam	Kcal/Hr	645000
Total	Kcal/hr	1296000
Average enthalpy	Kcal/T	500
Total steam required	T/Hr	2.59
Production	T/Hr	10
Reqd. Sp. consumption	T/T	0.26

Specific steam consumption-28 Plants



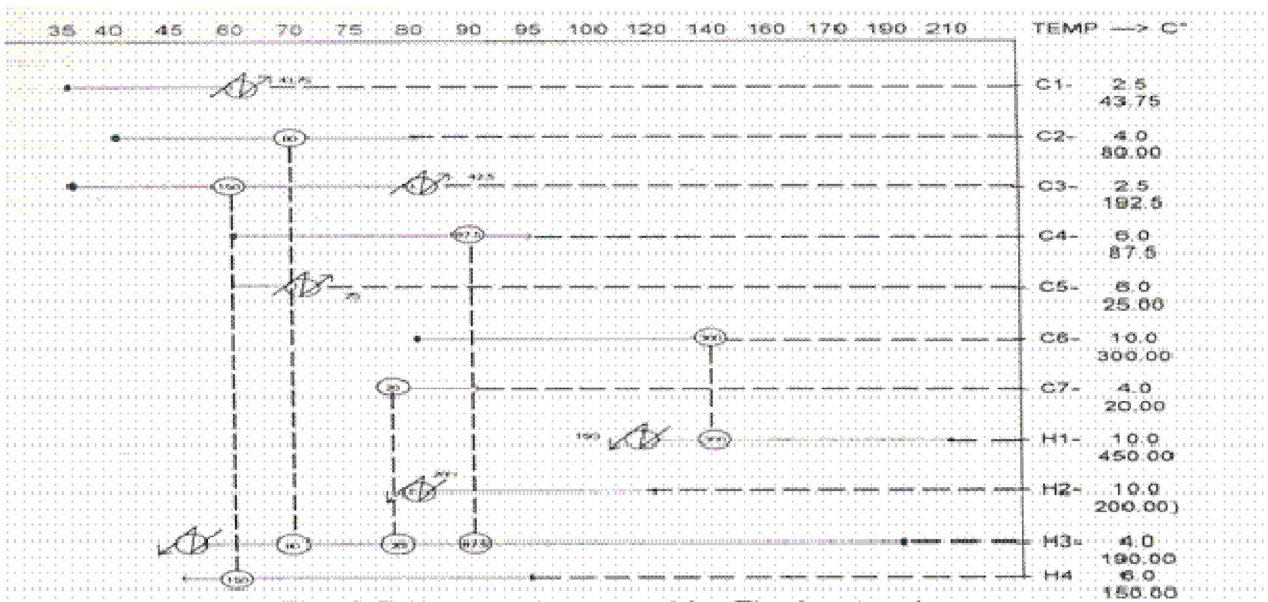


Fig. 6.7 Heat exchange grid - Final network.

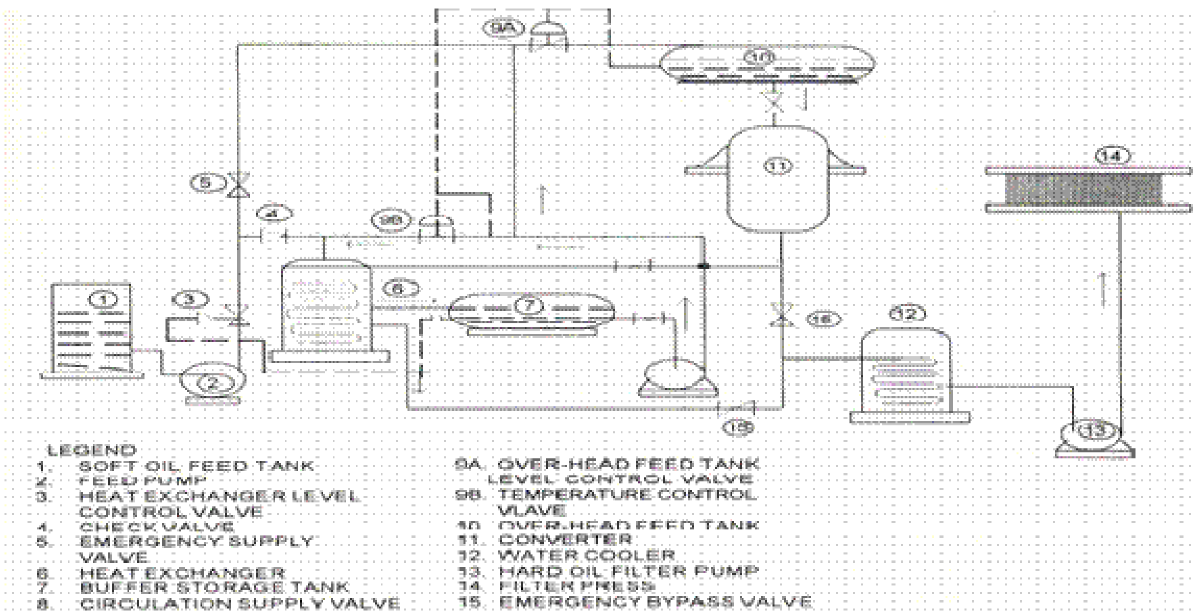
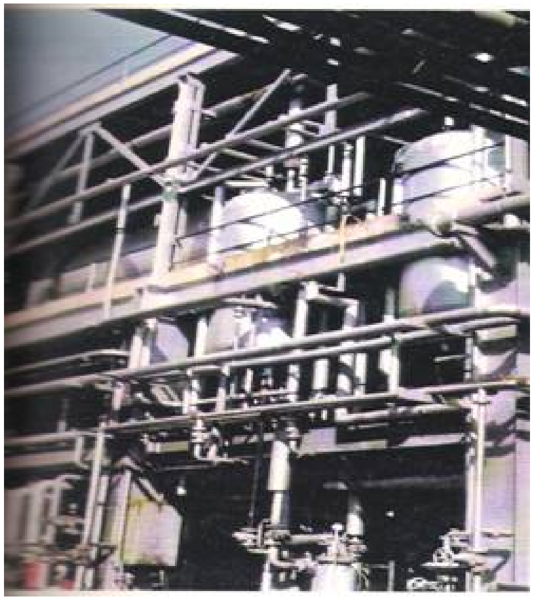
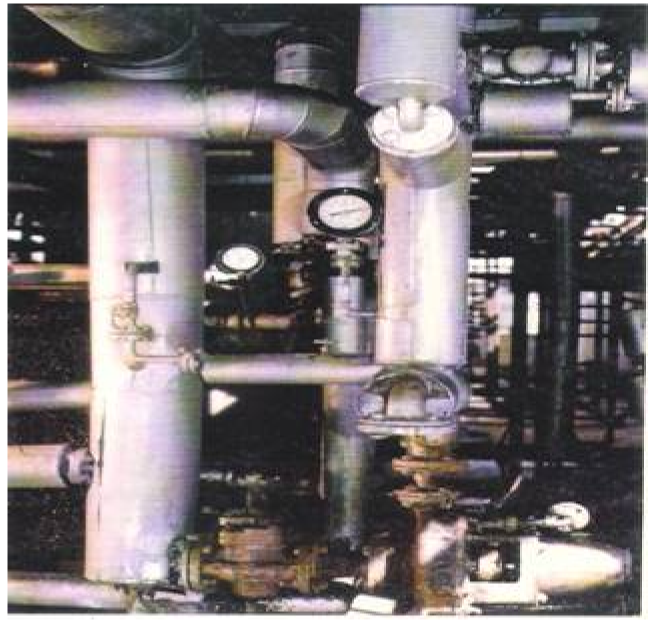


Fig 6.9 - Modified heat exchange system.

Installations



CD PLANT



HEN PIPING FOR CD

Practical demo of HEN in Edible oil processing

CONVERTER HEN SYSTEM

Operating results

- Pre-HEN consumption-1.2 T/T
- Target consumption-0.55 T/T
- Best achieved-0.75 T/T

Retrofit challenges-Proper sizing & laying out HEN system
Dynamic heat transfer coefficient behavior of oil

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Case study

Paper

Step by step approach-Retrofit solution

Min. energy	Actual usage	Gap analysis	Constraints	Implementation
Requirement	Measurement system	Benchmark	Technical	Long term journey plan
Process Synthesis	Accounting system	Overall gap	System	Intermediate & short term Plan
Synthesis of HEN	Monitoring	Component Gap	Economic	M&E mechanism
Exergy analysis	Overall usage	System evaluation	Financial	
Overall minimum need	Discreet Usage	Equipment evaluation	Others	

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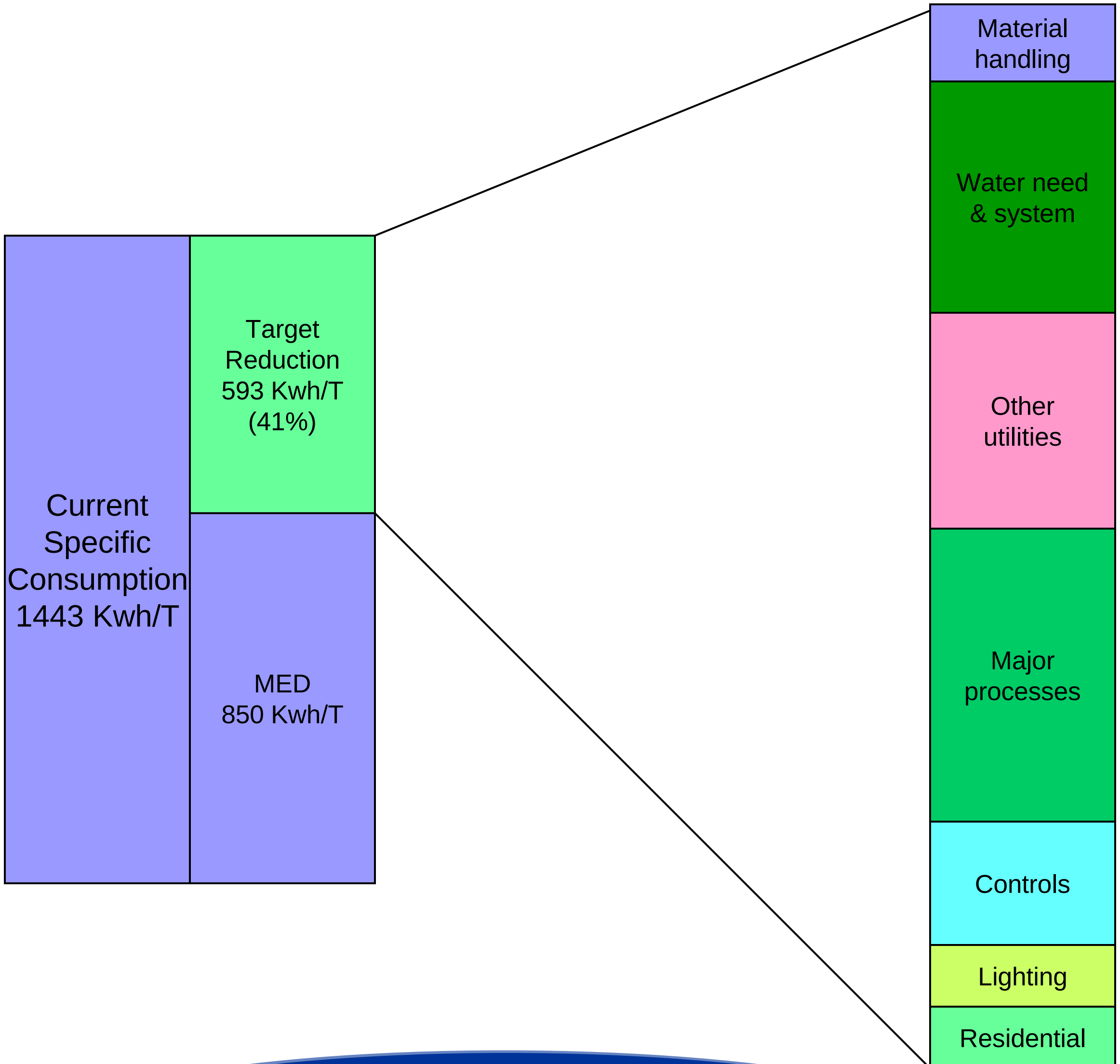

Developing long term plan and Setting annual targets

Scaling the Technology Ladder - Plan

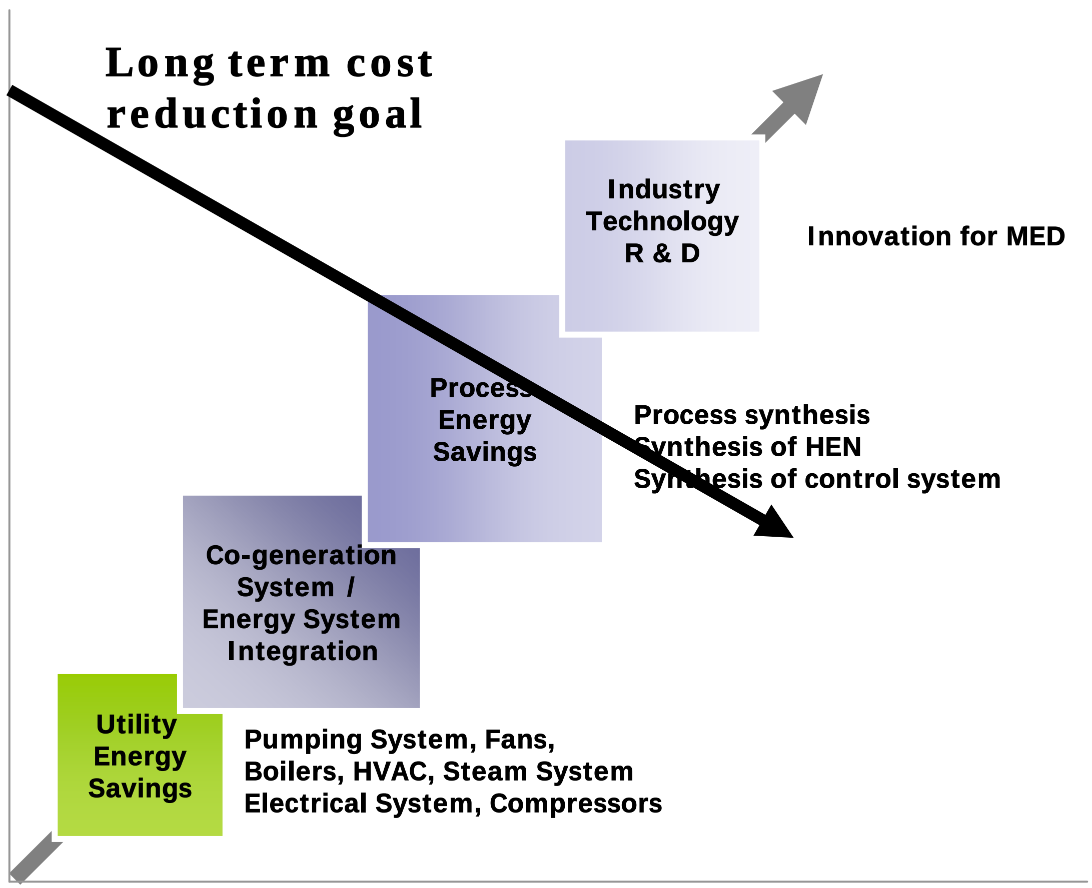

Table 5.2 Electricity Consumption in Paper Industry (Kwh/Tonne)

Company	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	10 year (% chg)
Seshasayee Paper & Boards	1755	1873	1816	1760	1829	1740	1503	1387	1353	1364	-22
Amrit Banaspati Co.	1315	1330	1312	1434	1352	1237	1102	1097	1170	1050	-20
West Coast Paper Mills	1468	1451	1306	1281	1295	1286	1312	1216	1174	1189	-19
Parijat Paper Mills	500	431.22	391.19	371.77	373.4	434.7	610.03	609.87	461.81	408.64	-18
Andhra Pradesh Paper Mills	1538	1738	1664	1615	1628	1674	1360	1324	1313	1263	-18
Delta Paper Mills	1162	1295	1251	1190	1119	1095			1136	982	-15
Sirpur Paper Mills	2009	1995	1867	1793	1798	1855	1834	1742	1763	1788	-11
Tamil Nadu Newsprint & Paper	1659	1654	1630	1607	1595	1556	1629	1717	1657	1527	-8
Satia Paper Mills	1203	1138		1221	1055	1147	1184	1185	1167	1115	-7
Ballarpur Industries	1406	1439		1443	1447	1436		1398	1430	1354	-4
Orient Paper & Inds.	1742.18	1823.44	1973	2045	1734	1731	1689	1601	1698	1687	-3
Shree Bhawani Paper Mills	1168	1033	1036	976	964	985	1060	1165	1163	1137	-3
Simplex Mills Co.	1126	1241	1054	1178	1012	1030	1077	1093	1161	1104	-2
N R Agarwal Inds.	547	517	484	554	587	561	464	610	591	548	0
Nice Papers		756.02	615.65	562.98	544.74	373.29	428.99			376.09	
Shree Ajit Pulp & Paper			430	377	344	309	306	298	301	296	
J K Paper		1662	1656	1691	1595	1478	1518	1497	1448	1416	
Abhishek Industries								840	820	810	
Victory Paper & Boards(India)					1308	1089	950	1020	823	776	
Emami Paper Mills				858	803	889	759	804	790	758	
Sangal Papers		793	961			851	756		694	730	
Global Boards		1384	1063	931	951	898	989.82	760.72	846.97	705.06	
Benchmark Average	1476.87	1352.24	1247.48	1228.99	1198.20	1223.73	1111.07	1147.20	1109.43	1037.49	
GJ/tonne of Paper industry	5.32	4.87	4.49	4.42	4.31	4.41	4.00	4.13	3.99	3.73	-30
Average	1116.00	1092.01	1029.79	1191.44	989.62	972.09	948.32	970.07	1118.61	1082.45	
GJ/tonne of Paper	4.02	3.93	3.71	4.29	3.56	3.50	3.41	3.49	4.03	3.90	+3
No. of companies	78	85	92	108	111	111	92	83	65	41	

Status of paper industry-CMIE 2006

DSCL ENERGY SERVICES

MED Application-Looking Ahead

- The MED process is expensive and complex-would require huge capacity building at both ends-Industry and Service Providers

- Market competition for global players likely to help in faster penetration

- Energy and environmental compulsions would also catalyze-example of sugar

Nanoscience*-Exciting Application of MED Concept

- Production of hydrogen from water
- Selective catalyst for EE in manufacturing processes
- High efficiency solar cell at 1% of present cost
- Super light weight materials
- Nanostructured materials for fuel cells, batteries etc
- Biotechnology for materials synthesis and energy harvesting

*www.sc.doe.gov/bes/reports/files/NREN_report.pdf

Thank you