AN APPROACH TO CONSERVE ENERGY THROUGH RESEARCH AND DEVELOPMENT EFFORTS

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ABSTRACT

Paper industry is highly energy intensive and there will be continuing vigilence by pulp and paper mill managers to enhance conservation efforts. Scandinavian and other developed countries have made significant progress in this direction. R&D sectors in these countries have played a vital role in fulfilling goals of energy conservation programme. Energy efficiency of new process has always played a key role in R&D work. Energy is a major constraint faced by Indian Paper Industry. Paper Industry has set a target of 20% reduction in energy consumption by 1990. In addition to in-plant measures to conserve energy the steps needed will entail application of energy saving technologies and identification of fossil fuel substitute energy resources. There will be an increasing thrust on R&D sectors to achieve these goals. In today's environment of energy awareness, perhaps avenues of cooperation between industry, government and research institutes can be paved to make R&D efforts more effective. The present paper discusses some of the R&D areas which are considered important in terms of energy conservation and also R&D work initiated, at CPPRI, which are aimed to conserve energy.

Introduction:

Energy has become the third largest cost component behind fiber and labour in producing a tonne of paper. Costs of both power and fuel are going up by leaps and bounds and for the survival of industry major thrust in coming months must be on research and development in this area with an increased emphasis on reduction to practice of all viable energy-conservation and energy-generation alternatives. Industry's greatest challenge and opportunity will be to effectively maximise it's fuel flexibility and it's ability to fulfill a major portion of it's energy needs, from internal non-fossil sources.

The report of sub-committee, for energy of Development Council for paper and allied products, reviews the present status of energy usage techniques prevalent in paper industry (1). The recommendation of this committee for management and conservation of energy will form valid guidelines for achieving a reduction in energy usage by about 20% by 1990.

Energy audits, use of mechanical pump seal, cogeneration systems, new and efficient heat recovery systems, concept of total recycle, high pressure steam generation, improved evaporator system, more efficient heat recovery systems and pumps and motors designed for actual operating needs are essentially in-plant process modifications and are the types of energy conservation programmes that can be implemented in most pulp and paper mills. The other concurrent approaches, to control, manage and reduce energy costs and usage in pulp and paper mills, will be (i) increased use of renewable energy resources, (ii) improvements in energy efficiency and use of less purchased energy and (iii) efforts to commercialize major technological concepts in pulp and paper making processes such as new technique for pulping, forming, water removal and coating.

New technologies could impact our nation's energy situation. However, serious attention obviously will have to be given, in applying some of the landmarks in process technology, under Indian conditions. It may not be possible in existing mills to achieve the economics of the scale in the matter of energy consumption that are available in the west, considering multiplicity of equipment of limitted capacity in our paper mills. However according to energy committee survey (1) even a modern mill in India consumes 70% more primary energy and 7% additional electrical energy to produce one tonne of paper when compared to Scandinavian mills. This shows that there is a wider scope to enhance energy conservation efforts.

In Sweden Paper Industry has managed to cut it's use of oil fuels by over 70% in a decade (2). In USA energy from residual fuel and self-generated sources, now accounts for an estimated 57 - 58% of total energy (2). Japan is making heavy investiments in fossil fuel substitute energy programmes (3). Japan, in 1975, used 6.62×10^3 k. cal of total purchased energy per tonne of a paper produced and this was reduced to 4.37×10^3 k.cal by the end of 1983, which accounts to about 34% reduction in it's purchased energy. In Indian mills purchased energy accounts for about 70% and varies from 7.62 to 13.25 M.kal/t paper. Most of the developed countries have made significant progress in fulfilling the target of energy conservation programmes. Some of the Indian mills have already taken some of in-plant energy conservation measures. From the trend in energy conservation measures taken minimum target of 20% reduction in energy consumption by 1990, has been fixed. Our technologists and scientists must apply themselves to the task of achieving this goal and reduce the consumption of power and fuel based on total energy concept.

R&D has to play a key role in energy conservation programme. With our wide range of raw material appropriate energy efficient process technologies need to be developed. Effective and increased utilization of secondary fibers, development of suitable high yield pulping processes, concept of total recycle, identification of fossil fuel substitute energy resources, and possibility of applying some of the landmarks in process technologies in pulping, forming, water removal, chemical recovery and coating, are some of the important areas where R&D will be an vital tool. The present paper discusses some of the important areas, where energy can be conserved. Central Pulp and Paper Research Institute has given priority to R&D projects relating conservation of utilities. Findings of some of the research projects which are aimed at energy conservation are also discussed.

DISCUSSION:

Chemical Pulping:

Integrated mills are going to use increased amounts of hardwoods in their raw material furnish. These tropical woods are dense in nature and require longer cooking cycle and higher dosages of cooking chemicals as compared to traditional raw material bamboo. From the information available from mills, it can be generalized that mills using more hardwoods consume excess steam compared to mills using less hardwood or only bamboo. Cooking conditions of some raw materials are given below:

Table-1

PULPING CONDITIONS OF SOME RAW MATERIALS

Raw Material	Density kg/m^3	Chemicals as Na_2O,%	H. Factor/ Temp°C
Bamboo	570	15	1400 (165)
Mixed woods	550-650	20	2100 (170)
Eucalyptus tere-cornis.	560	16	1760 (165)
E. globuls	510	14	540 (165)

From the cooking cycles listed in Table-1, it is evident that mixed hardwoods require more steam per tonne of the pulp produced. Due to their high density longer cooking cycles are required. Longer cooking cycles not only require more steam but the concentration of resulting black liquor solids will on lower side. Monzie etal (4) have shown that it would be possible to reduce the length of cooking cycle by destructuring of chips. Cooking time of 120 minutes, in pulping of beech, was reduced to just 45 minutes by destructuring. Results of pulping of destructured chips are given below:

Table-2

PULPING OF BEECH DESTRUCTURED CHIPS

Particulars	Conventional Chips	Destructured Chips
Chemicals as A.A.,%	22.0	22.0
Cooking temp, C	170	170
Cooking time, mints.	120	45
Pulp yield, %	47.3	49.0
Kappa number	21.6	21.4
Breaking length, km.	7.35	7.03
Burst Index, kPa.m2/g	4.9	4.4
Tear Index, $mN.m^2/g$	8.54	7.01

The results show that destructuring does not affect the quality of pulps. They have also established that it is possible to reduce the material to liquor ratio, which is important from steam economy view point. It has been reported by Mitra (5) that reduction of liquor to wood ratio from 4.4 to 4.0, savings of US $ 250,000/year was achieved by way of energy conservation.

Continuous digesters are more energy efficient with resulting black liquor having 2%- 4% higher solids content. Possibility of use of continuous digesters, must be explored. Indigenous equipment manufactures should make efforts to design & develop suitable continuous digesters which can be adopted to our size of mills.

High Yield Pulping:

Today new processes, like thermomechanical and chemi-thermomechanical pulping, are capable of producing high strength mechanical pulps. In developed countries there is an increased use of these pulps not only in wood containing papers but also, in mass produced varieties like writing and printing papers. Increased use of high yield pulps is considered important in terms of conservation of national resources. Studies, on production of high yield pulps from indigenous fiber resources, particularly from fast growing low density raw material, have shown that satisfactory quality pulps can be produced which can atleast partially substitute chemical grade pulp in writing and printing papers. Some of the properties of TMP and CTMP pulps produced from indigenous raw materials is given in Table-3.

Table-3

PROPERTIES OF TMP AND CTMP PULPS

Pulp	Total specific energy kWh/t pulp*	Pulp Yield %	Tensile Index N.m/g	Tear Index $m.N.m^2/g$
Whole Mesta TMP	900	91.0	29.0	3.60
Whole Mesta CTMP	1100	86.4	23.0	4.10
Eta reed TMP	1100	96.7	17.5	3.49
Subabul TMP	1000	94.6	18.5	2.00
Subabul CTMP	975	88.6	52.0	5.00

*Energy requirement for freeness value around 400-500 ml CSF.

The strength properties show that some of these high yield pulps could be a potential source high yield pulp component in the pulp furnish.

Energy intensiveness of these pulping processes can not be overlooked. However, with the advent of technology it has become possible to recover the electrical energy in the form of steam. Thus heat recovery in TMP or CTMP should be considered as an integral part of TMP system. Following Table-4 gives the pattern of energy requirement with varying proportion of TMP in pulp furnish.

Table-4

ENERGY PATTERN FOR DIFFERENT PULP FURNISHES

Pulp Furnish (%) TMP*	Chemical**	Total energy* G.cal/100 t pulp
0	100	278
10	90	276
20	80	274
30	70	272
40	60	270

*TMP, 3000 kWh/t pulp corresponding to 2.58 G.cal/t pulp

**Chemical pulp - Energy will be 0.35 G.cal power + 2.43 G.cal steam.

Thus from the energy pattern it is clear that there is a marginal change in the total specific energy requirement by replacing chemical pulp by TMP. However a TMP system operating without heat recovery exhausts about 75% of input refining energy to atmosphere. By controlled refining and effective steam collection and heat transfer equipments, it is possible to recover upto 70% of the total refining energy(6). The Bravican mill of Holmens Bruk has an efficient heat recovery system. The total amount of energy recovered, in TMP system, amounts to approximately 25 G.cal/h which corresponds to 700 kWh/t pulp (7). Thus with development of heat recovery system and use of TMP and CTMP pulps in writing printing and other grades of paper substantial proportion of energy could be saved. There is a scope to explore the possibility energy saving by the use of high strength mechanical pulps either from indigenous or imported sources.

Agricultural residues and Secondary fibers:

Wide range of agricultural residues constitute the second major fiber resource after forest based raw materials. Nearly 40% of the country's installed capacity is fulfilled by small mills based on agricultural residues. Most of these small mills are depending entirely on purchased energy. The energy consumption, though on lower side compared to integrated mills, varies from 3.8 to 6.2 G.cal/t paper. Mostly chemical pulping process is being followed in most of these mills. Batch digester or tumbling digesters are used. Higher bath ratio are required to be maintained which consumes more steam. CPPRI studied the application of vapour phase pulping process for straws and bagasse and the pilot plant results have confirmed that by employing this process there will be a substantial reduction in steam consumption and also volumes of effluents generated are less. The results of pilot plant studies are given below:

Table-5

VAPOUR PHASE PULPING OF RICE STRAW (8)

Particulars	Conventional liquid phase	Vapour phase
NaOH, %	13.7	13.6
Straw to cooking liquor ratio	1:5	1:3.1
Black liquor solids, %	9.6	18.4
Steam consumption t/t pulp	4.8	1.7
Effluent m^3/t pulp*	61	38

* Black liquor and washings.

The results clearly show that by vapour phase process it is possible to reduce steam consumption by nearly 60%. Vapour phase process can be effectively carried out in Pandia type continuous digesters. Small mills should seriously think of applying vapour phase process.

Studies at CPPRI, show that it is possible to produce better quality chemical grade pulps from agricultural residues by applying milder cooking conditions. (Table-6)

Table-6

PULPING CONDITIONS FOR RICE STRAW

Particulars	Soda process		Chemimechanical process
NaOH, %	10	10	12
Cooking temp, °C	160	140	90
Total pulp yield,%	48.0	50.1	63.8
Kappa number	26.3	28.5	-
Burst index,kPa.m^2/g	3.95	4.30	1.80
Tensile Index, N.m^2/g	59.5	67.5	53.5
Tear Index,m.N.m^2/g	5.10	5.50	3.30

Above results show that it is possible to obtain satisfactory quality pulp even by applying milder cooking conditions. Small mills should try to keep optimum temperature and time for cooking.

Secondary fibers:

Increased use of waste paper should gain momentum in the present circumstances of energy crisis. Waste paper utilization not only saves fibrous raw material but a saving in total energy will be nearly 60% as that required for vergin fiber. In Europe as high as 50% of waste paper is being utilized while in India only 20% of waste paper is used. Enhanced efforts should be made for effective utilization of this valuable secondary fiber resource. Proper methods of collection, screening and economic deinking process should pave the way for increased utilization of waste paper. Serious efforts should be made to reuse the waste newsprints for the manufacture of newsprint and also cheaper grades of papers.

Pulp Washing:

Washing of pulps is an important operation from the viewpoint of chemical losses and steam energy requirement in subsequent stage of evaporation of black liquor. Utilization of foul condensate in place of hot water generated by heating fresh water has resulted in gainful utilization of blow heat which enabled to increase the temperature of black liquor by 4-5°C (10). A compromise between dilution factor and soda losses needs to be made to reduce the load on evaporation. In one of the mill by changing the dilution factor there was an increase in chemical losses from 22-25 to 30-35 kg/t pulp. However 10% reduction in the volume of black liquor per digester was achieved, which has led to a substantial reduction in steam requirement in evaporation.

Concentration of black liquor to be fed to evaporators will have profound influence on the steam requirement in evaporators. Following table gives the steam demand with varying concentration of weak black liquor solids.

Table-7

EFFECT OF BLACK LIQUOR CONCENTRATION ON STEAM DEMAND

Black liquor solids, % w/w	10	12	14	16
Water to be evaporated t/t pulp for 45% solids	13.84	13.04	12.27	11.47
Amount of steam* required t/t pulp	4.33	4.08	3.83	3.58

* 4 effects with a steam economy of 3.2

For every one percent increase in solids it is possible to save nearly 25 t of steam/day for a 100 tpd pulp mill. More R&D efforts are needed to improve the washing efficiencies so that more concentrated black liquor can be obtained.

Bleaching of Pulps:

Substitution of CE stages of bleaching by oxygen bleaching has advantages over conventional bleaching sequences. Nearly 25 kg/t pulp of organic matter is liberated during CE stages which is going as waste through effluent. By adopting oxygen-alkali it is possible to utilize this organic matter as fuel in furnace. It has been reported that for 120/tpd mill about 21 tonnes of extra steam/day can be generated by adopting oxygen bleaching (9). The possibility of applying oxygen bleaching, under our conditions, should be explored. High consistency and lower temperature conditions during alkali extraction and hypochlorite stage of bleaching should be practiced.

Chemical Recovery system for Small Mills:

Development of techno-economically feasible recovery system for small mills is still a pressing problem. These mills are contributing nearly 30% to the total production of paper and paper products. About 105 units, with an installed capacity ranging from 2000 to 10,000 tpa, are operating today. Absence of chemical recovery has lead to wastage of valuable chemicals and organic matter. Organic matter, dissolved during pulping, having fuel value equivalent to 0.25 million tonnes of coal is being discharged through effluents. Conventional recovery system is not feasible due to high capital cost. CPPRI studied extensively on auto-cuasticizable ferrite process for the treatment of straw spent liquors. Laboratory and plant scale studies have indicated that this process shows a promise of being well suited for small mills.

The advantage of this process over conventional chemical recovery system are:

i) Simplicity and flexibility of the process;
ii) Require about 37% less capital inputs;
iii) Higher degree of causticizing efficiency;
iv) No smelt is formed so the process is safe; and
v) Auto-causticizing agent Fe_2O_3 is cheaper compared to lime and can be recycled.

Results of investigation on this process were encouraging and have raised hopes of having a techno-economically feasible recovery system for small mills.

Stock Preparation:

The electrical energy required for stock preparation varies from mill to mill and ranges between 150 - 300 kWh/t of the product (1). The energy for beating of fibers varies with the type of raw material used for pulping. Energy requirement in terms of PFI revolution, for pulps from different raw materials is given in Table-8.

Table-8

PFI MILL REVOLUTION FOR 35 °SR. SLOWNESS

Raw Material	RPM
Bamboo	4000
Spruce	8200
Mixed hardwoods	3100

Thus energy requirement is influenced by fiber length of the pulp fiber. Longer the fiber more will be refining energy required. The energy efficiency during beating, to a large extent, is influenced by the type of refining equipment. Today wide angle and conical refiners are common type of equipments used for refining of the stock. It is experienced that these equipments are not energy efficient. Following table gives the energy requirement with different type equipments.

Table-9

ENERGY REQUIREMENT IN DIFFERENT BEATING FQUIPMENTS

Beating/Refining Equipment	Energy kWh/ SR/100kg	Energy** kWh/t to raise slowness to 35°SR
Conical refiner (11)	1.67	300
Wide angle refiner (11)	1.41	254
Beloit Jones double disc refiner*	0.90	162

* Pilot plant scale data of CPPRI.
**Initial slowness, 17°SR.

From the above data it is clear that disc refiners are highly energy efficient compared to conical and wide angle refiners. Thus installation of energy efficient double disc refiner saves substantial portion of the energy required for stock preparation. More R&D efforts should be made to find out suitable plate patterns for refining of pulps from different raw materials. Plate patterns with higher bar crossing frequency should be preferred.

Black liquor evaporation and Combustion:

Evaporation:

Black liquor evaporation is an important operation and the efficiency of evaporator units will determine the the steam economy. Important properties of black liquors having influence on the evaporation and combustion characteristics are viscosity, surface tension, foaming index, swelling volume. There is a wide variation in these properties with the type of raw material processed. Black liquors from most of indigenous fibrous raw materials show high viscosity, poor colloidal stability and poor combustion properties. From efficient evaporation point of view it is desirable to have colloidally stable black liquor with low viscosity value at higher concentrations. High viscosity and precipitation problems have affected evaporator efficiencies. In developed countries a mill using conifers evaporate their spent liquors to 60-65% solids concentration in evaporators. While Indian mills the highest concentration which can be obtained in multiple effect evaporaters will not be more than 50%. Mills using hardwoods have restricted their evaporator outlet concentration to just 45%. However, it is possible to bring down the viscosity by maintaining an optimum level of residual active alkali in black liquors. Following table gives some of the important properties of spent liquors from different raw materials.

Table-10

PROPERTIES OF SPENT LIQUORS FROM DIFFERENT RAW MATERIALS

Raw material	Residual active alkali as Na_2O, g/l	Viscosity mPa.Sec. at 55% solids at 80°C	Precipitation point	Swelling volume ratio	Activation Energy k.J/mol.
Bamboo	7.1	310	No*	24	92
Mixed hardwoods	4.2	280	35	18	131
<u>E.tereticornis</u>	7.9	380	No	27	119
Pine (tropical)	8.9	37	No	47	-
Poplar	5.7	81	No	31	105

*Black liquors do not tend to precipitate during evaporation.

Bamboo ,eucalypt and mixed hardwoods exhibite very high viscosity compared to pine and poplar. Studies on the effect of residual alkali reveal that viscosity problems can be overcome by maintaining a minimum residual alkali around 6 g/l. Following table gives viscosity changes with R.A.A.

Table-11

VISCOSITY OF HARDWOOD BLACK LIQUORS WITH DIFFERENT R.A.A.

Residual Alkali g/l as Na_2O	Brooke field viscosity m.Pa.Sec. at 55% solids at 80°C
4.15	280
5.90	100
6.30	74
8.7	59

Thus by sacrificing little more NaOH, the viscosity problem can be controlled. Higher viscosities not only affect the steam economy of evaporater units, but also require sufficient energy in pumping. Some of the mill samples show viscosities as high as 1000 mPa.Sec. Following figures show energy required for pumping the black liquors with different viscosities.

Table-12

ENERGY TO PUMP BLACK LIQUOR OF VARYING VISCOSITIES

Viscosity m.Pa.Sec.at 80 C	Energy* ft. lb/sec(kW)*
300	649 (0.88)
400	689 (0.93)
500	728 (0.99)
700	810 (1.10)
1000	930 (1.26)

*Calculation based on 340 m^3/day feed rate.

With the use of long tube and forced circulation type evaporators energy for pumping high viscosity black liquors will be substantial and low viscosity black liquors will help in saving electrical energy required for pumping. Though the behaviour of black liquors during combustion process is not known precisely but it is generally experienced that hardwood black liquors show poor combustion properties. Poor combustion properties ultimately will impact the efficiency of energy conversion system of recovery boiler. Problems in the combustion process of kraft recovery furnace frequently appear to be related to variation in the composition of spent liquors. Nevertheless the commonly measured properties of the liquor (heat value, solids content, chemical composition and viscosity) have not revealed the factors responsible for the poor combustion. In the present paper two important properties i.e. Swelling volume ratio and activation energy explain the poor combustion behaviour. Lower swelling volume ratio and higher activation energy for hardwood black liquors (Table-10) are responsible for poor combustion. Higher the activation energy more difficult the combustion will be. More R&D efforts should be made to improve the combustion properties of these spent liquors.

CONCLUSIONS

From the above discussion it is clear that important R&D areas, which are considered important from energy conservation and even energy economic point of view, will be:

i) Improved pulping and pulp washing techniques;

ii) Effective utilization of agricultural residues and secondary fiber resources;

iii) Improved efficiencies in black liquor evaporation and combustion; and recovery system for small mills;

iv) Development of suitable high yield pulping process for woody and non-woody raw materials;

v) Alternate energy resources.

Intensifying the R&D efforts in these areas should pave the way for effective implementation of energy conservation measures in pulp and paper industry.

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