ENERGY CONSERVATION IN THE PULP AND PAPER INDUSTRY IN INDIA

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In any country energy is a critical input ror production and consumption activities in the development of economy. In addition to capital, land and labour, energy is the fourth factor of production. The concern for development of economy in the country has created great interest in the global energy resource inventories and in their availability. The global oil and gas resources at the present rates of increase of production and consumption would get exhausted in approximately 50 years' time.

Table -1. gives energy consumption of pattern in Indian in different sectors. The Industrial sector is the second largest consumer of total energy, both commercial and non-commercial, acconting for nearly 30 % of the total energy consumption. The industrial sector consumes about 40 % of the total commercial energy. This is equivalent to 80 million of coal per year. Thus, the industrial sector is the largest consumer of commercial energy in the country. Of the energy resources in our contry, they are at present as follows:-

Coal	:	47 %
Electricity	:	45 %
Oil	:	8 %

Over 50 % of the commercial energy is used by the following six industries:

Steel	:	24.4 %
Textile	:	9.3 %
Cement	:	8.6 %
Fertilizer	:	6.5 %
Brick maing	:	4.9 %
Aluminium	:	3.3 %

According to the latest long term prognosis conducted by the F.A.O., the production of paper and board in the world would be of the order of 256 million tonnes in 1990. It assumes an annual increase of 3.7 %. Thus, to meet the overall demand of paper and board, it would be necessary to set up every week an additional capacity of 1,00,000 to 1,50,000 tonnes of paper and Board. The world consumption of the pulp and paper board during 1970-77 and the estimated consumption from 1975-1990.

In general, the growth in the economy and the increase in demand of energy are co-related. Figure-2 shows the dependence of GNP per capita and the energy consumption per capita. As indicated in this figure, countries with higher GNP per capita have much greater demand for energy per capita.

In our country capital is a scarce commodity. India depends to a large extent on foreign capital for new investments. The generation of more energy by installation of numerous power houses from conventional and non-conventional energy sources are in the offing in our country. To help the Government and the Industry, we must find out means of reduction of energy consumption per unit of production. Pulp and paper industry has an important contribution in this regard not only in the national interest but also to safeguard its continuous growth by way of higher profitability and reasonable cost of production.

The energy bill for the industrial sector in India amounted approximately to Rs.8,000 crores during the year 1980. The electrical energy in terms of kilo calories constitutes about 10 % of the total energy consumption and the thermal energy coal and oil constitute 89 % and 11 % respectively.

Based on a survey carried out by National Productivity Council, the paper industry has an annual energy bill of Rs 200 crores which is approximately 2.5 % of the total industrial sector energy bill. Although the pulp and paper industry does not occupy a very crucial position in the overall industrial energy bill of the country like textiles and cement, the importance of energy cost in relation to unit weight of the product is higher for paper than for the textile industry as would be evident from the table below:

Sector	Annual production	Annual energy cost in Rs Crores	% Energy cost to cost of manufacturing
Textile	4000×10^6 metres	624	11
Cement	22×10^6 tonnes	395	40
Paper	1.87×10^6 tonnes	187	18

Again the energy cost in Rs per k.g.of product is much higher than that of cement. The figures below indicate the comparison of energy costs in Re/tonne to product of cement and paper.

cement: Rs 280

Paper Rs1100

This indicates that energy is an important and critical input for the paper industry.

The capital demand and the operating costs for energy supply and for environmental control are now rapidly rising in the pulp and paper industry. Great efforts must be made to find energy saving technologies and loss costly solution to the energy control problems. There are no quick answers and therefore the dwindling fossil fuel and the regulation for a cleaner environment are likely to put strain on the industry in future.

Elesewhere in the Western world and more particularly in the Nordic countries, considerable efforts are being made to find or make use of alternative cource of energy supply. Modifying the process technology through better design of equipment and systems and increasing the energy consciousness through propaganda and education are crucial for conservation of energy.

1. INDIAN PAPER INDUSTRY

The Paper industry in India has made considerable progress since the installation of the first paper mill in 1832. Its present annual installed capacity is 2.165 million tonnes. Of the total number of 223 units, about 24 units are with an annual capacity of about 24 units are with an annual capacity of more than 20,000 tonnes/year, constituting 53 % of the total installed capacity. The break up of the capacity of various categories is as follows:-

Category	No.of Units	Annual Installed capacity.
I. Units having capacity more than 20,000 tonnes/year	24	11,72,360
II. Units having capacity more than 10,000 tonnes and upto 20,000 tonnes/year	13	1,68,300
III. Units having capecity more than 5000 tonnes and upto 10,000 tonnes/year	60	4,99,475
IV. Units having capaci ty more than 2000 tonnes and upto 5000 tonnes/year	65	2,30,420
V Units of 1 to 2000 tonnes per year capacity.	61	94,545
	223	21,65,100

2. DEMAND

According to the survey report prepared by HPC, to forecast the demand for paper, paper boards and newsprint till the end of the century, the principal findings are as follows:

(Tonnes'ooo)

Year	Aggregate Demand for Paper & Paper Board	Newsprint.
1984	1,409	293
1985	1,482	305
1990	1,909	371
1995	2,459	452
2000	3,168	550

In view of the financial constraints and of limited availability of forest raw materials, the future trend for meeting the demand for paper and paper board would be by way of expansion and modernisation of the existing capacities as well as installation of small and medium mills utilising the secondary and other agricultural residues as raw materials.

On the other hand, the demand for newsprint is estimated at 3,50,000 tonnes for the year 1984-85 which is slightly higher than the demand forecast in the survey report.

There are only four units, including HPC's subsidiary(Hindustan Newsprint Ltd) producing newspring :

		Installed capacity
NATIONAL NEWSPRINT & PAPER MILLS LTD		75,000
HINDUSTAN NEWSPRINT LIMIT		80,000
MYSORE PAPER MILLS LIMITED		75,000
TAMIL NADU NEWSPRINT LTD		40,000
	TOTAL	270,000

India has been a traditional importer of newsprint. In spite of the above indigenous capacities, India would continue to import newsprint at an estimated foreign exchange outgo of about 1200 millions per annum, unless new indigenous capacities are created to achieve self-sufficiency.

3. PRODUCTION

Production during the year 1983, was 1,178 million toones of paper and paper board indicating a very low percentage of capecity utilization viz. 61 % of the then installed capacity. Of the total production of various grades of paper, more than 50 % constitute writing and printing papers.

4. ENERGY CONSUMPTION IN INDIAN MILLS

The specific energy consumption of steam and electrical energy of a pulp and paper mill depends mainly on the basic concepts of the mill design, choice of the processes and equipment and installation of captive power generation. The specific energy demands of an Indian mill is high compared to a modern mill in Europe or America. Table-2 gives a comparative picuture of energy consumption between an Indian Mill as compared to a Scandinavian Mill. A modern mill in India consumes 70 % more heat energy and 7 % more electrical energy per tonne of paper as compared to that of a Swedish mill.

TABLE - 2

Description		Indian Mill (1980-81)	Swedish Mill (1979)
I. Purchased Energy(M.Kcal):			
(i) Fuel		9.37	3.53
(ii) Power		0.79	0.76
	Total	10.16	4.29
II. Fuel Sources (M.Kcal) :			
(i) Purchased fu el		9.37	3.53
(ii) Internal fuel		4.58	4.65
(B.L.,Bark, etc.)	Total	13.95	8.18
III. Fuel Utilisation (M.Kcal):			
(i) Steam cycle and Processes		11.47	7.38
(ii) Back pressure power		2.48	0.80
	Total	13.95	8.18
IV. Electricity:			
(i) Purchased power		918	902
(ii) Back pressure power.		658	787
	Total	1576	1689
V. Back Pressure po er generation efficiency, %		22.8	85

Note: B.L. - Black Liquor.

During the recent years in Sweden where the energy awareness is very great, the specific energy consumption to produce bleached kraft pulp in an integrated pulp and paper mill is 12 GJ/ tonne for steam and 2.1 GJ (580 KWH/tonne) for electricity giving a total energy requirement of 14.1 GJ/tonne for pulp. Similarly the energy consumed in converting pulp into paper is 8.5 G.J/ tonne for steam and 2.74 GJ/tonne (760 KWH /tonne) for electricity.Thus the energy consumption for the pulp and paper mill together is 20.5 GJ/tonne for steam and 4.8 GJ/tonne (1340 KWH /tonne) for electricity giving a a total of 25 GJ/tonne.

Table -3 gives the specific energy consumption of steam and power of also various mill in India.

TABLE-3

Mills	Specific Energy Consumption	
	Steam per tonne	Power KWH/tonne)
A	11.6	1305
B	16.9	1520
C	11.6	1710
D	13.0	1949
E	10.5	1576
F	20.0	1873
G	17.4	1947
H(Speciality Paper)	10.2	2750

The percentage of captive power generation varies between 23-100 %. The operating efficiency of energy conversion in a typical Indian integrated pulp and paper mill is 58 % as against 76 % in Sandinavia. The specific steam consumption varies from 10.2 to 17.4 tonnes of paper and the specific power consumption from 1305 to 1949 KWH/tonne of paper.

A decline in capacity utilisation automatically leads to a poor utilisation of available energy as the minimum energy demand of each section of the mill getd distributed over a lower volume of output. Secondly, frequent power cuts, load sheeddings leads to wasteful use of energy.The energy consumption figures have to be considered from the prevalent national scenario of power position.

The break up of steam consumption per tonne of paper of a typical Indian integrated pulp and paper mill is as follows:

1.Digester House:	2.00
2.Bleaching	0.20
3.Evaporator	1.72
4. Causticizing	0.62
5. Feed Water Heating.	1.15
6.Auxiliaries.	1.43
7. Paper Machine	4.00
8. Miscellaneous	0.50
Total	11.62

Steam from Black Liquor solids:	4.50
Steam from Auxiliary Fuel	7.12
Total	11.62

5. STEAM GENERATION

Most of the boilers in the medium and large paper Mills are of spreader stoker type. The pressure of steam various from 40 KG to 62 KG and the capacity of the boilers vary widely ranging from 10 tonnes/hr to 85 tones/hr. The fuel efficiency of steam generation varies widely depending on the type of boiler and the control systems installed in the boiler house and also the quality of coal. Generation of steam per tonnes of coal varies between 3.0 to 5.2 tonnes.

In some of the recently installed paper mills use of fluidised bed principle for burning coal has been initiated where the thermal efficiency are much higher-of the order of 80 % compared to 65-70 % in a stoker fired boiler. The fluidised bed technique also enables to use low grade coal with high ash content or ordinary coal with high percentage of fines and also uses waste materials generated in the pulp and paper mill. This would naturally reduce the cost of production of steam. In the recently installed mills, great efforts are continuously being made to select and adopt energy hsaving techniques.

DESIGN AND SYSTEM DEVELOPMENTS OF PULPING AND PAPER MAKING EQUIPMENT FOR REDUCTION OF ENERGY CONSUMPTION

For preparation of chemical pulp, the cellulosic raw materials are chipped, treated with chemicals and steam under pressure in digesters for pulping, washed, freed of dissolved materials, screened, cleaned and finally bleached. The bleached pulp is further processed in Stock Preparation and made into paper in Paper Machines. The waste liquor obtained by washing the digested pulp, called the 'Black Liquor', is concentrated in evaporators and burnt to recover chemicals and to generate steam.

The total demand of heat and electrical energy of a pulp and paper mill depends on the basic concepts of mill design and choice of processes and equipment. A mill may have a captive power generation plant to meet its full demand, elaborate effluent treatment plant, captive plant for generation of Vaustic andChlorine and other bleaching chemicals, captive lime burning or regeneration plant or an elaborate Bleaching System. The total steam and electrical energy demand would therefore, differ from mill to mill depending on whether the mill includes the above concepts.

Further, mills with similar concepts would also differ in their total energy demand depending on the choice of equipment and processes. A comparison of figures of consumption of steam and electrical power of mill should therefore, be viewed with great care for assessment of their technical efficiency. Whatever may be the consumption of steam and electricity, there is definitely great scope for reduction of the total energy demand of pulp and paper mills.

This note analyses how a large mill can reduce its heat and energy consumption by incorporating modern systems and new designs in pulp and paper making operations of the following areas:

6. PULPING: Use of continuous Pulping in place of Batch PulpingSystem,

7. BLEACHING: Adoption of Displacement Bleaching in place of Conventional Bealching in towers and rotary drum filters,

8. BLACK LIQUOR EVAPORATION:

a) Use of Falling Film evaporation in place of Rising Film Evaporation

b) Inclusion ofVapour Recompression Evaporation for initial concentration.

9. CENTRI CLEANING:

Ise of Centri-cleaners with low pressure drop.

10. APPROACH FLOW SYSTEM:

Incorporation of Double Dilution in Approach Flow System of Paper Machines in plce of conventional single dilution, and

11. DRYING OF PAPER:

Use ofCylinder Dryers with new Design.

Effects of energy consumption by integration of pulp and paper mills and by implementation of Effluent treatment programmes are indicate.

6. USE OF CONTINUOUS PULPING WITH HI-HEAT WASHING IN PLACE OF BATCH PULPING SYSTEM

Kraft chemical pulp is manufactured by cooking cellulosic raw materials in Alkaline solutions and thereby separating useable cellulosic fibres for further processing. This separation is achieved in pressure vessels where cellulosic raw materials are treated with chemical and cooking is achieved at varying temperatures by injection of steam at a pressure.

Cooking operations in digesters involve loading of raw materials into the digester, charging the digesters with steam and chemicals and after the cooking cycle discharging the cooked raw materials along with the spent liquor by a system of blowing. This is a Batch type operation and each cooking cycle takes six to six and a half hours. Nearly two and a half decades ago a few firms have developed continuous digesters and over the years they have been perfected. There are numerous installation operating efficiently all over the world. Most of the digesters in India, are however, of Batch-type. Advantages of the continuous digester over the batch digesters are:

1. Lower consumption of steam per toone of pulp.
2. Lower power consumption per toone of pulp.
3. Higher solids in spent liquor giving the advantage of higher feed concentration ofEvaporators.
4. Lower chemical consumption in cooking.
5. Higher pulp yield and lesser man power requirement

Diagram 1 shows the continuous digester with vapour phase cooking and hiheat washing adopted for HPC'S paper mills.

A comparative statement has been prepared indictting direct and indirect costs of the Batch versus the Continuous digester pulping systems. It will be observed that the capital cost of continuous digester with in.built diffusion washing system as compared to a Batch Digesters with Brown Stock Washing system is higher.

However, there are definite savings in the direct costs in case of continuous digester by way of lesser steam and power consumption., higher pulp yield and less pulping chemical consumption.

The following table gives a comparison of the various technical inputs between the operations of a Continuous versus the Batch digester:

DESCRIPTION	DIGESTER	
	BATCH	CONTINUOUS
1. Steam, T Steam/TBD unbleached pulp	1.582	0.9924
2. Power, KWH/TBD Pulp (Digesters+ VS Washers)	152. 92	56.0
3. Yield of Pulp, % of BD chips	45.6	46.0
4. Alkali Consumption for Pulping % Na_2O on BD chips.	18.0	16.275

The following table gives the savings, converted in terms of money, of Continuous Digester for a production of 376 tonnes Bone Dry (BD) unbleached and unscreened pulp/day and with 330 working days:

Description	Continuous Digester (Rs. in lakhs/yr)
DIRECT COST. 1. Savings in steam (Rs45/T steam)	32.925
2. Savings in Power (30P/KWH)	36.825
3. Savings in Bamboo	4.56
4. Savings in Cooking chemicals	1.49
5. Savings in Evaporation	8.43
6. Savings in Man-Power	0.62
Total	84.85
INDIRECT COST	
1. Savings in Depreciation and interest	7.38
2. Maintenance, Insurance etc	2.38
Total	9.76
NET SAVINGS FROM DIRECT AND INDIRECT COST	75.19 lacs

Note: Cost of equipment including erection

Batch digester Rs.599.66 lacs

Continuous digester 683,850 lacs.

The above summarised statement shows that a saving of approx. Rs.75.0 lacs/year can be achieved by going in for a continuous digester for a pulp production of 330 tonnes/day or Rs.68/BDT bleached p ulp.

Lower consumption of steam per tonne of pulp is dueto better utilisation of steam in the continuous digester system incorporating hiheat washing.

Recent developments of counter-current impregnation and counter-current cooking would further reduce the specific steam consumption. ~~Diagram 2 shows the principle of counter.current cooking~~. The flow of chips is from top to bottom passing through the impregnation zone, cooking zone and washing zone. Chemicals and free liquor are also heated to the cooking temperature and dispersed by recirculation. As the chip column moves downwards a sufficient volume of liquor is withdrawn in cooking zone, so that there is an upward flow of free liquor, provided by the cooking liquor and wash water at the digester bottom. At the digester top, chip and spent liquor flow concurrently.

It might be further stressed that the cost benefit in favour of continjous Digester due to improved and uniform pulp quality resulting in improved runnability of the Paper Machine and hence lesser breakages, have not been taken into account in the above calculations. Even then the additional capital investment of about Rs.82 lacs over that of Batch Digester can be recovered within a period of 2 years.

The above statement refers to Bamboo Pulping. However, continuous pulping of agricultural residues is also a cost saving device.

A few new and modern Kraft Pulp Mills have installed Kamyr continuous Digesters of both Hydraulic and Vapour phased types in India.

Most kraft pulping is done with batch digesters. The biggest drawback of batch digesters is their relatively high and uneven steam demand. One way to conserve steam is by duel pressure steaming i.,e by heating the digester initially with low pressure i.e, by heating the digester initially with low pressure steam (50 PSI) and then complete the cooking with high pressure steam (150 PSI). The steam compustion can be further red ced by the so-called Sunds.Ceelleco process in which the free liquor is drained from the digester at the end of the cook and then taken to a pressurised liquor accumulator. The digester is filled, then with washing liquor and is then blown by steam from the liquor accumulator. Fresh steam is used for steaming and pre-heating of chips. The hot cooking liquor is reused to heat the next batch in the form of black liquor or indirectly by white liquor pre-heating. In this way, most of the sensible heat of the black liquor is recovered and refused. The total steam requirement can be reduced by approx.40 %.

Again in the Rader system, the digester is completely filled with cooking liquor. At the end of the cook, the hot black liquor is displaced by filling the digester from the bottom with pulp washing filtrate. The hot black liquor is stored in an accumulator. Lower temperature black liquor is stored in a second accum lator. The hot black liq or is used to preheat the white liquor by means of a heat exchanger. Thus, cooking is carried out by first filling with low temperature black liquor in the digester then displaced with high temperature black liquor and finally with pre-heated white liquor. Compressed air is used to blow the digester. Steam consumption can be reduced by as much as 60 %.

Digester relief is another facotor for higher steam consumption in batch digesters. Steam accumulators are used in Scandinavia to save fuel by reducing swings in steam demand. The blow steam is used to preheat the white liquor and also in pulp washing.

7. ADOPTION OF DISPLACEMENT BLEACING IN PLACE OF CONVENTIONAL BLEACING IN TOWERS & ROTARY DRUM FILTERS

Bleaching of pulp is one of the most imporrant operations in processing of pulp. It is done to remove the colouring matters and the resideual lignin to make the paper white. Generaly, it is done by using bleaching agents like Chlorine, Chlorine dioxide, Hypochlorite, etc.in a manner of stages. In the Conventional system, the pulp is washed on Rotary drum vacuum filters after each stage of treatment and the chemical treatment is carried out in towers. The use of Drum Filters, pumping and circulation of pulp necessitates consumption of considerable energy in the form of electricity and steam.

An improved bleacing system call the 'Displacement Bleaching has been developed. This bleaching system has been in commercial operation in USA, Japan and Scandinavia for the last two years.

In the Displacement bleaching the pulp consistency is maintained constant while it moves in one direction. Bleaching solution moves continuously and transversely through the layer of pulp. continuously displacing the partially consumed bleaching liquor containing the reaction products diffused out of the fibres. The consistency remains constant throughout the successive bleaching stages with different chemicals. The chemicals in each stage displaces the chemicals in other subsequent stage. No washing is required between the stages. The pulp is washed at the end by fresh water at the same consistency displacing the solution. Maintaining the consiste cy at around 10 % in any number ofsequences of bleaching saves a substantial amount of energy and still more substantial amount of water in bleaching washing.

Diagram shows the flow of a conventional bleaching sequence with towers and filters as well as that of a displacement bleaching system with Chlorination (C)/Extraction (E)/Hypochlorite (H)/Extraction (E)Dioxide (D)states.

In the Displacement Bleaching the chemicals i,e the bleaching agents are displaced through the pulp instead of being mixed into the pulp. This results in fapid bleaching. The several stages of bleaching by different bleaching agents are carried out in a single tower in the Displacement bleaching. The advantages of Displacement Bleaching over the Conventional Bleaching System are:

1. Reduction in Electrical Energy,
2. Reduction in Steam Consumption.
3. Reduction in Water consumption.
4. Reduction in volume ofEffluent ddischarged and
5. Reduction in the cost of Civil Construction due to lower space requifement.

The following table gives acomparison of the various inputs like electricicty, steam water requirement, effluent discharges and the building area necessary for the two bleaching systems.

(Basis per tonne of BD Pulp)	Bleaching System	
	CONVENTIONAL	DISPLACEMENT
1. Electricity, KW	141.0	45.4
2. Stean, M.T	2.8	0.53
3. Fresh water, M^3	98.0	17.0
4. Effluent, M^3	98.0	17.0
For 330 MT BD PULP		
Building area, M^2	1640.0	72.0
Tower M^3	5000.0	400.0

A comparison of the two systems of bleaching in terms of their equivalent capital costs as well as the Operational costs has been given below. The capital cost for the conventional system is for two separate streets, each of 165 TPD BD.Pulp while that of the Displacement Bleaching is for a single street of 330 TPD pulp. The capital cost includes the cost of equipment, spares, civil engineering, erection of the bleaching plant as well as those of the water and effluent treatment plants for the entire mill.

The cost of water and effluent treatment plants of the entire mill has been included in the total costs of calculation of the two bleaching systems because the new bleacing system will need considerably less quantity of water and hence result in lesser effluent volume and capital cost. The total cost of investment, would, therefore, reflect a correct picture of the comparison of two systems.

		Bleaching System		
		CONGENTIONAL (2-Street)		DISPLACEMENT (Single-street)
1. Capital cost	Rs	11,23,85,120/-	Rs	13,16,67,779/-
2. Operating cost/year	Rs	6,47,63,908/-	Rs	5,46,60,015/-
3. Operating cost/tonne of pulp	Rs.	594.71	Rs	502.95

The capital cost investment in the case of Displacement Bleaching alone is higher by approx. Rs.2.8 crores than that of the Conventional Bleaching Plant. However, the capital cost of water and effluent treatment plants for rhe two systems of bleaching when taken into account will reveal an overall difference on approx.Rs 1.9 corres only. This is due to the lower cost investment in water and effluent treatment plants in case of Displacement Bleaching.

The operating cost includes the costs of electrical, power chemicals, steam, repairs and maintenance, depreciation and insurance for the bleaching plants as well as the water and effluent treatment plants. The depreciation, repairs and maintenance & insurance are based on the machinery cost while the interest is on the total capital investment of the particular section. It would be observed that the operating cost per tonne of paper in case of Displacement Bleaching would be lower by approx.Rs.93/- The higher investment cost in the case of Displacement Bleaching can be well justified by its lower operating cost and in fact the entire extra investment could be recovered within two to three years.

The higher capital investment in the case of Displacement Bleaching is partly due to better materials of construction which are mainly Titanium and Hestelloy. These materials, though many times costlier than the stainless steel, are more corrosion resistant and hence have a longer life.

Pumping of Pulp stock

Nearly 40-50 % of the total energy requirement in a pulp and paper mill is spent on pumping dilute suspension of fibres. The plup suspensions are usually at low consistency in the range of 3-6 %. If pumping can be carried out at higher consistancy/say over 10 %, then a lot of energy can be saved. One development for the design of a medium consistency pump has been made by Kamyr of Sweden. The so-called MC pump can use the pulp with a consistency of 10 % and more.

The Kamyr MC pump is basically a centrifugal pump with an open type impeller. The impeller extends axially into the pump inlet, where it acts as a tubulence generator and fluidises the fibre suspension before pumping. In the fluidised stage, the fibre suspension behaves like water.

The fibre suspension contains large quantities of gas or air which must be removed for smooth pumping action. The turbulence generator also removes the gas which axially enters a separate compartment behind the pump housing. A higher shear field is created resulting in fibre fluidisation. The gas is discharged through a vacuum pump system. The degased pulp improves the pulp flow and pressure stability on the discharge side of the pump. This pump has been used to pulp of 12 % consistency from a thickner outlet to a storage tower and also from a high consistency tower to another place. The reduction of energy consumption is considerable.

8(a) USE OF FALLING FILM EVAPORATION IN PLACE OF RISING FILM EVAPORATION

Chemical and heat recogery systems in the pulp mills are of prime importance when evaluating plant economics. In the chemical recovery system, one major area where considerable heat and power are consumed is the evaporation plant for concentration of black liquor.

Multiple-effect evaporators have been in use for Black Liquor concentration in the Indian Pulp and Paper Industry from the very beginning. Most of the evaporators are either Long Tube Vertical(LTV) or short tube types. The rising film LTV evaporator is the overwhelmingly dominant type in use in India.

In a B.L.Evaporator, liquir is inside the tubes and steam is outside them. In transfer of heat from a condensing vapour through a metal wall to a boiling liquid, the largest and the dominant thermal resistance is the liquid film. If this thickness of liquid film can be reduced, there would be greater heat transfer. One way of doing this is to increase the liquid velocity. In long vertical tubes, with low liquor level inside the liquor bubbles formed have a violent pumping action which causes high velocity. The high liquor velocity is also achieved by pumping the liquid through the tubes with a positive head. As the liquor passe through the tubes, it boils and the vapour and the liquid force out to the top of the tubes at a high velocity. This is known as "Forced Circulation".

The disadvantages of a rising film LTV Evaporator are:

1. Low heat transfer co-efficient at low boiling temperature, and,
2. Low temperature difference.

When these evaporators are used for concentration of Black Liquor from Bamboo, hardwoods and agricultural residues,scales are formed as these liquors contain several impurities inherent in raw materials.

Some of these scales are water solubles while others require chemical and/or mechanical cleaning of the tubes. The frequency at which the evaporators must be taken out of operation for washing varies from once a day with weak liquors or once a week with water boiling. The high rate of scaling and high frequency of downtime of washing has been the limiting factor for steam economy and plant utilisation capacity. In fact it has become a general practice in India that one of the bodies of a multiple effect evaporation system is taken out of the system and used as s standby for the cleaning intervals. Thus, a five-effect multiple effect evaporator is used as a four-effect one and a six-effect evaporator used as a five-effect one. This means larger capital investment and higher steam consumption.

Some phenomena which contribute to scaling are:

1. Precipitation of organic and inorganic salts forming sludge.
2. Precipitation of inorganic sales of Calcium Aluminium or Silica introduced as impurities in the fibrous raw materials.
3. Lime from Recausticier and water.
4. Deposition of solids due to inverted solubility,
5. Presence of fibre fines in Black liquor,
6. Abnormal viscosity and non-Neutonian characteristics due to high concentration of solids in Black liquor and
7. Decomposition of organics and their change in the phase equilibrium at elevated temperatures and higher concentrations.

Some of these phnomena can be controlled or leiminated. Filters, for example, can be used to remove the fine fibres, impurities can be controlled by the use of better grades of raw materials, by purging impurities from the mill system or by a close control of Ph.

While these measures can be taken, some may not be economically justified. A better way to solve these problems would be by proper selection and improved design of the evaporation plant.

The scaling problem occurs at higher temperatures and at higher concentration of solids of the black liquor. One simple way is to make use of forced circulation when the liquor is pushed up at a greater than normal velocity which itself acts as the dual role of cleaning and reducing the retention time of the liquor over the heating surface. There are several types of high solids concentrators where forced circulation is affected. One widely accepted and more effective concentrator is the so called "Horton High Solids Concentrator". In Horton concentrator the retention chamber away from the heating surface is provided where the organic components and certain salts, because of their inverted solubility or a shift in the phase equlibrium, precipitates and grow as sludge particles. The scaling components are released in the growth chamber and form a deposit on the existing sludge surface area. By re-cycling the sludge through the heat exchanger tubes, an environment is created where the super-saturated component deposits on the sludge particles and not on the tube surface. This concentrator has been used for concentrating black liquor of bagasse, Sisal, Eucalyptus and several other agri-cultural residues. Due to recirculation the power requirement is very high and therefore is recommended where the power costs are comparatively cheaper. A better method is to use the falling film LTV evaporator where the liquor is made to fall over the entire surface of the heating tube. The advantages of the falling film evaporators are:

1. Very moderate thermal drop needed,permitting smooth operation in quintuple, sextuple and septuple effects.
2. Availability of higher heat transfer coefficients over the long period of time and higher evaporation rates at the final stages.
3. Low fouling resulting from wetting of the heating tubes and absence of local over-heating due to very short retention time of liquor in the tubes. This is particularly advantageous to reduce the scaling problem.
4. A specially designed feeding system and the internal separator provided in the falling film evaporator system ensures separation of the scale forming agents in the separator itself and prevents entry of the same into the evaporation tubes, and
5. Flexibility in operation at reduced capacity. The power requirement of the falling film evaporator is also high.

There are many hybrid systems of falling film and rising film evaporators.

The falling film evaporators thus helps to overcome the problems of high viscosity and scaling tendencies of the liquor. It is also very attractive from the point of view of minimum capital investment. The lower capital investment is mainly due to reduced heating surface area. The following comparative table shows the power requirement and the steam requirement for concentrating bamboo black liquor for a production of 1,00,000 tonnes per year paper.

	CONVENTIONAL RISING FILK LTV EVAPORATOR	FALLING LTV EVAPORATOR
1. Power requirement	A.5-Effect 45 KWH	157.5 KWH
	B.6-Effect 67.5 KWH	221.25 KWH
2. Steam requirement	A.5-Effect 29,800 Kg/hr	30,500 Kg/hr
	B.6-Effect 24,535 Kg/hr	25,735 Kg/hr
3. Steam economy, kg of water Evaporation/Kg of steam	A.5-Effect 4.405	4.303
	B.6-Effect 5.35	5.1

Since scale formation is controlled and therefore the frequency of cleaning and shut down is reduced, the falling film evaporator has more running hours in an year. Assuming that 1 6-effect conventional rising film evaporator will work as a 5-effect one (one body always as a standby) and a 6-effect falling film LTV evaporator works with 100% efficiency, the operating cost difference in terms of power and steam will be as follows:

	CONVENTIONAL RISING FILM ETV EVAPORATOR	FALLING FILM LTV EVAPORATOR
Operating Cost/annum of power and steam	Rs. 107,27,640/-	Rs. 96,97,644/-

However, the falling film evaporator does not work at 100 % efficiency, as assumed, and generally the utilisation efficiency is 85 % of the time in a year and 15 % of time as a 5-effect one. Taking into consideration this fact, the difference in operating cost between the conventional rising film and the modern falling film evaporator system would be around Rs. 7.98 lacs/year or roughly Rs. 8 per tonne of paper. This saving does not include the savings due to lower interest and depreciation of lower initial investment of the falling film evaporator.

There is considerable interest in evaporating black liquor to higher than normal solids content in order to improve the energy balance in the recovery system. The energy advantage of removing more water at the multiple effect economy in evaporators compared to the removal of 1:1 economy is another step in improving the energy balance in the recovery system to increase solids content from 65 % to 80 %, approximately, 0.45 GJ/tonne is needed, but an additional 1.28 GJ/tonne is generated in the recovery furnace. Of the several equipment designs used for high solids concentration of black liquor, the use of tube and lamella types falling films evaporators, rising film evaporators, vapour compressor evaporators and indirect steam heated concentrators are in vogue. Falling film evaporators are very versatile with high thermal efficiency. The PFR evaporators installed in the Assam Pulp & Paper Projects of HPC consist of 3-pass liquor flow with a preheating section, a falling film section and a rising film section to concentrate bamboo liquor solids from 15% to 50%.

8.(b) INCLUSION OF VAPOUR RECOMPRESSION EVAPORATOR FOR INITIAL CONCENTRATION OF BLACK LIQUOR

The principle of Vapour Recompression Evaporation (VRE) has been widely used in various industrial applications.

Diagram 9 shows the principle of Vapour Recompression Evaporator for concentration of black liquor of a Kraft Pulp Mill. The vapour from the boiling liquor is forced through a compressor to increase its pressure and hence its temperature and is used again as the heating agent in the evaporator, where it condenses giving its latent heat. In fact, the total heat content of one kg. of vapour leaving the evaporator body is slightly less than that of the steam used to heat the evaporator tubes. Liquor is circulated as a falling film and the condensate leaving the evaporator is used to preheat the feed liquor. One thus gets multiple effect economy in a single effect evaporator.

Although Vapour Compression Evaporation has been used in evaporation of Sulphite liquor, it has not been used in Kraft liquor evaporation.

The compression of vapour requires electrical energy (drive motor) or high pressure steam(steam turbines), Since in a evaporator $Q = UxAxT$; where Q represents the flow of heat; U overall heat transfer coefficient; A Heating surface area of the tubes and T the temperature difference between the heating agent and the temperature in vapour space in the evaporator body, there must be a balance between the cost of compression and the cost of evaporation.

High temperature difference would mean higher compression ratio and cost while lower temperature difference would mean larger heating surface area of the tubes.

A comparison of the energy consumption has been made for a system where the Kraft liquor of a 15 % total solids (T.S.) is concentrated to 50 % T.S. in a 6-effect evaporator in one case and in a Vapour Recompression Evaporator system with 4 sumps each with pumps in the other case. The rate of water evaporation is 136,000 Kg/hr.(300,000 lbs/hr.) in both cases the temperatureof the water being 43°C (110°F).

COMPARISON OF ENERGY CONSUMPTION IN MULTIPLE EFFECT EVAPORATOR & VAPOUR RECOMPRESSION EVAPORATOR FOR KRAFT LIQUOR CONCENTRATION

	MULTIPLE EFFECT EVAPORATOR(MEE)	VAPOUR RECOMPRESSION EVAPORATOR(VRE)
Energy demand, Joules/Kg of water evaporation	$4.7x10^5$ $5.8x10^5$	$1x10^5$ $1.2x10^5$
lbs of Steam/lbs. of water evaporation	5 ($4.7x10^5$J/Kg) (200 Btu/lb)	-
Electrical Energy, KWH/Kg of water evaporation	-	0.026 KWH/Kg ($1.2x10^5$J/Kg) (50 Btu/lb)

It shows that energy consumption in VRE is approximately 1/4 of the consumption in MEE. VRE thus provides a better and efficient utilisation of energy.

Why is it then that VRE has not been widely accepted in the pulp and paper industry? Let us see the limitations of this process.

Kraft liquors have high boiling point rise and are viscous and often foamy. The former two increase with increase in the concentration of total solids.

For example, when Kraft liquor is concentrated from 20 % T.S. to 45 % T.S. the boiling point rise increases from 1°C - 2.8°C to 5.5°C. A single-stage compressor has a maximum ration of discharge to inlet pressure of 1.4 to 1, giving a temperature of 11°C above the boiling point of water. Increase in the boiling point rise of Kraft liquor will reduce the overall temperature difference (T). Although, multiple stage compressors in series operation can give a greater pressure difference, i.e. greater T, the capital costs and the operating costs cannot justify their use. VRE therefore can be used to pre-evaporate the Kraft liquor ahead of MEE. There is thus a limit to the final concentration of liquor due to the boiling point rise of high solids Kraft liquor in VRE.

In a mill where MEE has been installed, warm water is obtained from the evaporator condenser. An existing mill cannot have a VRE where only small quantity of cooling water is needed to condense the vapour in the non-condensate gas and hence VRE cannot form a source of hot water.

One advantage, however, from the effluent treatment point of view in VRE is that nearly 75 % of the BOD is in 10 % of the condensate and hence BOD removal is cheaper.

VRE can be installed in new plants for pre-evaporation of Kraft liquor to be followed by a reduced size and number of stages of MEE. Existing mills can use it to augment their evaporation capacity by incorporating VRE, where warm water from the evaporator condenser is in excess. VRE can be recommended where low cost electrical energy or highpressure steam from back pressure power turbine is available.

9. USE OF CENTRI CLEANERS WITH MODIFIED DESIGN

Centrifugal cleaners have been used in the Pulp & Paper Mills for many years. Centricleaners are used to remove the process contaminates, like sand, dust, rubber, iron and any uncooked knots, shives, barks, etc. All types of Centrifugal cleaners look basically the same. They have a tangential inlet, a central accept and a reject outlet in the conical part of the cleaner.

All types of Centriculeaners are based on the same principle. The centribfugal force creates a vortex in the cleaner. Due to difference in the specific gravity, the impurities get a higher settling velocity than the fibres. This results in the impurities being concentrated near the wall of the cleaner where they move downards and are discharged at the reject outlet as a thickened suspension.

During the last few years development in Cleaner design have taken place to make them more economical. These developments have resulted in increasing the cleaning efficiency, reducing the power consumption, reducing the space requirement and the maintenance costs.

A good Centricleaner should have :

1. a high overall cleaning efficiency over a wide operating range at low power consumption;
2. be able to eliminate plugging;
3. be compact with minimum space requirement and maintenance.
4. Use material of construction will not wear and siturb the cleaning efficiency; and
5. allow inspection of the cleaning units and make it possible to change units during operation without disturbing the production.

To get high cleaning efficiency, the centrifugal force should be as high as possible. The simple formula:

F1 MxV^2/R- Where F denotes Centrifugal force; on a particle; M its mass; V the tangential Velocity; and R the Radius of the Cleaning Unit.

determines the Force. To make centrifugal force high, one needs high tangential velocity and low radius of the cleaner. It is also true that higher the tangential velocity, greater will be the pressure drop over the unit.

With right dimension and right construction of the inlet and height of the cleaner, high cleaning efficiency can be obtained. However, high pressure drop increases the power consumption. If both pressure drop and radius are reduced in such a way that the ratio V^2/R is kept constant, then no change will occur in the Centrifugal Force F. By using a small cleaner, lower power consumption can be achieved for a given centrifugal force. The nozzle design and the material of construction of the cleaner are very important to reduce the power consumption for a given cleaning efficiency. The tangential inlet located as close as possible to the inner wall of the cyclone ensures smallest possible angular difference between the liquid flow floating in the cyclone and the flow entering through the nozzle. There have been several design modifications of Centricleaners giving improved performance.

In a Centricleaner a particle of a certain weight and size can circulate in a horizontal path due to the fact that the upward component of the centrifugal force equals the opposite directed component of the hydraulic force. This is called the level of balance

A particle wears down the cone rapidly and also wears itself down. This is avoided by having a negative angle way sown the cone to prevent the above wear. To get a declreasing radius with a negative angle down the cone, spirral or stepped cone designs are more successful. In a normal cone the accepted stock continuously leaves the cone part into the upward going stream in the vortex. However, small flows go back and hit the upward component flow close to the wall. Thus cross flow and turbulances result and the dirt due to these disturbances s thrown into the upgoing stream and joins the accepted flow. In the Stepped Cone there is no upgoing component at the cone wall and hence there are not cross flows and turbulances. This means we can save energy by minimising the turbulances in the cone part and also by getting the shaking action downwards the cone. With no cross flows and turbulances, the flow rate of the cleaner increases at the same pressure drop. principle of Trap Cone and Spiral Cone centricleaning of pulp A SC(Spiral Cone)cleaner can have a higher cleaning efficiency at a given Feed consistency with a lower reject rate than a flat cone cleaner.

The comparison of performance date between the Conventional and improved Centricleaners is given in the following table:

POWER CONSUMPTION IN CENTRICLEANERS.

DESCRIPTION	CONVENTIONAL	IMPROVED DESIGN
1. Pressure Drop	2.2 kg/cm^2 (22 MWG)	1.4 kg/cm^2 (14 MWG)
2. Energy Cost/year (assuming 1 KWH costs 30 Paise),Rs/lacs	15.4	8.5
3. Feed rate, lpm		
Primary	81,000	70,500
Secondary	27,000	18,800
Tertiary	7,200	6,300

The difference in operating energy cost is approximately Rs.7 lacs per year for 330 TPD bleached pulp mill.

10. INCORPOARATION OF DOUBLE DILUTION SYSTEM IN PLACE OF SINGLE DILUTION IN THE APPROACH FLOW SYSTEM OF THE PAPER MACHINE.

The pulp stock coming out of the machine refiners has to be diluted to a consistency less than 1% before the sheet formation takes place on the machine wire. This is done by mix ing the machine stock with white water from the white water silo collected mainly from the wire trays from the paper machine by means of a pump called the "fan pump" immediately ahead of the centricleaners. Approximately 80% of the water and as high as 40% of the fibres and fillers leaving the slice are drawn into the white water trays. The fan pumps, centricleaners, deculator, screens, the head box, wire trays and the white water silo from an inner loop in the paper machine water recirculation system. This inner loop circulates a huge amount of water and has a comparative short circulation period.

The largest circulation pump in the paper machine house is the fan pump circulating and feeding the centricleaners at a pressure head of 25-30 metres water approximately a quantity of 250 tonnes of water for every tonne of paper made. Diagram 10 shows the common method of stock dilution where the stock from the paper machine chest is diluted with white water of the trays, over-flow of the head box, accept from the secondary screens, etc., collected together in the white water silo. The diluted stock at a consistency of 0.5-0-8% is fed to the primary centri-cleaners for the removal of dirt and specs. The centricleaners operate on the vortex principle. The accepts go to the deculator. The deculator is an equipment for removal of air from the stock. The presence of air in the stock, which is in the range of 2 to 4% by volume, causes foam, affects drainage and impairs sheet formation. In the deculator, which is combined with the centri-cleaners to avoid another pumping stage, air is removed. This helps prevention of flocculation, improves drainage on the table rolls, gives better formation of sheet, causes increase of vacuum at the couch and decrease of porosity of the sheet. The secondary fan pump finally feeds the head box of the paper machine through the presure screens located between the centricleaners and machine head box. This common method of stock dilution is known as single-dilution system.

A look at the diagram would indicate that a huge quantity of water and stock is forced through the centricleaners at a considerable head, resulting in a considerable energy consumption. One method of reducing this energy consumption is to device improved cleaning system with reduced pressure drops through the centricleaning equipment. An alternative method would be to device some system by which the quantity of dilute stock fed to the cleaners is reduced. This can be done easily by either increasing the consistency of the dilute stock or by bypassing a part of the already cleaned stock through the centricleaners. The former alternative naturally will put a limit in the cleaning efficiency. The second alternative is shown in diagram 11. The overflow from the machine head box, the secondary screen accepts and a part of the wrire tray water, whichhave once been cleaned and have little change of picking of any contaminant accept air, bypass the centricleaners and go directly to the deculator receiver.

An additional pump, called 'dilution pump' is necessary for this purpose. The dilution pump feeds the deculator which is under vacuum. The dilution pump head is nearly half the primary pump head. Thus a great amount of energy can be saved. Besides, the reduced feed to the primary centricleaners reduces the feed to the cleaners in the subsequent cleaning stages. This arrangement shown indiagram 11 is the "Double-dilution System". A comparison of feed quantity, consistency, pump head and the absorbed power of various pumps in the inner loop of the paper machine white water circulation of the two systems is given in Table 1.

Adoption of the co-called Double-dilution system would enable a mill to save 20 to 24 % in power demand of a Single-dilution system. The other savings in terms of reduced size of deculator and number of cleaners would amount to 20 to 25 % of the equipment costs.

TABLE: 1

STOCK FLOW & POWER DEMAND(ABSORBED POWER)FOR SINGLE & DOUBLE DILUTION SYSTEMS OF A PAPER MILL PRODUCING 100,000 TONNES OF FINISHED PAPER PER ANNUM

	SINGLE DILUTION				DOUBLE DILUTION			
	Q (Ipm)	CY (%)	H (m)	P (Kw)	Q (Ipm)	CY (%)	H (m)	P (Kw)
1. Primary Fan Pump	60000	0.8	29	319	33000	0.8	29	192
2. Secondary Cleaners feed pump	15000	0.6	32	99	8000	0.6	32	58
3. Tertiary cleaners feed pump	5500	0.5	32	34	2700	0.5	32	18
4. Quarternery Cleaners feed pump	1400	0.25	35	12	1400	0.24	35	12
5. Dilution pump					25000	0.25	16	34
6. Secondary Fan Pump	54000	0.6	15	160	54000	0.6	15	160
7. Secondary Screen Feed Pump	3500	0.8	10	10	3500	0.8	10	9
				634				483

$$\% \text{ Reduction} = \frac{634-483}{634} = 23.8\ \%$$

A saving of $\frac{151KW \times 24 \times 330 \times 0.3}{100,000}$ would amount to Rs.3.59 lacs.

11. THERMORINGS IN DRIVER CYLINDER

Cylinder drying is the most common method of paper drying. The steam condensed in slow speed paper machines is removed by scoops which rotate with driers. As the speed of the machine increases, the pool of condensate forms a ring around the cylinder inner wall. Siphons are used to remove the condensate in the high speed machine. The heat transfer takes place through the condensed film, whose thermal resistance is almost 100 times that of cast iron wall of the cylinder. Diagram 17 shows the relation between the overall thermal resistance (paper+Cylinder wall+condensate film) and the machine speed. At higher speeds the condensate film resistance increases rapidly, thereby increasing the specific steam consumption in drying the paper.

Due to practical difficulties, there is a limit of reducing the clearance between the tip of the shoe of siphon and the cylinder wall inner surface. Hence if the film can be broken or made turbulant, the thermal resistance of condensate film is reduced, thereby increasing the overall heat transfer rate.

The driers for high speed machines can be ribbed inside for increasing the heat transfer rate. For existing machines thermorings are set along the drier axis at intervals which are determined by the film condensate thickness and the drier diameter. The elements of the thermorings are generally 4 mm thick and one metre long. Thermorings can reduce the specific steam consumption by about 6 to 10%. In some cases the machine speed could also be increased for higher production. The pay back period for thermorings is less than a year.

COMPRESSED AIR

Compressed air is used in several areas in process

& instrumentation controls. There are considerable differences between the consumption of compressed air at different mills depending on the type of the product, equipment, age and size. In many cases, it also depends on the interest the Management takes in rationalising and economising the use of compressed air.

An approximate estimation indicates that about 1.5% of the electrical energy consumption is used to produce compressed air.

Ith has been found that centralised installations of compressed air systems with large compressor units is most economic because:

1. Large units have low energy consumption per M^3 of compressed air produced.
2. The availability of central reserve capacity means smaller total installed compressor capacity and hence a higher degree of utilisation.
3. Low maintenance cost and smaller staff for supervision.

One of the greatest air consumer is the leakage. Unfortunately its importance is often underestimated. If the capacity of the compressor installation is twice that of the average consumption, the loss in percentage of the consumption is twice the percentage figured on capacity. Assuming 20 % is the loss due to leakage and $10M^3$ free air requires 1 KWH to produce compressed air, one can calculate the amount of savings a mill could ahieve.

INTEGRATED AND NON-INTEGRATED MILLS AND THEIR EFFECTS ON ENERGY CONSUMPTION

When a pulp and paper making operation is a continuous operation without intermittent drying of pulp, we call it an Integrated Operation and a pulp mill with such operation is known as Integrated Pulp and Paper Mill. Most of our mills in India are on integrated basis.

When a pulp mill and a paper mill are to be located at different places with considerable distance between them,the pulp is generally dried either in sheet form(Cylinder drying) or in Pallet form(Flash drying). This is on non-integrated basis.

In India there is a thinking to establish pulp mills to feed to a number of small paper mills to be located at several places in the country. The advantages of small paper mills are:

1. Disposal of industries;
2. Bringing the paper industry within reach of the middle level entrepreneur;
3. Reduction of gestation period and capital costdue to smaller size and lesser sophistication of equipment;
4. Development of Industrieseven in areas of poorer infra-structural facilities due to limitedrequirement of such facilities; and
5. Larger employment potential.

On the other hand there are several disadvantages from technical and financial angles. In an integrated pulp and paper mill there are some common service facilities to be provided for both pulping and paper making operations.The following are the common services generally provided in an integrated pulp and papermmill:

1. Steam generationsystem;
ii) Power generation system,
iii) Water supply, effluent treatment and disposal
iv) Workshop facilities;
v) Compressed air system ; and
vi) Laboratory facilities.

Since in an integtated plup and paper mill the above services are planned for providing facilities to both pulp and paper making activities, the unit cost of common services becomes cheaper. Apart from this, all large sized pulp and paper plants generally have their own captive power generation units and the process steam is obtained as extra-action steam from the extraction condensing type of turbo generators. In this way both steams and power can be obtained on a comparatively lesser unit cost.

Integration eliminates the handling, disintegration and the drying up of the pulp. The resulting cost savings are 10 to 20% of the total cost of pulp compared to a non integrated mill. The following table shows the consumption of steam and electrical power of integrated and non-integrated mills. The total requirement of steam and power per tonne of paper are thus ~~(shown in diagram 10)~~

	POWER (KWH/T)	STEAM (T/T)
Integrated Mill	1650	11.0
Non-integrated Mill	2000	13.0
EXCESS DUE TO NON-INTEGRATION	350	2.0

With increasing energy costs, these savings will be even more pronounced in future. Besides, reduction of energy consumption has become a social necessity. Not only there is reduction of energy costs but also fresh water consumption can be reduced through the link with the pulp mill resulting in less amount of polluting effluents.

Integration has many other advantages in cases when the once dried pulp impaired the pulp quality. Other advantages are of course on the maintenance and organisation side. In a particular case, the difference in cost of production between an integrated unit and a non-integrated one was of the order of 1000 rupees per tonne of paper.

Taken all effects together, savings by integration are of such a magnitude that competition with integrated mills for bulk grades, paper with reels and used in rolls, will be more difficult for non-integrated mills. Further larger units can afford costly equipment and system to reduce the operation cost. Whatever may be the philosophy of employment and dispersal of industries, an integrated paper mill and the economy of scale of larter mill would bound to have consequences in the structure of the paper industry in our country.

POLLUTION ABATEMENT AND ENERGY CONSUMPTION

I would like to touch the environmental control and its effects on the energy consumption of pulp and paper Mills. Here we have a conflicting situation. The majority of the Pollution Abatement Messures increase the consumption of both steam and electricity. For a chemical pulp mill with internal measures combined with primary and secondary treatment and sludge handling, both steam and electricity demand is of the order of 15 to 20 % higher than that of corresponding mill without these measures. However, new pulp and paper mills must be provided with all possible pollution abatement controls and treatment as it is the industry's social obligation and hence the steam and power consumption and their costs would be higher.