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

BY

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ABSTRACT

Due to unprecedented price rise of energy, their acute shortages and uncerteinities in securing new and reliable energy sources, continuous technological developments have been taking place in equipment design and system design in the field of pulp and paper industry.

The paper analyses and brings forth possibility of energy reduction in areas of pulping, bleaching and cleaning of pulp, black liquor evaporation, approach flow system and drying of paper.

Specific energy consumption in terms of both heat and electricity can be considerably reduced by adopting continuous pulping methods, incorporating new concepts of counter-current impregnation, cooking, hiheat diffusion washing and displacement bleaching.

Use of centricleaners based on improved design can reduce el energy considerably by cleaning pulp at higher consistency and at reduced reject rate without impairing cleaning efficiency.

Pre-evaporation of spent liquor in vapour recompression evaporators and use of falling film evaporation for scale forming black liquors can reduce steam demand in evaporation. Specific steam demand in paper drying can be reduced by 6-10% using Thermo-rings or by modifications of Drier inner surface.

Effects of energy consumption by integration of pulp and paper mills and by implementation of effluent treatment programme are indicated.

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INTRODUCTION

During the last few years there have been unprecedented price rise of energy, acute shortages and uncertainties in securing new and reliable energy sources. The industrial world has been put to a great strain. In addition, the capital demand and the operating costs for generating and supply of energy are rapidly rising. Increased cost of production on the one hand and the consumers incapacity to pay for higher price on the other hand, have led to a situation which may change the very structures of our industry. Great efforts are being continuously made to find out energy saving technologies. Continuous technological developments in process equipment design and system have been taking place. Some of these developments have found wide acceptability in the pulp and paper industry of many countries.

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 Caustic and Chlorine 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 mills 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 el energy consumption by incorporating modern systems and new designs in pulp and paper making operations of the following areas :

AA PULPING :

Use of Continuous Pulping in place of Batch Pulping System,

BB BLEACHING :

Adoption of Displacement Bleaching in place of Conventional Bleaching in towers and rotary drum filters,

CC BLACK LIQUOR EVAPORATION :

a. Use of Falling Film evaporation in place of Rising Film evaporation,

b. Inclusion of Vapour Recompression Evaporation for initial concentration.

DD CENTRI CLEANING :

Use of Centri-cleaners with low pressure drop,

EE APPROACH FLOW SYSTEM :

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

FF DRYING OF PAPER :

Use of Cylinder Dryers with new design.

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

AA 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 tonne of pulp

2/ Lower power consumption per tonne of pulp

3/ Higher solids in spent liquor giving the advantage of higher feed concentration to Evaporators.

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 in Assam.

A comparative statement has been prepared indicating 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 the 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 + BS Washers)	154.92	56.0
3.	Yield of Pulp, % on BD chips	45.6	46.0
4.	Alkali Consumotion for Pulping % Na_2O on BD Chips	18.0	16.275

The following table gives the savings, converted in terms of money, of a 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 lacs/yr.)
DIRECT COST	
1. Savings in Steam, (Rs. 45/T steam)	32.925
2. Savings in Power, (30 P/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 & INDIRECT COST	Rs. 75.19 lacs

NOTE : Cost of Equipment including Erection

Batch Digester	Rs. 599.666 lacs
Continuous Digester	Rs. 683.858 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 pulp.

Lower consumption of steam per tonne of pulp is due to 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 along with 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. Diagram 3 shows the flow of counter-current impregnation. Advantages of counter-current flow results in 1) increased chemical concentration, 2) reduced cooking temperature and hence 3) overall steam economy.

It might be further stressed that the cost of benefit in favour of Continuous 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 two years.

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

BB Adoption of Displacement Bleaching in place of Conventional Bleaching in Towers & Rotary Drum Filters.

Bleaching of pulp is one of the most important operations in processing of pulp. It is done to remove the colouring matters and the residual lignin to make the paper white. Generally, it is done by using bleaching agents like Chlorine, Chlorine dioxide, Hypochlorite, etc. in a number 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 bleaching system called the 'Displacement Bleaching' has been developed. This bleaching system has been in commercial operation in USA, Japan and Scandinivia 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 consistency at around 10% in any number of sequences of bleaching saves a substantial amount of energy and still more substantial amount of water in bleaching washing.

Diagram 4 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) stages.

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 rapid 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 of Effluent discharged, and
5. Reduction in the cost of Civil Construction due to lower space requirement.

The following table gives a comparison of the various inputs like electricity, 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.	Steam, MT	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 cost of calculation of the two bleaching systems because the new bleaching system will need considerably less quantity of water and hence result in lesser effluent volume and capital cost. The total cost investment would, therefore, reflect a correct picture of the comparison of the two systems.

		BLEACHING SYSTEM	
		CONVENTIONAL (2-Street)	DISPLACEMENT (Single-St.)
1.	Capital cost	Rs. 11,23,05,120/-	Rs.13,16,67,779/-
2.	Operating cost/yr.	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 the two systems of bleaching when taken into account will reveal an overall difference of approx. Rs. 1.9 crores 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 & insurence 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.

CC (a) Use of Falling Film Evaporation in place of Rising Film Evaporation.

Chemical and heat recovery systems in the pulp mills are of prime importance when evaluating plant economies. 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. Diagrams 5,6,7 & 8 show a climbing Film Evaporator, forced circulation evaporator falling film evaporator and a hybrid Climbing-Falling Film Evaporator respectively.

In a B.L. Evaporator, liquor 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 passes 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 coefficient 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 clearing 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 a 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 salts 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 phenomena can be controlled or eliminated. 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 effected. 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 equilibrium, 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 recycling 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 agricultural 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 100,000 tonnes per year paper.

		CONVENTIONAL RISING FILM LTV EVAPORATOR	FALLING FILM 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 a 6-effect conventionel 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 LTV EVAPORATOR	FALLING FILM LTV EVAPORATOR
Operating Cost/annum of Power and Steam	Rs. 1,07,27,640/-	Rs. 96,97,644/-

However, the falling film evaporator does not work at 100% efficiency, as assumed, and generally the utilisation efficiency is 85% which means the 6-effect evaporator will work as 6-effect 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.

CC (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 $Q = U \times A \times T$; 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 evporation.

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 temperature of 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	4.7×10^5 5.8×10^5	1×10^5 1.2×10^5
lbs. of Steam/lbs. of water evaporation	5 (4.7×10^5 J/kg) (200 Btu/lb.)	--
Electrical Energy, KWH/kg. of water evaporation	--	0.026 KWH/kg. (1.2×10^5 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 ratio 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 high pressure steam from back pressure power turbine is available.

DD <u>Use of Centri-cleaners with modified Design</u>

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 Centricleaners are based on the same principle. The centrifugal 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 downward 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 which will not wear and disturb 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 :

$F = M \times V^2/R$ - 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(Diagram 12).

A particle wears down the cone rapidly and also wears itself down This is avoided by having a negative angle way down the cone to prevent the above wear. To get a decreasing radius with a negative angle down the cone, spiral 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 turbulences result and the dirt due to these disturbances is 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 turbulences 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. Diagrams 13 & 14 show the 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 (diagram 15 & 16).

The comparison of performance data 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.

EE Incorporation 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 mixing 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 centricleaners 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 centricleaners 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 pressure 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 considerably 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 wire tray water, which have 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 in diagram 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 so-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 (lpm)	CY (%)	H (m)	P (KW)	Q (lpm)	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	0.25	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
	Total				634				483

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

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

FF. Thermorings in Drier 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.

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 pellet 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. Dispersal of industries;
2. Bringing the paper industry within reach of the middle level entrepreneur;
3. Reduction of gestation period and capital cost due to smaller size and lesser sophistication of equipment;
4. Development of industries even in areas of poorer infrastructural facilities due to limited requirement 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 papermaking operations. The following are the common services generally provided in an integrated pulp and paper mill:

i/ Steam generation system;
ii/ Power generation system;
iii/ Water supply, effluent treatment & disposal;
iv/ Workshop facilities;
v/ Compressed air system; and
vi/ Laboratory facilities.

Since in an integrated pulp 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 extraction steam from the extraction condensing type of turbo generators. In this way both steam and power can be obtained on a comparatively lesser unit cost.