# Energy audit and conservation in pulp and paper industry in India

## INTRODUCTION

## BACKGROUND

The Development Council for Pulp and Paper Industry in its meeting in November, 1982 appointed various sub-committees for suggesting measures for development of the industry. The work of Energy Sub-Committee was entrusted to Mr. N. S. Sadawarte in the capacity as Chairman and Mr. L. N. Chowdhary as member.

Accordingly, Mr. N S Sadawarte, Co-opted additional members. They were eminent personalities from Paper Industry as well as in the field of Boiler Manufacturing Consulting Firms and representatives from financing institutions (ICICI), Mr. J S Matharu, Industrial Adviser, DGTD and Member Secretary of the Council offered all his help and took keen interest in the working of the Committee.

It was agreed by all to lay hands on earlier work done on the subject and avoid duplication. National Productivity Council (NPC) in collaboration with Indian Pulp and Paper Technical Association (IPPTA) has been active in this subjects since 1981. The Industrial Credit and Investment Corporation had arranged a workshop of Energy Seminar in Bombay in April 1981. Both these reports were decided to be used. As a follow up action of NPC Seminar, NPC had appointed a committee in February, 1981 and circulated a questionnaire to all paper mills. This was followed by visits of NPC experts to the mills for on the spot evaluation. Their analysis and findings made the most valuable contribution for this report and their effort deserves high compliments.

Taking NPC report as a document, the Energy Committee decided to develop this theme further. The Committee met three times and also visited Ballarpur Mills (Shree Gopal Division), Star Paper Mills, Central Pulp Mills.

There has been increasing awareness inthe field of energy conservation at all places. All were eager to have fruitful exchange and Committee is grateful to the Management of the above mills.

The report reviews the present situation, identifies areas of conservation, keeps in view of technological trends abroad, offers recommendations for energy savings and also sets a time bound target of reducing energy usage by 20% by 1990.

## ENERGY INTENSIVE NATURE OF PAPER INDUSTRY

Generation and use of energy is basic to all industry. Paper Production is an energy-intensive process. Among heavy industries, paper making ranks with the steel and petrochemical industries in the total amount of energy consumed.

In many industries, energy costs constitute a relatively smaller proportion of the total manufacturing cost with the result that any increase in it would either be absorbed or be passed on to consumer without much resistance. This is not true in case of the energy intensive industries such as cement, paper, aluminium and steel where there is a partial or full price control. An increase in energy cost of a large order could upset the financial viability of these industries.

## STRUCTURE OF INDIAN PAPER INDUSTRY AND ITS RAW MATERIAL BASE

### Structure of Indian Paper Industry:

Large scale mechanised paper making technology was introduced in the country in the very beginning of 19th century. The paper industry in the country has made a steady progress since 1924 when the technology of bamboo based production of paper was established.

The paper and paper-board industry in the country has developed by adding a number of units of varying capacities. As in January, 1983

(Table 1) the total installed capacity was 2.16 million tonnes per annum including paper, paper board and newsprint distributed over 179 units. The unit capacity of large-scale paper making industry which was originally around 30 TPD (tonnes per day) has grown to the order of 100 TPD and today many units are as large as 150-250 TPD.

The mill capacity ranges from 5-10 TPD for the smallest units to about 250 TPD for the largest paper mill in the country. Recent capacity additions in the newsprint area are of 300 TPD size.

The paper mills are broadly classified into five categories based on installed capacity. Table 1 shows installed capacity of paper industry in the country category and region wise as on January, 1983. About 65% of the total installed capacity was represented by integrated mills (category-1). This accounts for only 16% of the total number of mills in the country.

The paper industry raised its capacity from 0.14 million tonnes (17 units) in 1951 to 2.16 million tonnes (179 units) by the beginning of 1983. About 20% of the present paper making capacity was in existence prior to the fifties. During fifties, about 50% of the capacity was created, thus 70% of the present capacity came up prior to seventies during the low energy cost era. Balance of 30% capacity was added in the seventies mainly through schemes necessitating addition of balancing equipments in large mills and through the proliferation of small mills based on agricultural residues.

Of the existing paper production capacity

- — 33% lies in the Southern Region
- — 29% in the Eastern Region
- — 26% in the Western Region and
- — the balance 12% in the Northern Region.

State-wise distribution and installed capacities are shown in Table 1.

The seventies were characterised by a drastic reduction in the growth rate of the industry compared to the 1950-70 period. Shortage of conventional raw materials such as bamboo and steep escalation of investment costs inhibited the growth of large number of small paper mills. A redeeming feature during the seventies has been the appearance of a large number of small paper mills has a 10,000 TPA capacity or less. These mills were based on hitherto wasted, unconventional materials such as bagasse, agricultural residues like rice straw, cotton rags, hemp, jute cuttings, grass etc.

**Raw Materials Base:**

Large integrated units having capacity of more than 20,000 tonnes per annum use mostly forest produce such as bamboo, hardwood and very little soft wood as the main fibrous source. These mills are generally located in the vicinity of forests, far away from urban areas.

Large mills use bamboo to the extent available and mixed hardwoods for pulping. Mixed hard woods are relatively poor raw material as far as pulp quality is concerned. Use of soft wood is limited, contributing to very insignificant percentage in the total consumption of raw materials. The 28 large integrated mills having installed capacity of 1.4 million tonnes use on an average 60–75% bamboo, 25–35% hard wood and very minimal amounts of other fibrous raw materials (Table 2).

Small paper mills use on an average 55% agricultural residues, 40% waste paper 5% purchased pulp and other long fibre material such as cotton linters, rags etc (Table 2).

The principal reason for the increasing contribution of small paper mills to the nation's installed capacity is the availability of excise concession for (a) mills using unconventional raw materials and (b) mills of capacity below 15,000 TPY etc.

Advantage of using agricultural residues as raw material is a comparatively lower requirement of chemicals for cooking and bleaching and lower energy consumption. Their availability in many cultivated areas is ample and cost is comparatively less. Being the residue of an annual corp, their supply is assured. Hence most of the capacities added during the past 4–5 years are based on agricultural residues.

Waste paper recycling, though practised in India, the percentage recycled is far too low compared to many European countries and Japan where it is as high as 50% compared to only 20% in India. The advantages of recycling of waste paper are well known. In addition to conservation of virgin fibres, saving in total energy, will be nearly 60% of that required for virgin fibre. Modes of collection and gradation will have to be improvised in our country in order to improve recycling efficiency. A centralised waste paper pulping unit with latest cleaning and deinking system is worth exploring.

## INDIAN MILLS GROWTH AND CAPACITY UTILISATION

Togther with energy, per capita paper consumption is regarded as an index of literacy and

TABLE—1 REGIONWISE AND CAPACITYWISE DISTRIBUTION OF PULP AND PAPER MILLS (1983)

| STATES | CATEGORY I | | CATEGORY II | | CATEGORY III | | CATEGORY IV | | CATEGORY V | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Total Capacity | No. | Total Capacity | No. | Total Capacity | No. | Total Capacity | No. | Total Capacity | No. | Total Capacity |
| Andhra Pradesh | 4 | 233100 | — | — | 3 | 29000 | 2 | 6000 | — | — | 9 | 268100 |
| Assam | 1 | 27000 | — | — | — | — | — | — | 1 | 1000 | 2 | 28000 |
| Bihar | 1 | 60000 | 1 | 13500 | 4 | 7500 | 1 | 3000 | — | | 4 | 84000 |
| Delhi, Haryana and Punjab | 1 | 51000 | 3 | 54800 | 11 | 100000 | 4 | 14500 | 10 | 16930 | 29 | 237230 |
| Gujarat | 2 | 64600 | 1 | 14000 | 8 | 63200 | 11 | 42000 | 11 | 15565 | 33 | 199365 |
| Karnataka | 3 | 172000 | 1 | 10300 | 2 | 15000 | 3 | 10920 | 2 | 2200 | 11 | 210420 |
| Kerala | 3 | 113000 | — | — | — | — | 1 | 2700 | — | — | 3 | 115700 |
| Madhya Pradesh | 3 | 180700 | — | — | — | — | — | — | 2 | 2850 | 5 | 183550 |
| Maharashtra | 2 | 89400 | 1 | 44200 | 5 | 34800 | 12 | 43000 | 5 | 6160 | 28 | 217560 |
| Nagaland | 1 | 33000 | — | — | — | — | — | — | — | — | 1 | 33000 |
| Orisa | 2 | 126500 | 1 | 18000 | — | — | — | — | — | — | 3 | 144500 |
| Rajasthan | — | — | — | — | 1 | 9000 | 1 | 4500 | — | — | 3 | 13500 |
| Tamilnadu | 1 | 55000 | 1 | 15000 | 3 | 23000 | 4 | 15800 | — | — | 9 | 108800 |
| Uttar Pradesh | 1 | 46000 | — | — | 2 | 20000 | 5 | 13440 | 15 | 24265 | 23 | 103705 |
| West Bengal | 4 | 148000 | 1 | 13500 | 5 | 34775 | 3 | 11000 | 5 | 6720 | 15 | 213995 |
| TOTAL : | 28 | 1399300 | 12 | 183300 | 41 | 336275 | 47 | 166860 | 51 | 75690 | 179 | 2161425 |
| Percentage % | 15.6 | 64.8 | 6.7 | 8.5 | 22.9 | 15.5 | 26.3 | 7.7 | 28.5 | 3.5 | 100 | 100 |

TABLE - 2

DISTRIBUTION OF RAW MATERIALS ANDPULPING PROCESSES.

| S. No. | Mill Category. | Raw Materials. | Approx Usage %. | Process adopted. |
|---|---|---|---|---|
| 1 | Large | Bamboo | 75 | Kraft |
| | | Hardwoods | 22 | |
| | | Softwoods | 1 | |
| | | Others | 2 | |
| 2 | Medium | Agricultural Residues | 80 | Soda |
| | | Wast Paper | 15 | |
| | | Purchased Pulp | 5 | |
| 3 | Small | Agricultural Residues | 40 | Mechanical |
| | | Waste Paper | 60 | |

TABLE—3

PER CAPITA CONSUMPTION OF PAPER.

| Country | Kgs. per year. 1960. | 1973 | 1981 |
|---|---|---|---|
| U.S.A. | 196 | 290 | 268 |
| Canada | 127 | 205 | 197 |
| Japan | 47 | 145 | 143 |
| U K. | 107 | 137 | 124 |
| France | 58 | 109 | 115 |
| India | 0.9 | 2 | 2 |

standard of living. Table 3 gives per capita consumption of paper of three difftrent years in some developed countries as well as India.

Our per capita consumption (current figure is around 2.0 kg/year) is only small fraction of that of developed countries. The imperative need to increase this figure would require an accelerated rate of growth of the industry which would necessarily be accompanied by massive inputs of capital and energy. A general picture of growth rate of the paper industry may be obtained from Table 4 which indicates the growth for the period 1950-1981 and the projections until 2000 AD.

Table 5 indicates categorywise growth of paper industry from 1979 to 1982. A major change in the growth has been in small-sized paper mills of capacity between 2,000 to 10,000 TPA whereas, there is a marginal increase in number of units in the higher capacity range (20,000 TPA and above).

Capacity utilisation of paper industry declined in the past decade, more so after the energy crisis of 1973. The capacity utilisation which was 95.5%, steadily declined to 67.9% in 1979. Shortage in the

TABLE—4.

GROWTH OF PAPER MILLS IN INDIA.

| Year. | Capacity Million Tonnes. | Rate of growth for each period%. | Over all growth rate/annum %. | per capita capacity Kgs. |
|---|---|---|---|---|
| 1950 | 0.14 | — | — | — |
| 1960 | 0.26 | 7.0 | — | — |
| 1970 | 0.87 | 13.0 | — | — |
| 1976 | 1.14 | 4.5 | 8.5(1950-76) | 2.0 |
| 1281 | 1.68 | 7.0 | — | 2.5 |
| 1986 | 2.20 | 5.5 | — | 3.0 |
| 1991 | 2.80 | 5.0 | — | 3.5 |
| 1996 | 3.50 | 4.5 | — | 4.5 |
| 2000 | 4.25 | 4.0 | 5.5(1976-2000) | 4.5 |

*Source : NCP interim Report on Energy Utilisation in Paper Industry.

## ENERGY AUDIT AND CONSERVATION IN PULP AND PAPER INDUSTRY IN INDIA.

supply of raw material and energy, particularly power, are some of the major constraints in improving capacity utilisation.

Table 6 shows capacity utilisation in different mills—capacitywise and agewise and shows that there is actually no impact of age or installed capacity on the capacity utilisation.

## ENERGY CRISIS

Indian Paper Industry uses the external fuel sources to an extent of 70%. This is very high compared to mills in developed countries which depend on outside sources only to the extent of

TABLE—5 GROWTH OF PAPER INDUSTRY CATEGORYWISE

| Category. | No. of Units. 1970. | 1980. | 1981. | 1983. | Total Installed Capacity. 1979. | 1980. | 1981. | 1983. |
|---|---|---|---|---|---|---|---|---|
| I | 19 | 20 | 22 | 28 | 10,75,460 | 11,14,860 | 11,27,860 | 13,99,300 |
| II | 6 | 8 | 9 | 12 | 1,12,500 | 1,20,500 | 1,48,500 | 1,83,300 |
| III | 23 | 24 | 31 | 41 | 1,05,900 | 2,44,775 | 3,26,275 | 3,36,275 |
| IV | 27 | 31 | 33 | 47 | 1,11,160 | 1,47,510 | 1,47,770 | 1,66,860 |
| V | 31 | 37 | 41 | 51 | 53,145 | 60,095 | 66,145 | 75,690 |
| Total | 106 | 121 | 136 | 179 | 15,30,165 | 16,56,740 | 18,16,550 | 21,61,425 |

CATEGORY—

| | | | |
|---|---|---|---|
| I | Above | 20,000 | Tonnes Per Year (TPY) |
| II | Between | 10,000 | 20,000 Tonnes Per Year (TPY) |
| III | Between | 5,000 | 10,000 Tonnes Per Year (TPY) |
| IV | Between | 2,000 | 5,000 Tonnes Per Year (TPY) |
| V | Less than | 2 000 | Tonnes Per Year (TPY) |

TABLE—6 AGE, INSTALLED CAPACITY AND CAPACITY UTILISATION

| | Age Years | Installed Capacity (TPA) | Capacity Utilisation (%) 1978 | 1979 | 1980 |
|---|---|---|---|---|---|
| 1. | 98 | 83,000 | 96 | 89 | 86 |
| 2. | 16 | 75,000 | 99 | 101 | 82 |
| 3. | 5 | 60,000 | 88 | 86 | 61 |
| 4. | 18 | 55,000 | 62 | 87 | 78 |
| 5. | 12 | 40,000 | 86 | 75 | 86 |
| 6. | 44 | 24,000 | 97 | 96 | 77 |
| 7. | 12 | 7,500 | 85 | 90 | 91 |
| 8. | 3 | 2,200 | 119 | 128 | 94 |
| | Total : | 3,47,000 | 86 | 87 | 76 |

Source : Summary Proceeding Papers ICICI Workshop on Energy (P, 39).

30–50%. The fuel component in our paper industry contributes to as high as 15 to 20% of the total cost of production at present compared to 6–12% before the energy crisis. This single most important factor which must be given utmost consideration to keep up viability of the paper industry. Mills started before the energy crisis were not required to pay much attention to the energy conservation aspect because of the low fuel cost. But these mills are now hard hit by the energy crisis and have to adopt to conservation methods.

The period of review for energy costs can be divided into 3 phases ;

**Pre Energy Crisis (1970-73)**

Prior to energy crisis when oil and coal prices were more or less the same per unit of steam generation.

**Energy Crisis (1973-79)**

In 1973, oil embargo was imposed by Arabs. OPEC was conceived and as a result oil prices continued to rise.

**Post Energy Crisis (1979 onwards)**

After the second steep hike in furnace oil prices, oil price which was just Rs. 295/– ton in 1970-71 has reached Rs. 2,900/– ton in May, 1983 registering a rise of 985%. Table 7 shows yearwise fuel oil and coal prices and corresponding steam cost.

TABLE—7

| Year. | Fuel Oil Price Rs/ton. | Fuel Oil Price Index. | Steam Cost. Rs/Ton. | Steam Cost Index. | Coal Price (100% transport by rail Rs/Ton). | Coal Price rise Index. | Steam Cost Rs/Ton. (Steam by Coal). | Steam Cost Index. |
|---|---|---|---|---|---|---|---|---|
| **PRIOR TO ENERGY CRISIS—** | | | | | | | | |
| 1967–68 | 175 | — | 13.46 | — | 90 | — | 20 | — |
| 1968–69 | 227 | — | 17.46 | — | 90 | — | 20 | — |
| 1969–70 | 261 | — | 20.07 | — | 95 | — | 21 | — |
| 1970–71 | 295 | 100.00 | 22.69 | 100.00 | 100 | 100 | 22.2 | 100.00 |
| 1971-72 | 296 | 100.33 | 22.77 | 100.35 | 102 | 102 | 22.6 | 101.8 |
| 1972–73 | 333 | 112.88 | 25.61 | 112.86 | 108 | 108 | 24 | 108.1 |
| **AFTER ENERGY CRISIS—** | | | | | | | | |
| 1973–74 | 665 | 225.42 | 51.15 | 225.6 | 120 | 120 | 26.6 | 119.8 |
| 1974–75 | 878 | 297.63 | 67.53 | 297.52 | 128 | 128 | 28.9 | 127.93 |
| 1975–76 | 1028 | 348.47 | 79.07 | 348.47 | 150 | 150 | 33 3 | 150.00 |
| 1976–77 | 1030 | 349.15 | 79.23 | 349.18 | 160 | 160 | 35 5 | 159.9 |
| 1977–78 | 1050 | 355.93 | 80.77 | 355.97 | 205 | 205 | 45.5 | 204 9 |
| 1978–79 | 1150 | 389.83 | 88.46 | 389.86 | 208 | 208 | 46.2 | 208.1 |
| **AFTER SECOND PRICE HIKE—** | | | | | | | | |
| 1979–80 | 1564 | 530.17 | 120.31 | 530.23 | 248 | 248 | 55 | 247.7 |
| 1980–81 | 2307 | 782.03 | 177.46 | 782.10 | 275 | 275 | 61 | 274.7 |
| 1981–82 | 2711 | 918.98 | 208.54 | 919.08 | 315 | 315 | 70 | 315.3 |
| 1982–83 | 2905 | 984.79 | 223.46 | 984.84 | 415 | 415 | 92 | 414.4 |

Notes :
1. Price rise and steam cost is based on 1970-71=100.
2. One ton fuel oil generates 13 tonnes of steam @ 600 psig, 750°F.
3. One ton coal generates 4.5 tonnes of Steam @ 600 psig, 750°F.

TABLE—8

COST OF PURCHASED ELECTRIC POWER IN MAHARASHTRA, GUJARAT AND BENGAL.

| Year | Cost of Purchased Electric Power | | |
|---|---|---|---|
| | Maharashtra. Rs/kwh. | Gujarat. Rs/kwh. | Bengal. Rs/kwh. |
| 1972-73 | 0.11 | | |
| 1973-74 | 0.13 | | |
| 1974-75 | 0.15 | 0.19 | |
| 1975-76 | 0.18 | 0.25 | 0.24 |
| 1976-77 | 0.21 | 0.29 | 0.26 |
| 1977-78 | 0.23 | 0.32 | 3.27 |
| 1978-79 | 0.28 | 0.34 | 0.30 |
| 1979-80 | 0.31 | 0.39 | 0.35 |
| 1980-81 | 0.36 | 0.52 | |
| 1981-82 | 0.52 | 0.63 | |
| 1982-83 | | | |
| May, 1983. | | | |

**Purchase Power Cost**

Purchased power tariff also increased steeply yearwise. Table 8 indicates purchased power rates in Maharashtra, Gujarat and Bengal. Power prices which were only 15 paise per kwh in 1970-71 has risen to a level of 90 paise per kwh in April, 1983. The trend in other states is not much different.

The states blessed with hydro power have power in the range of 25-35 paise per kwh (Kerala & Karnataka).

To combat above situation, most mills have started taking some of the following measures ;

— Switch over from oil to coal and install more efficient boilers.

— Higher power generation from back pressure turbines

— Increased number of brown stock washing stages.

— Switch over from cnical refiners to disc refiners.

— Renovation of press sections.

— Install energy efficient evaporation system.

— Improve power factor.
— Adopt better heat recovery systems.
— Reduce water requirement by recycling and segration.
— Switching on to low energy consuming raw materials such as waste paper and agricultural residues.

## ENERGY CONSUMPTION PATTERN IN INDIAN PULP AND PAPER INDUSTRIES

Unlike other energy intensive industries, paper industry requires large quantum of low grade energy (electric power) and the rest is essentially low grade energy (process heat). But high grade energy resources in the form of fossil fuels are extensively used in the paper industry to meet the low grade energy requirements. **Hence thermodynamics second law efficiency of paper** production is the lowest among the energy intensive manufacturing sectors. Second law efficiencies of steel production is 21%, cement manufacture is 10%, petroleum refining is 9% and paper manufacture is only 1%.

The most attractive and easiest way to improve the second law efficiency of paper making is to boost the cogeneration potential of paper mills, This would enable a better thermodynamic matching of the energy source (fossil fuels) employed and the end use energy task in the industry.

About 30% of total energy requirement of large paper mills is met by the surplus net energy available in the chemical recovery process and the rest 70% is purchased as fuel and power. **Specific total purchased energy in the large mills varies from 7.62 to 13.25 M Kcal/Tonne of paper.** Process heat consuption in the large mills varies from 11.6 to 16.9 T of steam/tonne of paper and electric power consumption from 1305-1873 kwh/tonne of paper, (Table 9).

Large mills cogenerate to the extent of 25 to 60% of the total power requirement. One particular mill generates 100% of its total power requirement.

Coal is the main fuel in the paper mills for steam generation. Oil is used only as a standby fuel. More oil is consumed by the mills situated far away from coal fields where the reliability of coal supply and its quality is poor. A mill in the South located far away from the coal fields used oil to the extent of meeting 18% of the total energy input to generate steam in a particular year.

Oil is used to boost the steam generation in the power boilers as well as chemical recovery boilers. Oil is used in all the recovery boilers for start ups and some of the old recovery boilers burn it continuously for flame stabilisation and higher steam generation.

The energy requirement of paper industry throws a considerable burden on the energy demands of the manufacturing sector of our country. The estimated total energy requirement of paper indusry based on the installed capacity as on March, 1982 at seventy per cent capacity utilisation was 2.39 million tonnes coal equivalent and 1356 million kwh electricity. The projected energy consumption of paper industry in 2000 AD, based on 4.25 million tonnes installed capacity and 75% utilisation will be 5.4 million tonnes of coal equivalent and 3186 Million kwh of electrical energy. They would contribute to around 7 per cent of the energy requirements of the whole manufacturing sector of the respective sources in that year.

The projected figures for thermal energy and electrical energy for the year 2000 AD (which is virtually more than double the present requirement) is an alarming figure, not only for the Government but also for the industry. To meet this demand, there will be a tremendous pressure on our coal and oil resources.

Pressures on future energy demand can be considerably reduced by narrowing the wide variation in the energy use prevailing in our paper industry (Table 9).

## ENERGY CONSUMPTION PATTERNS IN OTHER COUNTRIES

In the present 'hot' energy situation, it is of interest to compare energy supply and consumption patterns in different countries. The comparison of Finland with North America, indicates compulsion of circumstances. The first difference lies in Finnish energy costs which is one of the highest. This has made Finnish industry leaders highly energy-minded. The second difference concerns design philosophy. Projects to reduce energy consumption or to improve the energy supply system have received very high priority among investment alternatives, which was reflected upon the return-on investment requiremets for such projects. The third difference is the level of the energy conscious attitude among mill personnel. It must start from the top and be maintained through proper supervisory methods and guidelines for equipment maintenance.

One example from Finnish paper industry is the tendency to prefer larger boiler units equipped for several different or alternative fuels. Thus four-fuel steam boilers are found quite feasible even

TABLE—9

ENERGY CONSUMPTION PATTERN IN INDIAN PULP & PAPER INDUSTRY :

| Sl. No. | Mill. | Prodn. | Purchased fuel | | Avg. Cal., Value Kacl/Kg. | | Purchased Electricity (Kwh.) | Total Purchased Energy, M.Kcal | Energy input MKcal /T. | Energy Cost Rs/T. | %age of Self generation | Self generation kwhr /Ton of Paper | Reported Specific Energy Consumption. | | Installed Capacity (TPA) | Product Mix | Raw Material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Coal | Oil | Coal | Oil | | | | | | | Steam T/T | Power kwh/T | | | |
| 1. | Mill—A. | 36931 (80–81) | 46034 | 1680 | 5250 | 10000 | 25970400 | 281400 | 7.62 | 869 | 46.3 | 606 | 11.6 | 1305 | 46200 | Writing Printing Kraft | Wood -90% |
| 2. | Mill—B. | 61300 | 125328 | 200 | 5225 | 10000 | —Nil— | 656800 | 10.71 | 343 | 100.0 | 1520 | 16.9 | 1520 | 85000 | Writing Printing | Bamboo–75% Wood -25% |
| 3. | Mill—C. | 66832 | 129903 | 1465 | 4500 | 10000 | 83810440 | 670400 | 10.03 | 998 | 28.4 | 497 | 11.6 | 1710 | 75000 | Writing Printing Packaging | Bamboo–40% Wood -60% |
| 4. | Mill—D. | 51283 (80–81) | 89447 | 2923 | 4500 | 10000 | 102564716 | 519900 | 10.03 | 1090 | 23.4 | 610 | 13.0 | 1949 | 67500 | Newsprint | Bamboo–51% Salari Pulp -55% (4x) |
| 5. | Mill—E. | 30000 (80–81) | 109740 | 425 (FW–600) | 5000 | 10000 (FW–2250) | 19345835 | 570900 | 10.03 | - | 58.3 | 902 | 20.0 | 1873 | 30000 | Writing Printing | Bamboo–70% Wood -30% |
| 6. | Mill—F. | 12694 Paper 2295 Pulp. | 30572 | 2287 | 5500 | 10000 | 19372000 | 207710 | 13.25 | 1182 | 32.5 | 649 | 17.4 | 1947 | 33000 Paper 39000 | Writing Printing Pulp Sheet. | Bamboo–100% |
| 7. | Mill-G. | 12052 (1981.) | 34500 | 36 (HSD) | 4500 | 10000 | 38342400 | 187600 | 12.12 | 1344 | 5.0 | - | 10.2 | 2750 | 12000 | Tissue & Speciality. | Hemp & -80% Jute Pulp. -20% |
| 8. | Mill—H. | 53701 (80–81) | 77438 | 11068 | 5001 | 11200 | 49284570 | 545644 | 10.16 | - | 41.8 | 659 | 18.5 | 1576 | 52800 | Writing Printing Board-Craft. | Bamboo–70% Wood -30% |

Source : Interim Report on Energy Conservation by NPC. Madras.

with extensive automatic control. The fuels most frequently used in multiple-fuel furnaces are hogged fuel, spent sulfite liquor, peat, pulverized coal and oil. Such boilers have been built for pressures upto 1,700 psig.

TABLE—10 AVERAGE BLEACHED KRAFT PULP MILL ENERGY BALANCE IN USA & FINLAND.

Energy Consumption per air dry ton of pulp.

| | | USA | Finland |
|---|---|---|---|
| Heat GJ/t | Process heat | 21.0 | 16,0 |
| | Mechanical driven | 0.8 | |
| | Backpressure power | 0.6 | 2.6 |
| | Total Consumption | 22.4 | 18.6 |
| | By-product fuels | 14.0 | 16.0 |
| | Other fuel source | 8.4 | 2.4 |
| | Total fuel source | 22.4 | 18.6 |
| Power Mht/t | Mechanical drives | 0.20 | — |
| | Backpressure power | 0.15 | 0.65 |
| | Other electricity | 0.40 | 0.10 |
| | Total power | 0.75 | 0.75 |
| Fuel Gj/t | Heat generation | 28.0 | 21.9 |
| | Process fuel | 2.3 | 1.8 |
| | Total on site consumption | 30.3 | 23.7 |
| | By-product fuels | 17.5 | 18.8 |
| | Other fuels | 12.8 | 4.9 |
| | Total fuel mix | 30.3 | 23.7 |
| | For other electricity | 4.0 | 1.0 |
| | Gross sonsumption | 34.3 | 24.7 |
| | External energy | 16.8 | 5.9 |

SOURCE : PULP AND PAPER INTERNATIONAL NOVEMBER 1981, P 67.

Typical measures taken by the Finnish industry are as mentioned below :

— A 20% reduction in pulping steam consumption in batch digesters.

— 40–50% drop in steam consumption for soot blowing in recovery boiler.

— 10–15% drop in steam consumption in bleach plants mainly through improved temperature control.

— 10–20% reduction in oil used in lime kiln.

— 30–40% drop in power consumption for refining.

— 10% drop in power consumption for grinders.

— 6–8% drop in steam consumption on paper machines.

There are variations in energy consumption patterns of North American and Scandinavian mills, the latter is more energy deficent (Table 10). The major difference between the two is in the design features adopted by the mills. Scandinavian mills use.

— Low liquor to wood ratio and indirect heating in batch digesters.

— Two stage batch digester heating.

— Good pulp washing efficiency.

— Evaporation of spent liquor to high solids, concentration.

— Low flue gas temperature from lime kiln.

— Efficient press section in pulp dryers and paper machine.

— Closed and well insulated dryer hoods with heat recovery.

— Closed water systems.

— High pressure boilers.

— Higher boiler efficiency.

— Efficient by-product fuel and waste fuel hea recovery.

— Using 2-stage heaters for the combustion air.

North American mills were production orinted rather than energy efficiency oriented.

As indicated above, the total demand of heat and electrical energy and its utilisation in a pulp and paper mill depends largely on the basic concepts of the mill design and choice of processes equipment. The efficiency of energy utilisation in majority of the mills in India is far from optimum based on inter mill comparative performance both within and outside the country (Tables 9, 11).

Energy efficiency of a typical Indian mills is much lower when compared to its counter part in the developed countries. Absence of modernisation at an aggregate level has reflected in lower energy efficiencies vis-a-vis mills in developed nations.

For instance a relatively modern mill in India consumes 70% more heat energy and 7% additional electrical energy to produce one tonne of paper, when compared to the energy consumption in a Scandinavian mill. Table 11 shows comparison of break up of energy utilisation of typical Indian & Swedish kraft mill. Fig. 1 gives specific heat consumption sectionwise of Indian mills as compared to Swedish mills.

TABLE—11 COMPARISON OF BREAK—UP OF ENERGY UTILISATION OF A TYPICAL INDIAN INTEGRATED BLEACHED KRAFT PAPER MILL VS. A SWEDISH INTEGRATED BLEACHED KRAFT PAPER MILL

| | 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 fuel | | 9.37 | 3.53 |
| | ii) Internal fuel (black liquor bark etc) | | 4.58 | 4.65 |
| | | Total | 13.95 | 8.18 |
| III. | Fuel Source Utilsation (M. Kcal) | | | |
| | i) Steam Cycle & 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 |
| | Back pressure power | | 658 | 787 |
| | | Total | 1576 | 1689 |
| V. | Back pressure power generation efficincy | | 22.8 | 85 |

Another interesting feature is that the mills abroad (North America and Swedish) are less dependent on purchased fossil fuels and power as they use more of the locally available by-product energy resources with attendant high efficiency. For example a Swedish mill purchased on an average 40% of total energy requirement to produce one tonne of paper as against 70% an average figure for Indian mills.

The overall operating efficiency of Energy conversion systems (Fuel to steam & power) is phenomenaly low in Indian mills compared to that of mills in the developed nations. Fig. 2 shows the sankey diagram of energy conversion systems of a typical above average Indian integrated kraft mill based on data published in 1981. It can be observed from the sankey diagram that 42% of the total energy input in the form of fuels (both purchased and by product) is lost in the conversion processes. In other words the operating efficiency of energy conversion system in a above average Indian integrated mill is only 58% as against 76% of a typical Scandinavian mill. Also the over all efficiency of by-product power generation in this Indian mill is only 17% as against the possible back pressure power generation efficiency of 80%. The energy demand in pulp and paper industry for the major pulp and paper producing countries of the world is given in Table 12. This table reveals that the by-

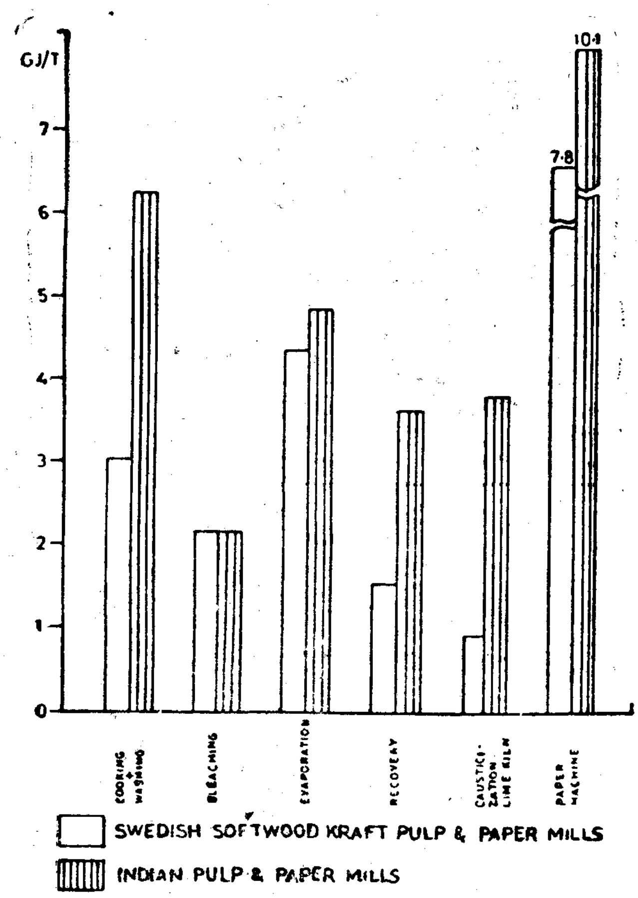



FIG.1: SPECIFIC HEAT CONSUMPTION OF SWEDISH SOFTWOOD AND INDIAN PULP AND PAPER MILLS

product fuel utilisation and back pressure power generation is the highest in Scandinavian countries compared to the other countries.

## FUTURE ENERGY SOURCES

Opportunities to increase the world's supply of hydrocarbons, to diversify the sources of this supply, and to substitute one fuel for another exist now and will continue to exist well into the next decade and even into the next century, with no enormous price escalations needed.

In the next few years, the number of major oil exporting nations will expand to include Mexico, the United Kingdom and the People's Republic of China. The resulting disparity of national interests will cause quite varied responses to changing supply-demand situations in world markets.

### World Demand

Expert's long-range projections of world energy demand have been changing substantially in recent years. Today's estimate for the year 2000 is more than 22 per cent lower than the earlier one.

After adoptation of the new federal milage standards in USA, the decline in barrels of energy (BOE) consumed by automobiles in the United States is forecast to be 25 per cent.

Efficiency improvement in Japan and Western Europe will be more modest, of course, because the historically high gasoline prices in these areas have resulted in car designs stressing minimal gasoline consumption.

Future energy prices will depend heavily on the availability of international supplies as a function of the marginal costs of the recovery of additional natural fuel resources.

As for the development of other new energy systems based on advanced technology (particularly those of large scale), one can expect price pressures until the mid-1980s. There after, as world energy prices rise, new systems may become commercialized.

In 1975, oil supplied 46 per cent, solid fuels 29 per cent, natural gas 18 per cent, hydrolectric power six per cent, and nuclear power one per cent of the world's energy needs. By 2000, the share of petroleum is expected to have dropped to 35 per cent and the share of nuclear power to have risen to 11 per cent.

Effective energy management can be important to the success of future growth strategies of oil-importing developing countries, according to the experts.

### Balanced Agriculture and Industry :

It is in the poorer countries that a more fundamental shift is proposed toward the meeting of basic needs as the first stage in an altered development strategy. In those cases, energy implications would appear to flow from the emphasis on highly decentralised and relatively self-sufficient sub-economics on labour intensively in both industry and agriculture; on the supply of low-cost wage goods, and on the general availability of basic educational and health services.

Adoption of more labour intensive activities will be weighed more critically, since capital and energy seem to be complimentary.

One major thrust of the search for lower cost alternatives to petroleum has been to increase the efficiency of use of traditional fuels in rural areas, through the addition of capital.

The potential gains are so large that these kinds of improvements may lead to a net decrease

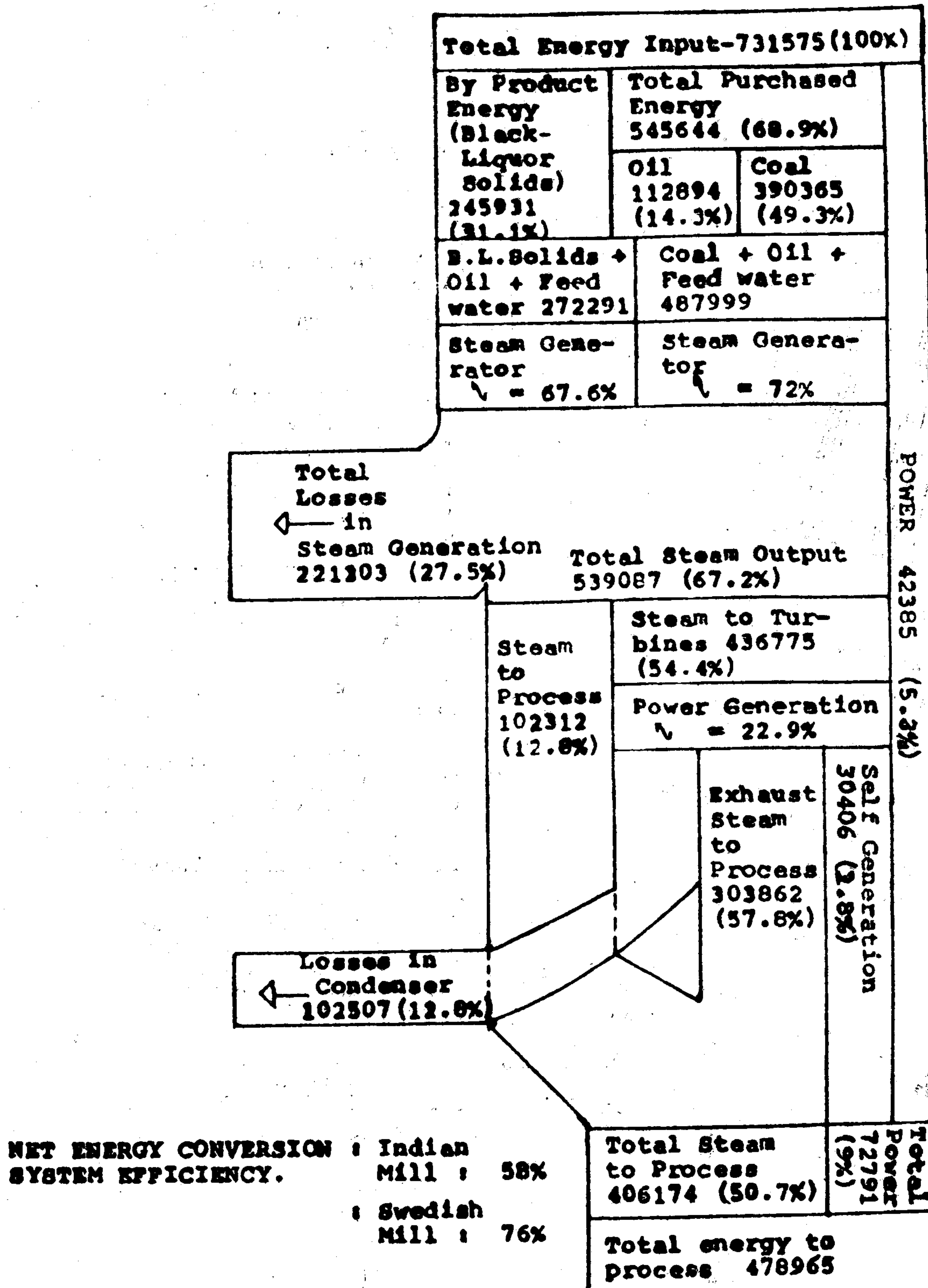



FIG. 2 : SANKEY DIAGRAM OF ENERGY CONVERSION IN A TYPICAL LARGE MILL.

## TABLE—12 ENERGY CONSUMPTION IN THE PULP & PAPER INDUSTRY COMPARED WITH TOTAL 1979.

| Country/Total | Unit | USA. | Canada. | Sweden. | Finland. | USSR. | Japan. | Brazil. |
|---|---|---|---|---|---|---|---|---|
| Primary Energy | PJ/Yr. | 80,000 | 8,500 | 1,900 | 0,900 | 44,000 | 14,000 | 5,000 |
| Electricity | TwH/Hr. | 2,400 | ,320 | , 90 | , 35 | 1,200 | ,500 | ,120 |
| **Pulp & Paper** | | | | | | | | |
| Fuels | PJ/Yr. | | | | | | | |
| Byproduct fuel | ,, | ,800 | ,230 | ,140 | 90 | ,140 | ,140 | 40 |
| Other Fuel | ,, | 1,030 | ,310 | , 80 | 65 | ,180 | ,240 | 60 |
| Other Electricity | TwH/Hr | ,500 | ,240 | 90 | 55 | ,110 | ,170 | 35 |
| Total | PJY/r | 2,330 | ,780 | ,310 | ,210 | ,430 | ,550 | ,135 |
| % of country | | 3 | 9 | 17 | 23 | 1 | 4 | 3 |
| **ELECTRICITY** | TwH/Hr | | | | | | | |
| Back Pressure Power | | 9.0 | 3.0 | 4.0 | 5.5 | 4.0 | 6.0 | 0.6 |
| Others | | 49.0 | 24.0 | 9.0 | 5.5 | 11.0 | 17.0 | 3.4 |
| Total | TwH/Hr | 58.0 | 27.0 | 13.0 | 11.0 | 15.0 | 23.0 | 4.0 |
| % of country | | 2 | 8 | 14 | 31 | 1 | 4 | 3 |
| Back pressure power as % of Total P&P Power | | 16 | 11 | 31 | 50 | 27 | 26 | 15 |

**Glossary of Terms –**

1 EJ = 1 exajoule = $10^{18}$ joule,
1 PJ = 1 petajoule = $10^{15}$ joule,
1 TJ = 1 terajoule = $10^{12}$ joule,
1 GJ = 1 gigajoule = $10^{9}$ joule,
1 Quad
1 Mtoe = $10^{15}$ Btu. = 1.055 EJ
1 million metric ton oil equivalent.
1 Million BTU/Short ton = 1.16 GJ/metric ton.
1 TWK,
TwH/Yr (Tera Watt Hour) = $10^{9}$ KWH.

(Source/PULP & PAPER INTERNATIONAL)
November 1981, P.67.

TABLE—13

HYDROPOWER POTETIAL AND USE BY REGION, 1980.

| | Technically Exploitable Potential. | Exploited Resources. | Share of Potential Exploited |
|---|---|---|---|
| | (Megawatts) | | (Percent) |
| ASIA | 610,100 | 53,079 | 9 |
| South America | 431,900 | 34,049 | 8 |
| Africa | 358,300 | 17,184 | 5 |
| North Aerica | 356,400 | 1,28,872 | 36 |
| USSR | 250,000 | 30,250 | 12 |
| Europe | 163,000 | 96,007 | 59 |
| Oceania | 45,000 | 6,795 | 15 |
| World | 2,200,000 | 3,63,000 | 17 |

SOURCE · WORLD ENERGY CONFERENCE, SURVEY OF ENERGY RESOURCES, ECONOMIC IMPACT 1982, P 40 1

TABLE—14

SELECTED COUNTRIES OBTAINING MOST OF THEIR ELECTRICITY FROM HYDROPOWER, 1980.

| COUNTRY | SHARE OF ELECTITY FROM HYDROPOWER (PERCENT) |
|---|---|
| GHANA | 99 |
| NORWAY | 99 |
| ZAMBIA | 99 |
| MOZAMBIQUE | 96 |
| ZAIRE | 95 |
| SRI LANKA | 94 |
| BRAZIL | 87 |
| PORTUGAL | 77 |
| NEW ZEALAND | 75 |
| NEPAL | 74 |
| SWITZERLAND | 74 |
| AUSTRIA | 67 |
| CANADA | 67 |
| INDIA | 30* |

SOURCE : UNITED NATIONS, WORLD ENERGY SUPPLIES. ECONOMIC IMPACT, P 40.

*ESTIMATED AT CPM.

in the overall capital output ratio. Biogas, plants, for example, produce more fuel and fertilizer than burning dung directly, solar cookers use direct solar energy ; and improved wood stoves can increase the useful energy received from a quantity of wood as much as tenfold.

**Hydroelectric Power**

Harvesting the full potential of hydropower can still be a major source of energy today. Hydropower contributes to nearly 25% of the world's electricity today.

Table 13 gives the hydropower potential, regionwise, in the world as in 1980. Table 14 gives share of electricity from hydropower for some elected countries of the world, which indicates the dismally low figure for India

## SPIRALLING COST OF ENERGY INPUTS

Prices of energy inputs have steeply increased during last decade after 1973 oil crisis. Purchased power rate which was 19 paise per unit in 1974 has shot upto 90 paise (374% increase) in Gujarat State (Table 4).

Fuel oil was available at Rs. 175 per ton in 1967 has skyrocketed to Rs. 2,900/Ton in May, 1983 (1560% increase). Similarly coal price has increased by 4.6 fold compared to 1967 price (Tables 7 & 15).

There was an increase of 29% in one year on the cost of energy purchased and 7.5% increase in cost of energy per ton of realization value, in paper industry.

## COST OF WASTAGE OF 1 KWH CONNECTED POWER AND 1 KG OF STEAM LEAKAGE

1 kw reduction in operating amounts to approximately Rs. 6,000/- per year saving at purchased power rate of 80 paise per unit.

Steam consumption per ton of paper in Indian integrated mills varies from 11 to 13. Even saving of 0.1 ton/hr steam of 60 psig on continuous basis amounts to one lac rupees saving in energy cost per year.

## FINDINGS OF NATIONAL PRODUCTIVITY COUNCIL

The impact of higher energy prices and shortages on the Indian economy has been very significant. Manufacturing sector being a major client consuming 40% of the total commercial energy has

TABLE—15 YEARWISE PRICES OF PURCHASED POWER, COAL AND FUEL OIL.

| Year (s). | Purchased Power Tariff ps/kwh. | Purchased Power Price Rise Index. | Fuel Oil Price Rs./Ton. | Fuel Oil Price Rise index. | Coal Price Rs./Ton. | Coal Price Rise Index. |
|---|---|---|---|---|---|---|
| 1967–68 | — | — | 175 | — | 90 | — |
| 1968–69 | — | — | 227 | — | 90 | — |
| 1969–70 | — | — | 261 | — | 95 | — |
| 1970–71 | — | — | 295 | 100.00 | 100 | 100 |
| 1971–72 | — | — | 296 | 100.33 | 102 | 102 |
| 1972–73 | — | — | 333 | 112.88 | 108 | 108 |
| 1973–74 | — | — | 665 | 225.42 | 120 | 120 |
| 1974–75 | 19 | 100 | 878 | 297.63 | 128 | 128 |
| 1975–76 | 25 | 131.6 | 1028 | 348.47 | 150 | 150 |
| 1976–77 | 29 | 152.6 | 1030 | 349.15 | 160 | 160 |
| 1977–78 | 32 | 168 4 | 1050 | 355.93 | 205 | 205 |
| 1978–79 | 34 | 178.9 | 1150 | 389.83 | 208 | 208 |
| 1979–80 | 39 | 205.25 | 1564 | 530.17 | 248 | 248 |
| 1980–81 | 52 | 273.6 | 2307 | 782.03 | 275 | 275 |
| 1981–82 | 63 | 331.6 | 2711 | 918.98 | 315 | 315 |
| May' 83 | 90 | 473.7 | 2905 | 984 84 | 415 | 415 |

Notes :
1. Purchased Power Rates in Gujarat are mentioned.
2. For estimating price rise index for fuel oil & coal, base year is taken as 1970-71.
3. For estimating price rise index for purchased power, base year is taken as 1974-75
4. 100% Coal Transportation by Railways.

to bestow much greater attention to Energy Management than before. Being energy intensive, Energy Management in paper manufacture deserves special attention.

## PAPER INDUSTRY IN INDIA :

A general picture of the paper industry may be had from the Table 3 which gives the growth for the period 1950-76 and the projections until 2000 AD. From 0.14 million tonnes in 1950, the installed capacity rose to 1.14 million tonnes in 1976 and 1.5 million tonnes in 1980. The total investment made is Rs. 10,000 millions. The energy requirement for 1980 production level is put at 1.6 million tonnes coal equivalent and 1700 million units of power.

At the production level of 1986 installed capacity of 2.2 million tonnes, the projected requirements of energy would be 2.4 million tonnes coal equivalent and 2400 million units of power.

They would constitute 6.1 per cent and 2.7 per cent of the energy requirements of the entire manufacturing sector of the respective sources in that year.

In the long term horizon till 2000 AD for increasing the per capita consumption from the present 2 kgs. per annum to 4.5 kgs., the existing capacity will have to be trebled. Corresponding increases in energy inputs will be needed which in absolute terms would be substantial.

## RAW MATERIALS AND PROCESSES :

Large mills are located around forest resources such as bamboo and hardwoods. The fibre sources for the medium and small mills are any two or more of non-wood materials ; bagasse, agriculture residues such as rice and wheat straw ; sabai grass, jute, cotton waste, cotton rags, cotton linters, hessian, and substantial proportion of waste paper. Table 2 gives the distribution of the raw materials and pulping processes adopted in the Indian mills.

## PAPER MAKING PROCESSES

The processing steps of paper manufacture comprise of acquisition of raw materials, raw material preparation, pulping, pulp bleaching and paper board production.

## ACQUSITION OF RAW MATERIALS :

The conventional raw material for paper making is bamboo which is the preferred long fibre source. Large mills are based on this non-wood souree. Arising out of the necessity to conserve bamboo; mixed hardwoods and plantation eucalyptus are being used which in some mills constitute

70 to 80 per cent of the furnish. Raw materials are usually harvested manually and transported by road and rail. Often agricultural residues are transported by bullock carts to small mills.

**PULPING :**

The mechanical pulping process uses either round wood or chips; but the chemical pulping process uses chips exclusively. Fines produced after collection by screening can be used for pulp manufacture or as fuel. Use of bio-technology may extract fuel value from dust and also render residue as fertilizer.

Mechanical pulping involves holding wood block, that may or may not have been previously steamed against a grind stone. The wood may also go through a chipper and then to a disc refiner where the chips are ground between two discs. Defibrating is also an operation using chips that are pre-softened by soaking, steaming or mild chemical penetration.

Kraft pulping uses an alkaline solution consisting of sodium hydroxide and sodium Sulphide to digest wood chips at high pressures and temperatures. It can be done in batch or continuous digesters. Different grades of kraft pulp are produced by varying the extent to which the chips are digested, and with each variation, a different yield and energy requirement results.

Kraft pulping requires process recovers the costly pulping chemicals from spent liquor. The spent chemicals, dissolved lignins and carbohydrate fractions which are generally termed as black liquor are first concentrated by evaporation and then burned in a recovery boiler. The inorganic chemicals are withdrawn as chemical smelt and organics burn off to produce steam as a bi-product. The smelt is dissolved and recycled. Energy content of the black liquor depends on its organic content. The lower the pulp yield, the higher is the organic content and hence greater the energy content.

Sulphite pulping uses a solution of sulphur dioxide in ammonium, calcium or sodium hydroxide to digest wood chips at elevated pressures and temperatures. The cooking process is usually done in batch digesters.

It may be seen in Table 16 that 22 out of 29 units in our country use kraft process, which constitutes 80% of the total production. The 29 mills between them produce 90% of total production.

TABLE—16

KRAFT, SODA AND SULPHITE MILLS IN INDIA.

| Sl. No. | Pulping Process. | No. of Units. | Production annual tons. | Percentage of production. |
|---|---|---|---|---|
| 1. | Sulphate (Kraft) including Kraft semi-chemical | 22 | 10,24,850 | 80 |
| 2. | Soda | 4 | 76,700 | 6 |
| 3. | Acid Sulphite | 1 | 23,000 | 2 |
| 4. | Mechanical | 1 | 15,000 | 1 |
| 5. | Chemi-Mechanical | 1 | 11,000 | 1 |
| | TOTAL | 29 | 11,50,550 | 90 |

**BLEACHING :**

Energy requirements for pulp bleaching depends on the type of pulp, the extent to which pulp is bleached and chemicals used for bleaching. For example, for the same brightness, hardwood pulp uses less energy than soft wood pulp, while bleaching to the same level of brightness.

Chemical pulp is bleached in stages. Higher brightness requires more number of stages and varieties of bleach chemicals. Very bright papers require 4 to 7 bleach stages, newsprint uses 3 bleach stages and corrugated media and liner require no bleaching at all.

Energy requirements for sulphite pulp bleaching is about one third less than for an equivalent sulphate pulp.

**PAPER PRODUCTION :**

The bleached or unbleached fibres are refined to the desired freeness additives are dosed and formed into sheets on a Fourdrinier or Cylinder machines. Water is removed by applying uacuum and by pressing the sheet between rollers. It is followed by drying on steam heated cylinder driers.

The output from the machine is called 'jumbo roll' and converting this into finished product requires energy which is often carried out within the mill itself.

**ENERGY CONSUMPTION IN PULP AND PAPER MILLS :**

With a view to study the Energy Management practices within the industry a sample survey was carried out. Since 80% of the industry production is based on kraft process and about the same capacity is with the medium and large mills, mills for the survey were chosen from these categories. The following pages discuss the Energy Management practices of these mills which broadly represent the industry practices as well.

## ENERGY CONSUMPTION IN LARGE MILLS :

The production and energy related data of six large mills is summarised in Table 17. There is a wide variation in energy consumption and costs among the mills. The purchased energy requirement varies from 7.32 to 13.25 G. cal per tonne of product. The steam consumption varies from 10.5 to 17.4 tonnes per tonne of product and the power consumption from 1305 to 1949 kwh. The amount of on-site power generation is 23.4 per cent to 100 per cent of the total power used.

The price differential between oil and coal being very significant, almost all large mills and a majority of the small mills use coal as the primary fuel. Coal cost for mills situated far off from collieries is substantially higher and it may be twice or thrice or even four times that of the cost to the mills located closer to the collieries. Mills located far away from the collieries are often required to use oil, to overcome coal shortages.

Whereas the specific purchased energy indicates the overall mill energy efficiency, and specific steam and power consumption that of process energy use efficiency, the difference between these two values for a given mill indicates the combined system efficiency of steam and power generation.

## SMALL MILLS :

Specific energy costs of ten paper mills together with annual production is given in Table 18 for the years 1978-79 and 1979-80.

That the specific energy consumption varies widely with the type of paper manufactured is

TABLE—17 COMPARATIVE ENERGY COSTS AND CONSUPTION IN LARGE MILLS

| Mill | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **Description Raw material %** | | | | | | |
| Bamboo | 75 | 100 | 40 | 51 | 70 | 90 |
| Wood | 25 | — | 60 | 44 | 30 | — |
| Pulp | — | — | — | 5 | — | 10 |
| Installea Capacity TPA | 85000 | 33000 paper 39000 pulp | 75000 | 67500 | 52800 | 46200 |
| Production TPA | 61300 | 12694 paper 2295 pulp | 66832 | 51283 | 53701 | 36931 |
| **Purchased energy** | | | | | | |
| Coal Tpa | 125328 | 30572 | 129903 | 89447 | 77438 | 46034 |
| Oil Tpa | 200 | 2287 | 1465 | 2923 | 11068 | 1680 |
| Power, 1000 | Nil | 19372 | 83810 | 102565 | 49285 | 25970 |
| Self Generation 1000 kwh | 931996 | 9327 | 33215 | 31283 | 35389 | 22380 |
| Parent of self total power | 100 | 32.5 | 28.4 | 23.4 | 41.8 | 46.3 |
| **Specific figures per tonnes of paper** | | | | | | |
| Energy cost Rs. purchased. | 343 | 1182 | 898 | 1090 | 1144 | 869 |
| Energy Gcal purchased | 10.71 | 13.25 | 10.03 | 10.13 | 10.16 | 7.62 |
| Power kwh | Nil | 1296 | 1213 | 1339 | 917 | 699 |
| Self generation kwh | 1520 | 649 | 497 | 610 | 659 | 606 |
| Total Power kwh | 1520 | 1947 | 1710 | 1949 | 1576 | 1305 |
| Steam Tonnes | 16.9 | 17.4 | 11.6 | 13.0 | 10.5 | 11.6 |

known. The comparative consumption and costs for different grades of paper in a small paper mill located in Tamil Nadu is given in Table 19.

The increasing trend in specific energy consumption and costs with decreasing gram weight of paper is evident. The costs vary from Rs. 400/- to Rs. 760/- and energy consumption 3.8 to 6.2 G. cal depending on the grade of paper.

**MANUFACTURING :**

Sectionwise specific energy consumption is given in Table 19-A for two mills.

TABLE—18

COMPARATIVE COST OF POWER AND FUEL IN SMALL PAPER MILLS.

| Mill Nol. | 1978-79 Production Tonnes. | 1978-79 Cost, Rs. per tonne. | 1979-80 Production Tonnes. | 1979-80 Cost, Rs. per tonne. |
|---|---|---|---|---|
| | | | Rs. | Rs. |
| 1. | 7499 | 359 | 8986 | 351 |
| 2. | 3000 | 734 | 5600 | 545 |
| 3. | 1732 | 512 | 1791 | 557 |
| 4. | 6864 | 529 | 7089 | 558 |
| 5. | 4265 | 544 | 4751 | 617 |
| 6. | 1200 | 525 | 1693 | 700 |
| 7. | 4756 | 793 | 7048 | 703 |
| 8. | 2478 | 893 | 2398 | 889 |
| 9. | 7923 | 788 | 8073 | 925 |
| 10. | 4369 | 1142 | 4908 | 1129 |

The overall energy consumption per tonne of product for Mills—1 and 2 respectively are 10.560 and 8.092, G. cals and the corresponding percentages of steam and power are 87 to 13 and 85 to 15. The figures indicate abnormally high specific consumption levels compared to those in the developed countries. The following pages highlight the industry practices and discusses as to why these high levels of consumption arises, through brief explanations and data presented through the tables.

**PULP PLANT :**

Operating data and practices of the pulp plant comprising of the chipper house, digester house brown stock washing and bleaching is provided in Tables 20, 21 and 22. The high consumption in chipper house is due to the use of multiple units of low capacity chippers and their manual feeding and chip conveying using the pneumatic system. The chipper house is power intensive requiring 6 to 8% of total mill power. Digester house, on the other hand needs large quantities of heat energy. The heat requirement is particularly high because of the widespread use of stationary vertical batch digesters Direct cooking is more prevalent than the indirect cooking method. Direet cooking not only needs more steam but also results in much lower liquor concentration, which in turn requires more steam in evaporation. The recovery of blow heat is yet to gain wide spread aeceptance in the industry. Blow heat can be recovered as hot water for mill use. Continuous digesters are not preferred because of their limited flexibility and higher capital costs in dealing with the Indian raw materials.

TABLE—19 COMPARATIVE ENERGY CONSUMPTION AND COSTS FOR DIFFERENT GRADES OF PAPER IN A SMALL PAPER MILLS IN TAMIL NADU.

| Grammage (variety) | Production per day tonnes. | POWER: Power/t product kwh. | POWER: Power cost/t product Rs. | FUEL: Steam/t product tonnes. | FUEL: Coal/t product tonnes. | FUEL: Coal cost/t product tonnes. | Total energy/t product Rs. | Total energy/t product Gcal. |
|---|---|---|---|---|---|---|---|---|
| 120 gsm. (wrapper) | 28.0 | 816 (0.702) | 222 | 3.3 | 0.68 (3.060) | 177 | 399 | 3.762 |
| 60 gsm. (White offset printing). | 28.0 | 889 (0.765) | 241 | 3.6 | 0.74 (3.330) | 192 | 433 | 4.095 |
| 40 gsm. (Cream Wove) | 20.2 | 1307 (1.124) | 354 | 4 6 | 0.94 (4.230) | 244 | 598 | 5.354 |
| 30 gsm. (White manifold) | 13.2 | 1819 (1.564) | 494 | 5.1 | 1.03 (4.635) | 268 | 762 | 6.199 |
| Average | 22.4 | 1208 (1.039) | 328 | 4.13 | 0.85 (3.825) | 220 | 548 | 4.864 |

Note : Figures in brackets are equivalent Gcal.

TABLE—19A

SPECIFIC ENERGY CONSUMPTION IN INTEGRATED KRAFT PAPER MILLS

| | Section | Per tonne of Product. Mill-1. | Mill-2. |
|---|---|---|---|
| I. | **Steam in tonnes** | | |
| | Pulp Mill | 3.9 | 2.7 |
| | Evaporators | 4.0 | 2.5 |
| | Soda Recovery | 0.5 | 1.1 |
| | Bleach Plant | 0.4 | 0.4 |
| | Paper Machine | 4.0 | 3.0 |
| | Deaerator | 1.2 | 0.8 |
| | Total Steam | 14.0 | 10.5 |
| | Gcal | 9.184 | 6.888 |
| II. | **POWER** in Kwh | | |
| | Chippers | 120 | 80 |
| | Digesters | 60 | 50 |
| | Washing and Screaning | 150 | 130 |
| | Bleach Plant | 90 | 130 |
| | Soda Recovery | 180 | 120 |
| | Stock Preparation | 280 | 130 |
| | Paper Machine | 470 | 550 |
| | Utilities and others | 250 | 210 |
| | Total Power | 1600 | 1400 |
| | Gcal | 1.376 | 1.204 |
| III. | Total Energy (I+II) Gcal | 10.560 | 8.092 |
| IV. | Percentage Steam to percent power | 87/13 | 85/15 |

Longer cooking time and heavy steam load fluctuations because of non-staggering of bateh digesters also increase steam and fuel consumption.

Pulp washing and screening are power intensive. Power consumption in screening is high because of the high system positive pressure and high pressure drop due to improper sizing of control valve. Washing is carried out in three stages, mostly using drum washers with vacuum. Open screening system is the cause of high dilution factor leading to higher chemical losses and subsequent evaporation load. Usually three stage centricleaning system is adopted. The pressure drop with these traditional low consistency centricleaners is as high as 30 m. of water. Also with the three stage system fibre loss is high. All these lead to higher power consumption.

Bleaching requires large quantities of steam. The CEH and CEHH sequences are used on the former predominates. In CEHH sequence of bleaching, hot water is required at higher temperatures. Low consistency of pulp, higher pulp

TABLE—20

CHIPPER HOUSE ENERGY CONSUMPTION

| Sl. No. | Raw Material % | No. of chippers & capacity (tph). | Mode of chip conveying. | Installed Capacity. KW. |
|---|---|---|---|---|
| 1. | Bd/100HW | 4x45 | b/p | 3075 |
| 2. | 100 Bd | 3x30/1x1 25 | b/p | 1029 |
| 3. | 40 Bd/60HW | 10x5/1x20 | b/p | 1720 |
| 4. | 40 Bb | 2x7/4x10/1x4 | b/p | 1500 |
| 5. | 70 bb/80HW | 3x3/4x2.5 | p | 1000 |

Bb- Bamboo, HW-Hardwood.
b-belt, p-pneumatic

TABLE-21 DIGESTER HOUSE ENERGY CONSUMPTION

| Sl. No. | Digester Type & their No. | Steaming Method & its pr. kg/cm². | Bath Ratio. | Blow heat recovery. | Cond. Recovery % |
|---|---|---|---|---|---|
| 1. | SV/8 | (I) (a)/10 | 1:3.0 | HW | 30-40 |
| 2. | SV/4 | I/10 | 1:3.3 | HW | 80-90 |
| 3. | SV/8 | I/12.8 | 1:2.8 | — | 30-40 |
| 4. | SV/4 & RS/2 | D (b)/10 and RV/2 | 1:2.8 & 1:3.3 | — | — |
| 5. | SV/5 | I/10.3 | 1:3.5 | HW | 70-80 |

SV-Stationary Vertical RS : Rotary Spherical, HW-Hot water, I-Indirect, D-Direct.

TABLE—22

WASHING AND BLEACHING ENERGY CONSUMPTION

| Sl. No. | Brown Stock Washing | | | Bleaching | |
|---|---|---|---|---|---|
| | No. of Stages/ Streets | Dilution Factor. | B.L. Output $M^3$/T of BDP | B.L. washing Con. OTW | Sequ-ence. |
| 1. | 3 | 2.5 | 13.5 | 10.0 | CE.H |
| 2. | 3 | 3.3 | 10.0 | 14.5 | CE.HH |
| 3. | 4 | 3.0 | 8.5 | 16.0 | CE.HH |
| 4. | 3/2 | 3.5 | 8.5 | 13.0 | CE.HH |
| 5. | 3/2 | 3.0 | 7.5 | 12.5 | CE.H |

temperature and limited possibility of counter current washing are also responsible for higher heat energy consumption.

In most of the plants the available capacity is high and usually the bleach plant is run continuously at lower capacities thus increasing energy consumption. Absence of sufficient storage capacity for the bleached and unbleached pulp does not permit to stagger the operations. Top entry chests are still being used in a majority of the mills involving high horse power as opposed to the low energy side entry agitators.

TABLE—23 EVAPORATORS

| Sl. No. | Type. | Steam Economy/ no. of effecte in operation. | Concn. of Liquor. Inlet TW | Outlet TW |
|---|---|---|---|---|
| 1. | L.T.V. | 3.5/5 | 12 | 40 |
| 2. | S.T.V. | 2.8/4 | 14 | 42 |
| 3. | S.T.V. | 2.6/4 | 17 | 42 |
| 4. | L.T,V. | 4.35/5<br>3.8/4 | 13 | 40 |
| 5. | S.T.V. | 3.3/4 | 14 | 13 |

L.T.V. : Long Tube Vertical, : Short Tube Vertical.

**EVAPORATORS :**

A majority of the mills use short tube natural circulation evaporators made of mild steel tubes. The use of long tube forced circulation evaporators with stainless steel tubes wherever adopted are giving better performance. The older designs require steam at higher pressures of 7 to 8 kg/cm² as against 2 to 3 kg/cm² required in the new designs.

The number of evaporator effects in operation is 4 to 5 and is responsible for the poorer steam economy. Jet condensers are more common than the surface condensers; the latter can produce hot water required elsewhere in the process. Liquor and condensate are rarely flashed to produce flash steam. Backward flow is adopted in view of the increase in viscosity at higher concentration. This method requires more electric power compared to the forward flow system.

**PAPER PLANT**

Paper making requires large quantities of steam and power. Together they constitute between 30-35% of mill energy requirement. Small mills use breakers or beaters for stock preparation and medium and large mills use different types of refiners including conical and disc type. These refiners handle pulps at 3.5—4.5% consistency. The adoptation of single dilution system of approach flow requires 15 to 20% more power compared to the double dilution system. The machine house operating systems data for 5 large and 5 small mills is given in Table 24.

The high specific energy consumption in the machine room is due mainly to the continuation of old conventional methods of paper making. These methods consist of the wet end of the paper machine comprising of the head box, slice, foil, table rolls and machine clothing. Low consistency forming increases the water handling. Machine speeds are relatively low and fourdriniers are mostly used. The press section also did not undergo much change except in few cases. Steam is the only medium used for drying. A majority of the machine have no hoods at all; some are partially enclosed and a very few are totally enclosed. Heat from the vapours is not recovered from any machine. Most of the machines are provided with steam trapping system with straight through feeding system. The more efficient cascading system is yet to make headway.

Line shaft is the machine drive mechanism widely adopted driven by a DC motor. Very few mills have changed to Thyristor sectional drives. Steam turbine drives are also in use.

Individual paper machine capacities are even smaller; than the mill capacities when compared with the current capacities in the developed countries. The grades and varieties manufactured are also large. Frequent grade changes means higher specific energy consumption and reduced capacity utilisation. Steam costs being lower than that of electricity cost, there is a tendency to increase the use of steam. Humidity and temperatures are not closely controlled thus increasing heat energy con-

## TABLE—24 PAPER MACHINE HOUSE ENERGY CONSUMPTION

| Sl. No. | Machine Capacity tpd. | gsm. range. | Vacuum Pumps No. | Vacuum Pumps Installed. | Machine Drive type. | Press Section Moisture % En-try. | Press Section Moisture % Exist. | Type Condensate removal. | Hooding. |
|---|---|---|---|---|---|---|---|---|---|
| **A. LARGE MILLS :** | | | | | | | | | |
| 1. | 230 | 56–150 | 6 | 1490 | Steam turbine | 80 | 64 | Cascade | Full |
| 2. | 70 | 47–200 | 9 | 1010 | Thyristor | 81 | 66 | Cascade | Full |
| 3. | 75,70, 65,22,7 | 47–200 | 30 | 2400 | Steam turbine (2M/cs) Demotor (2M/cs) Thrystor (1 M/c) | 80 | 60 | Cascade (2M/cs) Trap (3M/cs) | Full |
| 4. | 55,50, 45,18 | 47–340 | 14 | 1300 | Steam Turbine (3M/cs) Thyristor (1M/c) | 80 | 62 | Cascade (3M/cs) Trap (1M/c) | Full |
| 5. | 60–30, 25,12 | 31–180 | 19 | 1100 | DC Motor (1M/c) Line shaft (1M/c) Thyristor (1M/c) | 78 | 60 | Trap | Full (2M/cs) Partial (2M/cs) |
| **B. SMALL MILLS :** | | | | | | | | | |
| 6. | 40 | 30–250 | 10 | 700 | Line shaft | 80 | 55 | Cascade | Partial |
| 7. | 30 | 47–120 | 5 | 280 | Thyristor | 80 | 60 | Cascade | Open |
| 8. | 30 | 45–150 | 4 | 288 | Line Shaft | 84 | 63 | Trap | Open |
| 9. | 10 | 34–80 | 2 | 223 | Line Shaft | 85 | 65 | Trap | Open |
| 10. | 10 | 60–140 | 4 | 330 | Thyristor | 82 | 65 | Trap | Open |

sumption. No paper machine in the country is computer controlled. Some mills have minimum instrumentation and a couple of them are automated.

**UTILITIES :**

Water and compressed air are the two utilities needed in large quantities in paper mills. The figures for selected mills is given in Table 25. Open water circuit systems is the primary cause of high water consumption level. The most efficient mill consumes twice as much as that of 1970 average US mill. Closing the mill systems, segregating, reusing and recycling the water can reduce not only the fresh water requirements but also heat energy and electric power for pumping.

Considering that about 50% of electric power is used in pumping, the need for improving mill hydraulic systems becomes evident. The need for reducing pressure losses in hydraulic system design, matching the drives and the driven equipment (eq-motor and pump), using more efficient motors and pumps is yet to be recognised and implemented by the industry.

Compressed air requirement depends among others on the degree of instrumentation and control systems 2 to 3% of mill power is used to provide compressed air. The high energy consumption is also due to the use of multiple units of small compressors of old inefficient design. Others contributing factors are the improper distribution system, leaks and wastages.

TABLE—25. COMPRESSED AIR AND WATER CONSUMPTION

| Sl. No. | COMPRESSED AIR Installed Capacity tpd. | No. of Compre-ssors. | Sp. Power consump-tion | WATER CONSUMPTION Source. | Daily water consum-ption KL. | Sp. Consump-tion KL/ Tonnes of paper. |
|---|---|---|---|---|---|---|
| 1. | 260 | 8 | 81 | River | 58,150 | 346 |
| 2. | 227 | 10 | 70 | River | 76,000 | 400 |
| 3. | 160 | 9 | 40 | River | 55.000 | 400 |
| 4. | 157 | 5 | 22 | Tube well | 30,000 | 250 |
| 5. | 85 | 9 | 2.4 | Tube well and River | 25,000 | 294 |

**RECOVERY BOILER AND LIME BURNING :**

The emphasis continues to be recovery of chemicals in the recovery section. Most recovery boilers have low steam pressures ratings, poor chemical recovery (60–80%) efficiency and high auxiliary fuel and power consumption. In a number of mills insufficient capacity has led to burn the black liquor in what are called as 'Roasters'. With roasters only 40–60% chemicals can be recovered, heat being totally lost. The recovery boilers have poor campaign time and require frequent cleaning and shut down. To improve chemical recovery, the boilers are provided with either the cascade evaporator in conjunction with electrostatic precipitator or the direct contact evaporator in conjunction with venturi scrubber. The former, which is more energy intensive, is commonly used.

Causticization of the green liquor requires burnt lime. Part of the burnt lime requirements can be met by reburning the filter cake in a rotary kiln. The high cost of oil dissuades the industry from recovering this burnt lime, as a result of which the entire requirements are purchased or produced separately in shaft kilns on-site. Use of producer gas can reduce operating costs, but even here the prohibitive cost of the gas plant puts a damper on industry's initiatives.

**STEAM AND POWER GENERATION :**

The steam generation parameters of the fossil fuel fired and chemical recovery boilers range from 18 Kg/cm² 310°C and 10 tph to 60 Kg, 440°C and 85 tph. Small mills invariably generate saturated steam at 10 kg/cm² and the capacities vary from 4 to 10 tph. The boilers were designed originally for high grade coal which is no longer available to the industry as it is being conserved for metallurgical industry. The poor heat recovery design of the boilers is also responsible for their low thermal efficiency. The data pertaining to steam generation is given in Table 26. Estimated efficiency of steam generation is 60–75% in medium and large mills and 50–60% in small mills.

Chain-grate firing system is the most common with large mill boilers. Spreader stocker is being increasingly used in the more recent mills. Small boilers are manually fired. A larger percentage of fires and poor quality of coal can be burned more efficiently on a spreader stocker with better load response. Non-availability of efficient coal fired boilers in the capacity ranges needed by small mills is inhibiting fuel efficiency improvements.

**CO-GENERATION :**

With the heat to power ratio at 80:20; paper industry is very well suited for adopting cogeneration system. Out of the 30 large and medium mills, 22 have captive power plants. The 22 mills together have an installed capacity of 191 MW with capacity ranging from 1 MW to 22 MW. The percentage of mill generated power varies from 23.4 to 100% of the mill requirement or 497 to 1520 KWH per tonne of paper. A major portion of the on-site power is generated by condensing turbine generators. Although not economical when compared to the utility power cost, this practice has come to stay as an insurance against recurring power shortages. The power generation couplings of 5 mills is shown in Fig. 3.

In most of the mills, mixed pressure cycles are in use indicating the gradual and often adboc additions to steam and power generation plants. In Indian paper mills the low conversion efficiencies of

## TABLE—26. STEAM GENERATION PLANT

| Sr. No. | No. of Boilers. | Year. | Rating TPH. | Pr .Temp. Kg/cm². °C. | Type of stroker. | Estimated deffciency (%). | Feed water Flue Gas Temp. °C/°C |
|---|---|---|---|---|---|---|---|
| 1. | 2-Fuel Fired (FF) | 65 | 2x85 | 60/440 | Spreader (S) | 70 | 145/ 182 |
| | 1-Soda Recovery (SR) | 66 | | | | | 145/ 160 |
| 2. | 3 FF | 75 | 3x13 | 40/400 | Chain | 70 | — |
| | 1 SR | 76 | 1x20 | 40/400 | — (C) | — | — |
| 3. | 5 FF | 65 | 2x19 | 2x29/390 | (C) | 70 | 102/180 |
| | | 72 | 2x16 | 2x30/420 | | | |
| | | 75 | 1x22 | 1x19/420 | | | |
| | 2 SR | 66 | 1x11 | 29/390 | — | | 103/160 |
| | | 81 | 1x30 | 34/420 | — | — | |
| 4. | 5 FF | 62 | 2x16 | 28/371 | (S) | 75 | 105/170 |
| | | 64 | 1x18 | 28/371 | (S) | — | — |
| | | 67 | 1x17 | 10/271 | (S) | — | — |
| | | 71 | 1x25 | 28/371 | (S) | — | — |
| | 2 SR | 62 | 1x14 | 10/Sat | — | — | — |
| | | 77 | 1x17 | 30/371 | — | — | — |
| 5. | 8 FF | 23 | 6x6 | 14/320 | (C) | 60 | 70/200 |
| | | 34 | 2x12 | 14/320 | (C) | — | — |
| | 1 SR | 55 | 1x13 | 14/320 | — | — | 70/120 |

generation plants, their poor integration and low steam parameters of the energy cycle are the weakest links in energy use efficiency. This is further aggravated by non-availability efficient designs, high capital cost of replacement and the generally unhelpful attitude of utilities to operate cogeneration plants in parallel with the grid. The mills also have not show the necessary initiative to rectify and rationalise the energy systems, thus maintaining the statusquo.

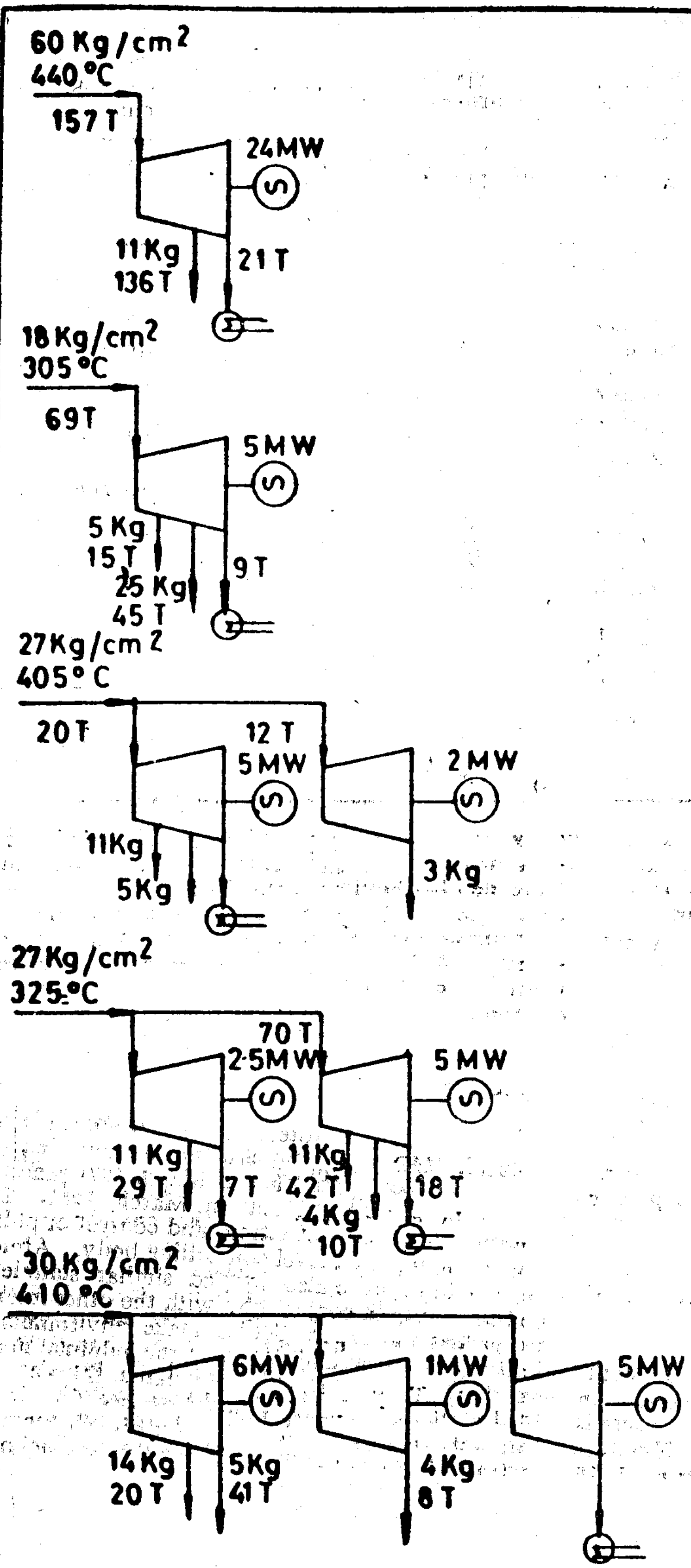
### OTHER FACTORS :

Most of the mills are wanting in general housekeeping, operating and maintenance practices. There is a good scope to conserve reasonable quantities of energy by improving general housekeeping, maintenance and operating practices. Elimination of water, air, steam leaks, improvement of insulation, power factor, and illumination, steam and electricity load management, decreasing the machine broke and avoiding frequent grade changing are simple cost effective measures.

Combustion control through operator skills upgradation and control instrumentation can improve thermal efficiency of the boilers. There is scope for further improving the recovery of condensate. Many old, boilers require retrofitting with waste heat recovery devices such as air heaters or economiser. Instrumentation for process control which has been neglected hitherto can no longer be neglected. They include boilers, vacuum pumps, compressors etc. Replacing them with larger and more efficient equipment can reduce power consumption significantly. Such efforts should be well coordinated and directed by appointing an engineer as Energy Manager, which is fully justified considering the energy costs as well as the energy shortages.

### POLLUTION :

In order to protect the environment from pollution hazards the Government of India enacted water pollution control act in March 1974 and the air pollution control act in March 1981. The Central Board for prevention and control of pollution is the national level controlling body. Almost all the States have also formed similar state level bodies. They in conjunction with the other interested parties and expert bodies make environmental impact assessment and arrive at the minimal national standards and prescribe standards through the Indian Standards Institution. There has been greater emphasis on water pollution control for obvious reasons and therefore are in vogue for considerable




| PERCENT SELF GEM | SELF GEM Kw A/t | OVERALL SP POWER Kw A/t |
|---|---|---|
| 100 | 1520 | 1520 |
| 46 | 606 | 1305 |
| 23 | 610 | 1949 |
| 42 | 660 | 17 |
| 28 | 497 | 1710 |

FIGURE-3. POWER GENERATION COUPLINGS IN SELECTED PAPER MILLS time. Air pollution control standards have yet to be prescribed and implemented.

The standards IS 2490 and IS 3307 prescribe the limits for industrial waste discharge which are given in Table 27.

Table 28 shows water consumption and effluent characteristics of a few selected paper mills. It can be seen from the table that the BOD of the effluent of a medium size paper unit is 5 to 6 times that of a large integrated mill. It is also seen that a small mill of 80 TPD, without chemicals recovery generates a water pollution load equivalent to a large integrated mill of 150 TPD with chemicals recovery.

Most of the large integrated mills have provided primary effluent treatment facilities. A few mills have secondary treatment facility with some others at the planning or implementation stage. More efforts are needed on the part of medium and small mills. According to the Technology Development Group Council for Paper, Government of India, the investment made by large kraft paper mills varies from Rs. 7 to 10 million towards primary and secondary treatment. Out of the two types of external treatment methods the primary clarification removes 70 to 90% of suspended solids, thus reducing 15 to 30% of BOD load. The secondary treatment is required for further reduction of BOD by 70 to 90%. It is estimated that 100 TPD integrated mill discharging 5 MGD waste will require Rs. 5 million towards investment for effluent treatment. The recurring expenses would be Rs 30 per tonne of finished paper. It has been observed that effluents from mills having chemical recovery, such as large mills, can meet the limits prescribed for irrigation after primary treatment. Medium and small mills without chemical recovery, however, require secondary treatment also. Mills using only waste paper can use their effluent for irrigation after primary treatment.

## INPLANT CONTROL MEASURES :

Inplant control measures which reduce fresh water requirement and measures which reduce effluents discharge are being looked into by most mills. By this approach one mill in Western India reduced fresh water requirement by 40%. The statutory regulation in course of time will no doubt compel the industry to implement inplant control measures.

As has been seen in the earlier pages energy and environment have a profound influence on the performance and profitability of the paper mills including the location of mill site, investment cost and running costs. The performance of most Indian mills is affected by several internal factors. The productivity trends in the paper industry is briefly outlined in Annexure 1. Raw material and energy shortages and their costs, the price regulation of paper products, the not-so-attractive return on investment in paper projects, credit squeeze and other institutional regulations (eg. pollution control and institutional barriers (eg. on parallel operations of on-site power plants in parallel with the grid) are some of the major impediments.

While some of these measures may be justified in the socio-economic context, there are a number of areas in which industry can independently act upon and in concert with the Government for the general growth of the industry. With particular reference to Energy Management, industry and Government should work for the fundamental objective of reducing the component of purchased energy in the total energy deployed.

## ENTERPRISE LEVEL MEASURES :

Nothwithstanding the governmental measures the industry can effect a number of energy saving measures by

— minimising wastages
— modifying operating parameters
— equipment rebuilding or
— adding equipment to improve capacity utilisation.

The first two offer very attractive return with little investment. The latter two require capital investment and provide attractive returns in the mid term.

### Wastage Reduction :

It aims at reducing leaks, spills and rejects. An alert production staff and good mill maintenance practices are the prerequisites. Some of these measures are :

Minimising steam, water, and air leakages, returning all the black liquor and fibre spillages to the processes; keeping rejects at the pulp screens under constant check, using retention aids in paper making to maximise fibre recirculation, keeping paper machine web breakages under check, avoiding idle running of equipment, replacing oversize motors and the driven equipments such as pumps, balancing steam and power demands to avoid peaking, keeping steam traps in good working condition; avoiding over drying of paper etc.

### Process Parameter Modification

These inplant control measures are aimed at reorienting the process operating condition to

## TABLE—27. TOLERANCE LIMITS FOR DISCHARGE OF INDUSTRIAL EFFLUENTS AS PER INDIAN STANDARDS INSTITUTE.

| Sl. No. | Characteristics | Units | Discharge into inland surface waters IS—2490 (1974) | Discharge on land for irrigation IS—3307 (1965) |
|---|---|---|---|---|
| 1. | Temperature | °C | 40 | Not Specified |
| 2. | PH | | 5.5–9.0 | 5.5–9 0 |
| 3. | Total suspended solids | MG/L | 100 | Not Specified |
| 4. | Total dissolved solids | MG/L | Not Sp cified | 2100 |
| 5. | B.O.D. 5 AT 20°C | MG/L | 30* | 500 |
| 6. | C.O.D. | MG/L | 250 | Not Specified |
| 7. | Total Residual Chlorine | MG/L | 1 | Not Specified |
| 8. | Total Sodium | % | Not Specified | 60 |

*Note : In certain states B.O.D. limits are even lower than specified by ISI.

## TABLE—28 WATER CONSUMPTION AND EFFLUENT CHARACTERISTICS FROM DIFFERENT TYPES OF PAPER INDUSTRY

| Type of Mill | Capacity TPD | Water use gal/Ton | Suspended Solids ppm. | BOD ppm. | BOD Load kg./T. |
|---|---|---|---|---|---|
| **KRAFT PULP MILL :** | | | | | |
| Mill-1 | 200 | 70000 | 200–50 | 80–350 | 99 |
| Mill-2 | 150 | 100000 | 400-700 | 200–250 | 91 |
| Mill-3 (Partially Integrated) | 120 | 60000 | 400–600 | 200–300 | 60 |
| **AGRICULTURAL RESIDUE BASED :** | | | | | |
| Unbleached Paper | 40 | 20000 | 2400 | 1250 | 83 |
| Bleached Paper | 20 | 80000 | 1320 | 1300 | 423 |
| Unbleached Paper | 20 | 74000 | 253 | 250 | 67 |
| Bleached Paper | 20 | 70000 | 400 | 500 | 168 |
| **WASTE PAPER BASED :** | | | | | |
| Mill – 1 | 8 | 37000 | 400 | 150 | 11 |
| Mill – 2 | 5 | 12000 | 3200 | 300 | 9 |
| Mill – 3 | 15 | 37000 | 800 | 350 | 7.5 |

improve energy use efficiency. Some of these opportunities are :

Optimising the digester operation by minimising gas venting, two stage steaming, minimising cooking temperature and time, minimising liquor to wood ratio or improving yield to reduce overall steam consumption; using hot condensate from evaporators for brown stock washing and optimising the use of wash water at brown stock washers; modifying bleach plant sequence; filtering black liquor feed to evaporator to reduce boil out, maximising black liquor solids fed to the recovery boilers, controlling excess air more closely in the boilers; using more efficient forming wires; press felts and drier screens/felts.

**Equipment Rebuild :**

Equipment rebuilds to improve energy efficiency require capital investment. Some examples are :

Instrumentation to control excess air to fuel fired and recovery boilers, reviewing and improving thermal insulation, rebuilding paper mill press section; adding capacitors to improve power factors; adding one more stage to brown stock washing and lime mud washing units, using steam operated prime movers in the place of high horse power motors.

**New Fquipment Additions :**

These are mid term measures in energy cost saving. Some of the measures for evaluation are :

Blow heat recovery for batch digesters, adding efficient brown stock washers, developing black liquor desilication process, adding additional effects to the evaporators or reappraise vapour recompression, installing closed hood on paper machine driers and recovering heat in the hood exhaust.

## NEW PROCESSES AND TECHNOLOGIES :

In future, mill should aim to further reduce the dependence on purehased energy by adopting new processes and technologies. One of the first steps would be by burning dried mill wastes like wood dust, bark and mill sludge in the boilers. The back pressure generation should be maximised by using efficient boilers and turbo alternators and increasing the parameters of the energy cycle. The presently available firing systems for boiler cannot burn the low grade coal efficiency. The use of fluidised-bed combustion systems, can overcome these difficulties and higher boiler efficiencies will be possible.

The development of low capacity continuous digester needed by the Indian mills can increase heat energy efficiency significantly. Oxygen bleaching will be an advantage as its effluents can be reburnt and it eliminates toxic effluent from chlorination stage. The hazards in transporting chlorine will also be reduced. Tne development of suitable pulping aid which can eliminate sulphur from the process, is also important.

In evaporation technology several systems using blow heat for concentrating black liquor have come into use. Double effect and triple effect evaporators are in use in USA and New Zealand. Falling film evaporators are capable of working with smaller temperature difference. 8–10 bodies of falling film evaporators can concentrate the liquor to the firing solids content level.

Mills planning marginal expansions in capacity often face problems, because of the limited capacity of the recovery boilers. One method is by improving the operating efficiency. Larger capacity can be obtained by burning a part of the black liquor in a fluidised bed incinerator and then injecting the recovered inorganics into the recovery boiler where reduction takes place. This has been done in Canada. The most promising replacement for the kraft process appears to be the Swedish process. This process uses a cyclone furnace to gassify the black liquor organics and reduce and recover the inorganics as smelt Combustable gases are then burnt in a power boiler. A 100 TPD pilot plant is undergoing trials in Sweden.

A major part of the energy produced from black liquor is used up in evaporating the weak black liquor. About 40% fuel value inpnt to the recovery process is available as steam and power outside the recovery unit. By avoiding the direct contact evaporator this availability can be further increased.

The only operation where the use of external fuel cannot be avoided, is in lime mud reburning. Efficiency of the lime kiln can be improved using chain plate systems, flash drying of mud and better lime mud dewatering. Fluidised bed lime calciner offers promise.

The possibility of eliminating the entire causticisation operation using auto-causticising systems is being examined in Finland. If this process succeeds, the total inorganic load over the entire recovery system will be nearly doubled.

The press section should be modernised using the available technologies to give maximum possible dryness of wet web entering the driers. The drier section should be modernised replacing the convertional straight through feeding system by cascading system and should use steam at lowest possible pressure. Totally enclosed hoods and recovery of heat from the hood exhaust for reuse should be implemented High consistency forming can lead to substantial savings in fan pump electrical power consumption.

## GOVERNMENTAL MEASURES :

In order to accelerate the conservation efforts by the industry, Government should provide financial incentives and formulate approximate policies and programmes. Some of the incentives announced by the Government are discussed in Chapter "Recommendations '.

These measures in themselves should spur interest in conservation but they require internal financial resources to take advantage of this fiscal incentive. Thus mills having internal sources alone can take advantage of this incentive. In order for the industry as a whole to take advantage of this benefit, Government may provide a soft loan window.

Alternatively mills should be allowed to retain a specified portion of excise duty payable by them in a separate account as a medium term loan at a nominal rate of interest exclusively for financing the cost of energy saving devices and system.

Cogeneration is already practiced in a few mills, and the present fiscal inventive may interest more mills. To maximise the primary energy saving potential of cogeneration, mills may be permitted to import under OGL boilers and turbines of modern and more efficient designs till such time they are available in the indigenous market in the required numbers. Similarly electricity boards should also to encourage operation of cogeneration and other captive plants in parallel..

Government should provide special incentives to mills using unconventional raw materials such as bagasse and agricultural wastes.

Because of the substantial net energy savings provided by recycling waste paper, special incentives and encouragement should be provided for mills based on recyaled paper. The Government may also consider importing waste paper in bulk quantities for increasing paper production, saving energy and reducing the pressure on forest resources.

Small paper mills may be extended encouragement to install chemical recovery plants. 50 TPD plant can now have technically feasible and economically viable chemical recovery nnit.

The paper industry development cell in the DGTD should advise the present and future paper mills on energy efficient technologies, devices and systems, and should act as an information source on matters relating to energy to promote conservation.

## INDUSTRY LEVEL MEASURES :

Enterprise level and Governmental measures in them selves are not enough to achieve tangible and sustaind savings. The role of industry associations and professional bodies can also play a very significant role by bringing awareness among the mills, committing the industry to set goals and targets, and encouraging exchange of experiences and information among individual mills and professionals. Some of the tasks for the industry associations could be :

Constitution of a apex committee consisting of members from DGTD, industry associations, professional bodies and research institutions, Government representatives and outside consultants/experts.

Setting a target of 20% reduction in energy coosumption by 1991 with 1982 consumption as the base for the industry as a whole.

Providing information guidance to individual mills to achieve targets.

To collect consumption data on fuels and power and also production data by individuals on a monthly or quarterly basis to monitor progress in energy conservation.

To analyse the energy data and develop energy consumption norms.

To arrange periodic meetings and seminars to review progress and inform of the further measures needed to be taken by the industry.

As an encouragement institute industry level awards for energy efficient mills.

To interact with the Government and mills on matters relating to energy policy, R & D etc.

## CONCLUSION :

The paper industry, one of the oldest in the country, is passing through a critical phase. Energy is an area if tackled properly can retrieve the industry's position to some extent from the present position of stagnation to one of dynamic growth. The need of the hour is one of concerted actions by the industry and the Government.

## COMMITTEE'S OBSERVATIONS AND COMMENTS TOWARDS DEMAND OPTIMIZATION METHODS

The interim report submitted by NPC was gone in details by the committee. Discussions that took place with operating personnels during the mill visits as well as practices followed by mills in developed countries confirmed basic areas and also opened new avenues.

This chapter therefoe, reitereates some of the important findings and also adds to the list of energy saving methods at number of Places.
A variety of factors such as

i) Product-mix
ii) Raw material furnish
iii) Capacity utilisation
iv) Type of fuel used
v) Extent of integration
vi) Size and age of the unit
vii) Over design/imbalance of equipment
viii) Installation and performance of energy conservation devices
ix) Operating practices, etc, influence unit energy consumption of differnt units.

The areas of energy conservation can be divided in four broad catagories namely :

i) Energy Generation
ii) Energy Transmission and Distribution
iii) Energy Utilisation
iv) Waste Stream Utilisation

The measures can be short, medium or long term type.

## ALTERNATIVE FUEL RESOURCES FOR ROTARY LIME KILN AND PULP DRYER

Due to escalating prices of non-renewable energy resources and depleting resources, industries all over the world are looking for renewable and cheap resources.

The use of producer gas is a satisfactory alternative fuel for lime mud reburning and pulp drying. It can produce cleaner flue gas and can give flame temperature required.

In USA, it is expected that fuel oil prices will increase faster than producer gas. Producer gas is being introduced by many mills in US for following applications in pulp and paper industries :

a) Pulp Drying
b) Process Steam
c) Rotary Lime Kiln
d) Power Generation
e) Auxiliary Burner for substitute fuel oil in Recovery Boiler.

Table 29 gives cost comparison between praducer gas and fuel oil in the United States. A note on producer gas is in Annexure-3.

TABLE—29

PROJECTED COST COMPARISON OF PRODUCER GAS WITH FUEL OIL IN USA

| | — YEARS — | | | | |
|---|---|---|---|---|---|
| | 1982/ | 1983/ | 1984/ | 1985/ | 1986 |
| Cost of Producer Oil (Dollars/Million Btu) | 3.02 | 3.31 | 3.62 | 3.92 | 4.27 |
| Cost of Fuel Oil (Dollars/Million Btu) | 5.00 | 5.6 | 6.22 | 6.84 | 7.52 |
| Petcentage Difference in Cost of Million Btu's generated by Producer gas compared to Btu's by Fuel Oil. | 65.5 | 69.2 | 71.8 | 74 5 | 77.3 |

(Ref. : TAPPI Journal Feb. 1983. P-75.)

## EFFICIENT OPERATION OF RECOVERY BOILERS :

Energy efficiency of recovery boiler operation can be increased by :

i) Developing and maintaining efficient process control system.
ii) Controlling input streams such as black liquor dry solids, excess air and salt cake make-up.
iii) Optimising the boiler cleaning system steam usage.

## CONTROL SYSTEMS

This is achieved by better maintenance of instruments, especially the oxygen monitor, air flow recorder, draft gauges, temperature reorders etc.

## LIQUOR SOLIDS CONTROL

Any variation in the liquor solids content entering the direct contact evaporator and the furnace will upset the furnace operation and also it will reduce the system flow. For every one per cent drop in solid concentration, steam generation will decrease by about 2 67%. Lower black liquor solids in the firing liquor upsets the furnace bed and will lead to auxilary fuel firing.

Recovery boilers incorporating ventury-scrubber and cyclone evaporators for direct contact evaporation of black liquor are out dated. High power input to the ID fan, lower steam output per ton of black liquor solids fired even at lower flue gas exit temperatures are the principal reasons.

Boiler designs with low power consumption and fitted with Electrostatic precipitators (ESP) are getting more popular. Draw back of the boilers fitted with ESP is that the temperature of the flue gas before ESP has to be kept above 150°C depending on acid dew point. Further recovery of heat from flue gases after ESP is possible by combustion air preheaters or through cascade evaporators.

## CONTROL OF EXCESS AIR

Changing excess air from 25% to 18% for example can reduce the load on induced draft fan by about 20%. Further, the steam generation is increased by 0.2 to 0.3%.

## INCREASE IN LIQUOR TEMPERATURE

Increasing the liquor temperature by indirect heating will not only result in higher steam generation since high concentration black liquor can be fired.

## SALT CAKE MAKE-UP

Any excess salt cake feeding to recovery boiler will reduce steam generation.

## BOILER CLEANING SYSTEMS

A regulated soot blowing operation by proper spacing and using reduced pressure for soot blowing will substantially save steam consumption.

Most of the Indian paper mills have either cyclone evapcrator or cascade evaporators to concentrate black liquor from 50% solids to 60 62% solids. Direct contact evaporation not only emits maodorous gases but also it is energy inefficient comlpared to multiple effect evaporators. Evaporationcarried out upto tha firing concentration in the multiple effect evaporators can result in higher steam generation in the recovery boiler. With such a design of multiple effect evaporators, a 100 TPD pulp plant can improve its steam generation in recovery boiler by nearly 1 tonne per hour.

In our paper industry, this is not being followed today since the black liquor from indigenous raw materials namely bamboo and hardwoods poses problem in increasing concentration upto 60 to 62% in multiple effect evaporators. New designs in evaporation such as falling film evaporation and plate type heating elements can eliminate these constraints in evaporating the liquor to fire concentration.

## MAXIMISATION OF CO-GENERATION

One of the means of achieving imroved energy utilisation is to generate steam at higher pressures balance the steam requirement in the steam and co-generate power. A planned process with minimal fluctuation in the process steam demand automatically dictates the justification of inplant power generation.

A proper selection of pressure and temperature of steam generating unit and proper phasing of extraetion from the steam turbine is absolutely necessary.

In order to do that, several factors such as process steam requirement, its pressure and temperature, sectionwise power reqiurement, its load and power factors, analysis of essential load, analysis of normal shutdown, emergency power requirement etc have to be taken into consideration.

Looking at the general trend that is prevailing in almost all the states, it may be concluded that it is necessary to go in for maximum cogeneration since this is the best way to mitigate the power crisis facing the country.

There are several steps necessary in the planning stage itself to achieve the maximum cogeneration looking into the flexibility of operation.

The overall efficiency of industrial cogeneration systems could be over 80% for a full back pressure turbine as against the efficiency of condensing thermal power plants which at the maximum is 40%.

Every megawatt of power generated in the industrial cogeneration plants would account for a fuel saving of 0.25 tonne of coal equivalent which otherwise would have been lost in condensing the steam in the thermal power plants.

But the only limitation to the back pressure turbine with single extraction is its poor flexibility. It cannot entirely absorb the variations in heat to power demand without loss of steam. Most of the paper mills in the country operate self generation in isolation from the grid supply. Parallel operation of self generation with grid supply will greatly smoothen the fluctuations and integrate heat and power demands to effect higher cogeneration and energy utilisation efficiency.

In the absence of parallel operation with grid, double extraction condensing turbines with maximum condensation corresponding to the normal maximum fluctuations would be a suitable choice.

Under these circumstances, the only way to maximise co-generation is :

— by generating steam at the highest possible pressure and temperature. In India, boiler manufacturers have capabilities to supply boilers to operate at 60 $Kg/cm^2$ pressure and 450°C temperature.

— by extracting steam at as low a pressure as possible. Normally, steam required in our mills is at around 3.5$Kg/cm^2$ and at 10 $Kg/cm^2$. It is necessary to maximise extraction of steam at lower pressures.

— by having parallel operation with grid to hava more flexibility of operation.

Though some installations have sufferd from faulty equipments basically our country has developed manufacturing facilities both for small and big boilers.

Small boilers can be upto the range from 5 to 20 tons/hour steam raising capacity and steam pressure and temperature up to 60 $Kg/cm^2$ and 450°C. In the large category, boilers can be from 20 to 80 tons/hour with pressure and temperature upto desired level.

They are thus ideally suitable for cogeneration. Small and big turbines sets available need an extensive after sales service for improving machine availability and reducing the down time.

**PARALLEL OPERATION WITH STATE POWER GRID :**

The cogeneration enhances its utility when working with the state power grid at a suitable voltage.

This arrangement is particularly useful for—

(a) Cold start up of the boiler/turbine plant and bringing it on stream without interruption (which would otherwise be necessary when parallel operation is not allowed).

(b) Efficient management of steam and power usage while coping with the varying plant conditions.

This is ideally suited to the Paper Industry as it can take care of the fluctuations in steam and power demand in the plant. The Central Pulp Mills Limited is perhaps the only medium size industrial unit in India working in parallel with the state grid from 1968. And it may be stated here that this parallel operation has not given any serious trouble so far. Although the main purpose of this parallel operation was an interruptionless cold start up, it has subsequently become a major tool of efficient steam power management in the present times of conservation and power cuts. Some of the salient features of this parallel operation may be stated as :

a) On load voltage regulator for incoming grid line.

b) Due care of the grid fault feeding capability through transformer impedances.

c) Co-ordination of the entire protection sysrem to save the inplant generation.

d) The neutral switch for opening grid transformer neutral during parallel operation.

e) Fast acting breakers for synchroniosation.

f) Sensitive and accurate protective relays Grid—OC, EF with TD Directional OC, under/over frequency for load shedding. Gen—OC With restraint, EF with TD Diff, (In addition there should be rotor EF and reverse power protection for generator).

g) Load shedding and load sharing arrangement.

h) The turbine governers of suitable drop characteristics.

i) The gen. voltage regulators of ouitable type and with reactive sharing arrangement.

j) KW, RKVA, amp, frequency and voltage indications for operator's control.

It may be stated that the stability of the Gujarat grid in voltage and frequency has allowed the above parallel operation to run smoothly even without on load V regulator and with manual controls for some time.

**ABBREVIATIONS**

OC — Over Current
EF — Earth Fault
TD — Time Delay
Gen — Generator
V — Voltage
RKVA — Reactive KVA

The co-generation unit being small as compard to the grid, suffers many disadvantages. The grid frequency generally rules as also the voltage. The grid failure of single phasing throws the grid connected load (depending on the point of interruption or fault) on the inplant generation, upsetting it completely, inspite of all the protections provided Since reactive exchange is a regular feature of the parallel operation, the pf offered to the grid needs watch and control.

Similarly all the sudden demands of reactive power are initially met by the grid, being the infinite but, equipment damages are likely by frequent synchronisation, sudden over-loads and abnormal running. A due care in this regard may however almost eliminate these causes.

The state grids may not be interested in purchasing the surplus power from such units say below 5—10 (MW) since the connected loads are quite large and reverse metering is involved. From the supplier's point of view, the reverse operation of transformer and V regulator, may be undesirable.

The synchronisation of grid with the back pressure turbine on load alone may be a little difficult since there remains a very little scope for control or adjustment.

In conclusion it may be said that the state grids should have no objection in allowing or in fact encouraging such parallel operation to facilitate the interruptionless cold start-up and in efficient steam power management in the present era of conservation and power cuts.

## STEAM GENERATION FROM MILL RESIDUES

In pulp and paper mill using forest based raw materials, bark, bamboo dust and slivers are the potential fuel sources. For those based on agricultural residues, pith from bagasse, dust and fines from straw ars the residual fuels. Quantity of these residues depend upon the type of raw materials used and method of raw material preparation. The modern concept followed in many developed countries is to use residues to the maximum extent as fuel for steam generation in specially designed multi-fuel boilers. Use of bark as fuel and other efficiency measures undertaken by them is the main reason in reducing the purchased energy to around 40% (in Scandinavian Countries) whereas, the same figure stands 70% in our country. Use of bamboo dust, slivers and bark from hard-wood as fuel can change the situation considerably. The present practice of debarking hardwoods in the forest may be shifted to the site to recover the bark. The increase in the weight to be transported in this case is hardly 10 to 15%.

The basic process of burning wood refuse fuels require the evaporation of moisture, the distillation and combustion of volatile components and the combustion of the remaining carbon material. These three steps are accomplished either separately or simultaneously depending on the type of equipment that is favoured for the particular installation.

Another source of fuel yet to be tapped is the sludge from the effluent plant. After primary and secondary clarification, the sludge has to be filtered in continuous belt filters and the sludge obtained can be used as fuel. Alternatively, sun dried sludge from sludge drying beds can be used as a fuel.

TABLE—30

CALORIFIC VALUE OF PAPER MILL WASTES AND SELECTED RENEWABLE RESOURCES FUEL

| Description | | Ash | Cal. Value Kcals/Kg. |
|---|---|---|---|
| Bamboo dust | — | 7–8 | 2200–2300* |
| Rice husk | — | 2–4 | 3000-3200 |
| Bark | — | 14.7 | 2500–2800 |
| Bagasse Pith | — | 5–6 | 3780–4440 |
| Saw Dust | — | 0.2 | 3000–3300 |
| Wood Shawings | — | 0.2 | 3800–3900 |
| Fire Wood | — | 0.9–4 | 4400–4600 |

*Very low.

Table 30 gives the ash content and the calorific values of paper mill wastes and some selected renewable resource fuels.

Boiler manufacturers in India are ready to offer the boilers exclusively suitable to burn mill wastes like bamboo dust, pith, husks, bark etc. Alternatively they can offer boilers suitable to burn these wastes in conjuction with coal.

The economics of burning mill wastes in the from of bricquets along with coal in the coal fired boiler is worth exploring.

## CONVERSION OF RECOVERY BOILERS TO POWER BOILERS ;

Most recovery boilers can be converted to power boilers by retrofitting to handle fuels such as coal, bark, oil or gas. Higher fuel costs, limited natural gas supplies, and stricter emission regulations are causing concern many pulp and paper manufacturers Also, as paper mills expand and new recovery boilers of higher capacities and lower emission rates need to be installed. It becomes economical to convert the old recovery boilers to power boilers rather than retire them completely from service. In our country, many older mills have installed new recovery boilers of higher capacity and as a result, old boilers have become idle.

**Conversion considerations**

The fuel to be fired should first be defined, as the choice of fuel directly affects the boiler changes and the fuel equipment design.

The material suitability of superheater must be checked. Due to the potentially increased steam flow capability of the converted boiler, the superheater pressure drop will increase.

## EFFICIENT STEAM GENARATION FROM COAL :

Improved operating efficiency, better maintenance and addition of auxilliary heat saving equipment will contribute to reduce consumption of fuel. Coal requirement can be lowered by nearly 5% when boilers operate at maximum efficiency. The possible measures are discuseed below :

a) Seek complete combustion by :

— properly designed coal crushing & screening system.

— Excess air in the combustion chamber should be kept to a minimum consistent with complete combustion.

— Ash should contain low unburnt combustible matter.

— Exit flue gas should not contain gaseous combustibles, such as carbon monoxide.

b) Radiation losses and leakage to be reduced by :

— Tight. well insulated boiler settings.

— Boilers designs with water cooled furnace.

**Control Systems** :

Better control of excess air often can be obtained by upgrading the combustion control system. Controls can be either simple or highly sophisticated. Simple ones regulate fuel and air flow actuated by steam pressure controller.

The most sophisticated control system use fuel and air flows and oxygen content of flue gas, steam flow rate, feed water flow rate and boiler pressure. Excess air is automatically trimmed to maintain oxygen in the flue gas at a desired level. The boiler efficiency obtained by sophisticated control is higher by 2% to 3% compared to simple control systems.

**Heat Recovery** :

Attention also must be paid to the considerable heat leaving the boiler in flue gas. A substantial portion of this can be recovered.

Flue gas exit temperature is determined by size and efficiency of secondary heat recovery system like economiser and combustion air heaters.

**Operating and maintenance practices** :

Attention should be paid to boiler control systems, burners, heating surfaces, feed water treatment, boiler water level, load factors and condensates.

## ENERGY TRANSMISSION AND DISTRIBUTION

Plant layout, electrical transmission voltage, transformer locations are some of the points which should be taken care at the initial stage of planning. Transmission line (both electrical and fluid) sizes have significant bearing on the transmission losses.

## STEAM DISTRIBUTION

## STEAM METERING :

An accurate steam metering is not only necessary for steam raising equipment but also for distribution net work. The quality of steam (superheat or wetness) is also required to be monitored. This basic step is not only for operation but also for monitoring usage and generating efficiency.

A periodic inspection and maintenance of steam metering system is required to establish steam balance since :

i) Many flow meters may be improperly calibrated.

ii) Steam lines are provided additional tie-ins to supply steam for additional consuming points.

iii) Process changes have required changes in steam. Pressure and/or temperature.

iv) Line and/or flow changes have affected the accuracy of metering or beyond the design range of the meter.

## DEMAND VARIATION AND LOAD SHEDDING

Sudden demand chages can cause inefficient boiler operation or wastage by way of safety valve blows. It is known that boiler efficiency is maximum within certain range of generation. Overloading or underloading may seriously affect the wastage of fuels. Proper distribution of demand (ie, load shedding) needs to be practiced avoiding loss of production.

Changes in steam demands caused by digesters and paper breaks in paper machine, soot blowing in boilers may give rise to fluctuating demand. Boiler pressure and steam generation rate indicated at main consuming points may help to reduce efficiency losses due to demand fluctuation. Scheduling of digesters will also help in this direction.

A suitable steam accumulation drum can also help to reduce the problem when all other methods fail.

## INSULATION

Proper insulation of steam pipe lines is also necessary. Usually it is observed that pipe joints and valve bodies are not lagged to save more laborious insulation work. But hundrerds of such unlagged joints and valves can be a considerable source of heat loss.

## STEAM LEAKAGES

Due to low prices of fuel earlier, more emphasis was paid to chemicals recovery. Steam leaks were repaired on the basis of safety or in accordance with operating supervisors judgement which often received low priority over other maintenance.

With rapid escalation of energy inputs, even minor leaks have become necessary to repair. It is essential to identify and record leaks and bring to the attention of maintenance department. Depending on the extent of leakage, maintenance team can decide under which conditions leaks can be repaired. Even on-line leak repair service is now available in the country for the cases where immediate shut-down of high pressure line is not possible.

A periodic survey can identify the numbers and size of leaks, previous history of each leak and quantity the total steam losses. A systemetic approach can result in effective planning and control of leaks. Even on-line leak repair service is now available in the country for the cases where immediate shutdown of high pressure lines is not possible.

Some times it is, difficult to quantify the amount of leakage. Some mills in USA decide the extent of leakage visually by stimulating leakages in steam pipes for observing the plume length for a known leakage through various orifice sizes, such a chart is shown in Fig. 4.

## ELECTRICAL TRANSMISSION

Electrical transformers should be located as near as possible to the load consuming centres. Use of higher voltage will reduce transmission losses and save heavy expenditure on cables. Motors of 400 HP or above can be changed to higher voltage rated motors.

## POWER FACTOR

The mill to mill power factor variation observed is between 0.85 to 0.90. This power factor needs to be raised to 0.95 by installation of suitable correcting devices such as Capacitors, Synchronous motors etc. Also all under-loaded motors which tend to decrease power factor may have to be replaced with proper size motors in a phased manner.

## ENERGY UTILISATION TRANSPORTATION

Transportation of raw materials, chemicals, fuels and finished goods have great effect on a mill's indirect energy requirements and put a strain on the nation's scarce energy resources. Raw material and fuel transportation to mill site needs careful consideration. All forms of transportation viz. rail, road, water and even air have to be evaluated.

## CAPTIVE CHEMICAL MANUFACTURE

New technologies are now available like 'membrane cells' for inplant generation of caustic soda, chlorine etc. These smaller units are not only energy efficient but can lead to considerable savings as further processing (ie evaporation of caustic solution and liquification of chlorine etc.) can be avoided.

## MATERIAL HANDLING

Material handling, transportation of unprocessed and semiprocessed solid materials has to be evaluated for its energy requirement.

Pneumatic conveying consumes around 10 times more energy than belt conveying. This is specially important for conveying chips from chippers to silo and silo to digesters. The other process bulk materials which are handled in sizable quantity are, bamboos, wood, limestone, lime, coal ash, lime mud, saltcake, soap stone etc,.

## CHIPPER HOUSE

Although the power requirement may vary with the raw materials being chipped, considerable

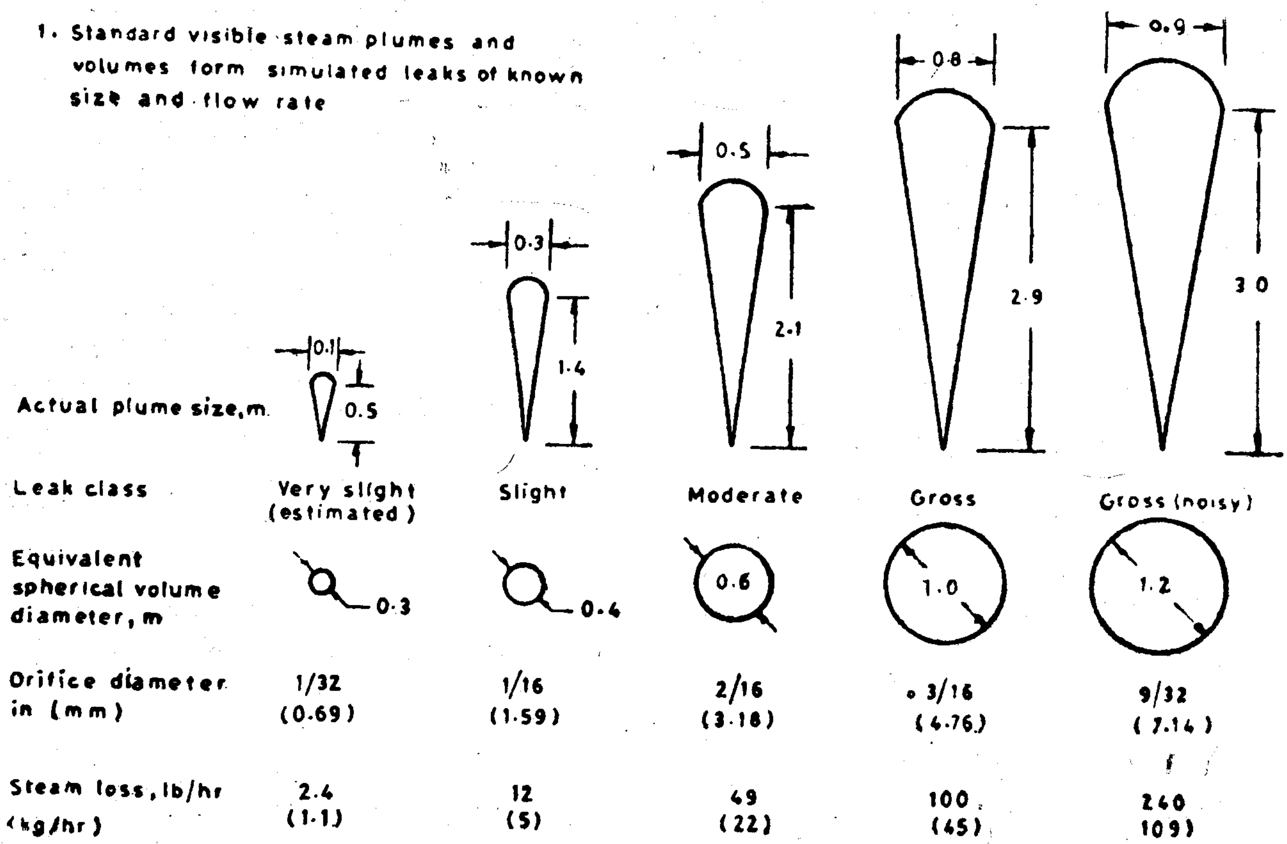



FIG. 4

scope exists to reduce power consumption in its area. It is quite possible to chip, screen and convey bamboo chips with less than 35-40 kwh/ton of paper. Present average consumption of power for chips preparation is around 60-75 kwh/ton paper.

Inefficient chippers have to be replaced. The feeders and feeding system has to be redesigned to give constant feed to chippers. Although bigger chippers tend to reduce power requirement, there is possibility of its getting underloaded if other supporting system is not adequately matched.

Chippers creating more dust and slivers result in higher energy consumption.

## PULPING & BLEACHING :

### Digester House

Continuous digesters are more energy efficient compared to batch digesters as they require about 40-50% less steam and give 2% higher concentration black liquor solids. Continuous available blow heat can be easily recovered.

It is difficult to adopt this technology for plants below 150 tons/day processing bamboo/wood as it is highly capital intensive as well as it is totally dependent on import of technology and sophisticated controls.

An attempt in this direction by Indian manufacturers in collaboration with the established overseas suppliers may result in economical designs more suited to Indian needs.

Major constraint which restrict most mills from adopting continuous digester system is its low flexibility in using difierent kinds of raw maierials in a single day.

### Continuous Digesters for Agricultural residues :

Agricultural raw materials are bulky and require less cooking time. Tubular continuous digesters (Pandia Type) are quite advantageous and are comparatively simple in construction and operation.

Their non-availability in India at competitive prices have restricted their use by small or medium sized paper mills based on agricultural residues.

**Batch Digesters**

More attention should be paid to batch digester system since it is used extensively by the paper industry. Apart from maintaining efficient operating conditions, some points worth considering are :

i. Changing over to indirect heating by installation of liquor heaters. Direct steaming not only adds to evaporation load as steam condensate dilutes the cooking liquor.

ii. Loading the digester to the maximum extent and keeping a low ratio.

iii. Recovering heat from continuous relief vapours from digesters by installing suitable devices to heat water for use in brown stock washing. It is estimated that about 3·5% steam may be lost in the digester relief lines used for venting air & gasses from digesters.

iv. Using two stage steaming by first using low pressure steam and later medium pressure steam helps in more back pressure power generation.

## BLOW HEAT RECOVERY

It is estimated that about 0.6–0.7 tons of vapours per ton of pulp are flashed during the blowing of digester into blow tank, It is necessary to trap this outgoing energy. Blow heat recovery systems are quite common in India.

The blow heat is utilised to generate contaminated hot water which in turn is used for heating fresh water through heat exchangers for process use.

However several factor affect the efficient recovery of blow heat. These limiting factors are low heat levels in hot water and generation of hot water in excess of requirement and other problems associated with maintenance. Schemes are now available for utilising blow heat for partially concentrating weak black liquor supplied to chemicals recovery section. These schemes require evaluation on mill to mill basis

Technology is available today to clean the digester blow vapours from batch type of digesters to a contamination level of 1 ppm. These vapours after condensation can be easily recycled in the process.

## DISPLACEMENT HEATING AND COLD BLOW TECHNIQUE (RDH SYSTEMS)

A comparatively simplified technique of displacement heating and cold blowing the batch digester with compressed air has been developed recently.*

The technique involves displacing hot black liquor with washer filtrate at the end of the cook. The digester is cold blown with the help of compressed air. The heat from digester black liquor is for heating the liquor for the following cooks.

This method promises not only 75% saving of digester steam but also a 2% rise in black liquor concentration supply brown stock washer. The system appears to be quite promising and can be easily adapted.

**Brown Stock Washing** :

Use of multi-stage counter current vacuum washers is quite common in the Indian mills. There are two important aspects of brown stock washing.

a) Specific power requirement which is mainly based on the washer design and number of stages.

b) Washing system efficiency or soda loss is a function of dilution factor employed.

A careful estimation of power requirement, soda loss, black liquor concentration and its steam cost of evaporation is required to decide optimum number of stages to be provided for brown stock washing.

Most of the Indian mills are using three stage counter current washing. Use of four stage washing with a press roll can increase the weak black liquor concentration to 16-18%.

Some scope also exists to modify washers drop leg arrangement to reduce power consumption in each stage by employing vacuum pumps.

## PULP SCREENING & CLEANING

The power consumption in screening and cleaning operations depend mainly on the equipment design. Normally 3 stage cleaning system is employed. Low pressure drop centricleaner designs now available can be considered for modification of existing facility in a phased manner.

This section handles very large volumes of dilute pulp slurries. The operating consistencies and design of hydraulic system plays an important role in reducing the electrical power input. Increa-

*R.S. Grant, Tappi March, 1983, Page 120 sing pulp consistency to primary centricleaners can help to save power, this may effect on pulp cleanliness, marginally.

### BLEACHING

The practice of using CEH or CEHH sequences in bleaching with barometric drop leg washers or displacement type washer is common except for small mills based on agricultural residues. Proper recycling of water will decrease bleach plant water requirement and to some extent steam requirement. This can result in energy savings. Using back water in a countercurrent sequence is quite standardised now. Effluents are let out only from chlorination stage and partly from extraction stage.

### OXYGEN BLEACHING

The recent developmets in oxygen bleaching have been favourable to its adoption in Indian mills. The modified process mixes oxygen with medium consistency pulp in a specially designed mixer Further processing does not require pressure reactors and process risks, are minimal. The adoption of oxygen bleaching technology will depend on oxygen availability at competitive price. It may be noted here that manufacture oxygen requires half the energy required for chlorine manufecture.

Oxygen bleaching stage may be followed by peroxide stage in a simple sequence of O-P-H to give normal brightness pulp. The major advantage of this system will be that O & P stage effluents can be closed with brown stock washing. This will permit the recovery of soda ash and the additional in the beach plant and organics be burnt on the recovery boiler for steam raising.

### CHEMICALS RECOVERY :

All large mills have chemical recovery section comprising of multiple effect evaporator, black liquor fired recovery boiler and causticising plant to regenerate cooking liquor. A few mills also have lime kiln in operation.

Chemical recovery section recovers cooking chemicals and generates by-product steam.

Steam generated by burning of black liquor solids in most cases not only meets the energy demand of recovery section but also contributes extra energy for utilisation in the other sections. Thus for a particular production level more the black liquor solids per ton of pulp by keeping the bleached yield same, more will be energy contribution to meet the needs of other sections. This indicates that generation of more black liquor solids per ton of pulp produced will be helpful towards reducing purchased energy demand.

### EVAPORATORS

The energy requirement of a given multiple effect evaporation system is greatly influenced by the concentration of weak black liquor available from brown stock washers. For example if the concentration of black liquor is dropped from 16% to 10% the steam consumption per ton of pulp in evaporators will almost double to achiexe same output black liquor concentration.

### OPTIMUM NUMBER OF EFFECTS

Although only 4 to 6 effects are provided in the evaporator system of most of the mills, there exists a possibility of using upto 8 effect in evaporators. The steam economy which is around 3-3.5 for quadruple effect evaporator may increase to 6 to 6.5 in case of 8 effect evaporators thus dropping steam requirement to almost half compared to quadruple effect evaporators. The case for increasing number of effect is quite strong.

The evaporator-recovery boiler combination becomes more efficient when highest possible concentration of strong black liquor is obtained from evaporators.

### FALLING FILM EVAPORATORS :

Introduction of new technology of "Falling film evaporators" which is now developed, has become more desirable.

The use of falling film type evaporators with plate type heating surface permits evaporation of the liquor to higher solids concentration, reduces water or chemical boilings for scale removal and give better control on exit black liquor concentration.

### VAPOUR RECOMPRESSION EVAPORATION

Technology has also advanced to a stage where energy saving may be possible by introducing vapour recompression evaporation. Vapour recompression utilizes electrical energy to compress the evaporated vapours to higher pressure for its use in the evaporation. The savings will depend upon the cost of electrical power against steam cost.

Few more points which need consideration are the replacement of short tube evaporators with long tube evaporators with forced circulation, use of higher vacuum in the last effect replacement of direct contact jet condenser with surface condenser, replacement of multistage steam ejector system with vacuum pump, providing sufficient heat transfer surface to allow use of steam at lower pressure (say around 2.5 Kg/cm²). The evaporator liquor flow circuit has to be properly designed so, that there is minimum flash vapours at inlet and outlet black liquor streams.

Replacing mild steel tubes with stainless steel tubes will also help to reduce scaling problem which eventually results in lesser cleaning & boiling requirements thereby saving energy.

## CAUSTICISATION :

Higher white liquor concentration and temperature will reduce steam demand in digester house. Lower white liquor concentration results in more evaporation load and lower brown stock washer performance.

Apart from other factors, the number of lime mud washing stages will determine the optimum white liquor concentration which can be achieved.

Recent trend of having 4 washing stages i. e. 3 lime mud washers (clarifiers) followed by lime mud filter is quite justified although many units operate with 3 stages only. Having more than one vacuum filter stage can again result in higher power demand.

## PAPER MAKING :
## STOCK PREPARATION :

The stock preparation section of paper machine is one of the major power consuming sections of the mill where potential of reducing power consumption appears to be significant.

The beating and refining operation consists of battery of refining equipment. Unlike other sections, this section is more flexible. Refiners scheme can be modified or inefficient equipment may be replaced in a phased manner.

Some of the possible process moification are refining at higher consistencies improving the loading of refiners, maintaining higher pH whenever possible, refining separately the various furnishes and broke with properly sized refiners etc.

Replacing beaters or conical refiners (Jordans) with more efficient double disc refiners will be useful. Optimization of refiner plate designs and operating speed for reduced energy consumption are some of the points which could lead to further reduction in power.

Waste paper cleaning processes consume energy mainly for pumping, dilution and rethickening etc., and care should be taken to follow proper sequence to the required extent only.

## PAPER MACHINE

Paper machine energy requirements form a subject of great discussion due to large share of energy and vast variation amongst the mills. The variation is not only due to the different products made by various mills but also due to the vast differences that exists in the designs and capacities of various paper machines. Speciality papers will have their own standards to be compared with.

There are older machines in operation, which were designed for its lower capital cost rather than energy considerations. Some recently installed second hand imported machines have also added to this list. Renovation of the machine should have both the objectives of increasing capacity as well as reducing specific energy consumption.

## WIRE & PRESS PART

While improving operational speeds of the machine, main updating may be required in the wire and press parts of the machine. Increasing dryness of paper web after presses (improving dryness from wire part also aids this) leads not only to increased production but also to substantial savings in the steam required for drying. (1% increase in dryness gives 4.0% savings in steam). The same number of dryers can produce more tonnage.

Further increase of capacity and energy reduction in drying without requiring to add dryers can be achieved by use of closed hoods, pocket ventilation efficient condensate removal etc.

The power requirements for vaccum pumps and fan pump are quite high. Proper selection of vacuum pumps, centricleaners and approach system can lead to further saving in power. Operating centricleaners at higher consistencies (say around 1%) to reduce power can be evaluated. The newer centricleaner designs available presently also have lesser pressure drops.

Other important aspects of enery savings in paper machine will be use of improved felts, reduction of breaks, maximum deckle utilization, reducing rewinding and finishing losses.

## UTILISATION OF WASTE STREAMS

Control of energy wastage and utilisation of enerey in waste streams need to be practised. After the process heat consumed finds its outlet with the effluents from that section.

## REUSE OF WATER AND WATER CONSERVATION

It has been observed that as the reuse of water is increased there is not only drop in process heat requirement but also reduction of power for pumping of mill water. Paper machine effluents can be partly used at the paper machine itself before clarification. The remaining effluent, after clarification, can be used in pape machine (for showers etc) or in the pulp mill area including its usage to dilute the pulp supplied to paper machine. Counter-current usage of bleach plant effluent has already been described. The unbleached screening plant effluent also can be recycled in screening section or it can be used for chips washing. All cooling water use should be controlled and the cooling water should be recovered for its reuse in mill.

Evaporator-Evapotor condensate finds its use in brown stock washing or causticising.

Blow heat-Utilisation of blow heat has been earlier discussed.

## RECOVERY OF HEAT FROM PAPER MACHINE DRYER EXIT GASES

This heat can be recovered by air to air heat exchangers. The resulting warm dry air can be utilised in the closed hood of paper drying section.

## STEAM CONDENSATE RECOVERY

As a rule all steam condensate is to be returned to boiler house. The use of direct steam for heating is to be avoided as much as possible to maximise condensate return. If sufficient attention is not devoted in this area the condensate return percentage may drop. It will be beneficial to pump condensate under pressure to avoid loss of flash steam.

## STEAM TRAPS

Faulty traps on steam lines can lead to live steam wastage. Wherever more number of steam traps are existing in an area, it will be worthwhile to collect and return the collected condensate to boiler house.

## BOILER BLOW DOWNS

Intermittant and continuous boiler blow-down can be diverted to mill process hot water system and thus the heat is recovered. Prior to its blow, it can be flashed and the flash steam can be diverted for feed water heating.

## OPTIMISING EQUIPMENT PERFORMANCE, DRIVE AND MOTOR HORSE POWER

Each equipment needs to be evaluated in terms of its operating spead, work out-put, mechanical drives like gear boxes, speed reduction, pulleys and belt drive and horse power consumed.

Usually some of the equipments like agitators, screens, mixers, pulpers, vacuum pumps, fans etc. could be run at lower speeds to match the desired output. After carefully evaluating these aspects the motor can be changed to suit the required horse power.

Modifying the mechanical speed reduction units for efficient power transmission can help to a great extent. Hydraulic variable speed reducers consume more power compared to the electrical variable speed drives. Improved technology ot variable speed drives like thyrister, eddy currenf couplings, AC inverter drives, etc, are now available.

## PLANT HYDRAULIC SYSTEM

About 40 to 50% of total power consumption in paper mills is for pumping of fluids from one point to another in various sections. Hence, much scope exists in this area for power consumption reduction.

## POWER

Power savings can be achieved by implementing simple measures like—

a) Optimising the hydraulic systems with the study of pump data sheets.

b) Changing and inter-changing of pumps and impeller to more efficient configuration.

c) Feasibility of variable speed drives for big pumps.

Designers tend to over-specifying flows, pressure heads etc. in order to be on safer side. On new projects, over-specifying should be minimised to the extent possible.

Under fluctuating load conditions, instead of recommending single over-sized pumps, where fluctuating load exists, couple of smaller pumps may be connected. Some pumps can be stopped or restarted knowing the actual requirement from time to time.

Pressure head is responsible for major power consumption. Some mills in India have already made attempts to study consequence of reducing mill water pressure gradually.

Another area effecting pumping costs involves the design of piping system. Thorough study of friction loss characteristics of fluid being pumped is required for choosing appropriate type of piping layout also.

## ENERGY MANAGEMENT AND ENERGY AUDIT

### ENERGY MANAGEMENT

Faced with increased energy costs, Industries all over the world are making attempts to reduce energy bill.

First step is to assess energy consumption in previous three years and conduct a survey on present status.

All consumptions are to be expressed in common unit—like giga calories or million kilo Cal/Ton of product. Ratios thus obtained are then compared with different mills data, producing same type of product and having similar equipments and consuming same type of raw materials.

Next important step will be to prepare an approved time bound programme of energy conservation based on short term and long term measures aplicable to individual sections. A record is created to compare the progress with the sectionwise goals.

### ENERGY AUDIT

Energy consumption in various sections of the mill is to be registered daily for making energy balance. Steam and power consumption are to be computed daily and analysed for variations in consumptions. Energy consumptions in various sections may be compared with best results obtained for a particular period in previous three years.

In order to determine the areas of priority for optimisation with the objective of reducing electrical demand, the consumption of sub-groups in particular sections has to be studied. For example, paper machine may be divided into four groups : Chemical Preparation, Refining System, Vacuum System, Drives and auxiliaries like Save-all, etc.

For conducting such analysis for day to day monitoring of energy, a team of personnel not connected with production activities should be formed. Such energy cell will collect and analyse the energy information and prepare recommendations with objective of :

a) Maximisation of energy generating efficiency.
b) Economic energy transmission.
c) Optimisation of energy uses.
d) Minimisation of waste streams.

The daily audit report should include energy inputs and distribution on sectional basis. One typical chart for daily evaluation of thermal and electrical energy utilisation is given in Annexure 3.

After assessing energy consumption, "energy cell" should inform concerned departments about the status of energy consumption and possible measures which can be taken. These have been listed in Annexure 4.

### CAPACITY UTILISATION TECHNIQUE

Key words for the above technique will be "in plant buffer storage" and "optimum operating rates". The daily audit system generates sufficient information to pin-point adequacy of in-plant storages and efforts required to optimise the sectional operating rates.

Each section has certain electrical or thermal load which is not directly dependent on rate of operation. For example, all agitators, vacuum pumps, majority of other pumps, in-plant utility provisions, thermal losses are constant irrespective of operating rate. Thus, higher operating rates will result in reduction of specific energy consumption. If a plant is over designed compared to its available feed or output requirement, it will be advantageous to stop the plant after running it with maximum rate.

Similarly certain sections, such as evaporators, recovery boilers, lime kiln etc., may have considerable energy losses during starting and stopping operations. And these sections need to be run on continuous basis by optimising the rate of operation with the requirements.

Adequate in-plant storages will be helpful in both these cases. Some examples of these storages are :

i. Multipurpose tanks in recovery section help to avoid unscheduled recovery and pulp mill stoppages by storing weak black liquor or white liquor or green liquor.

ii) In the absence of adequate blow tank capacity, digesters at times are to be depressurised by release of steam.

iii) Adequate pulp storage after pulp mill avoids stoppages of paper machine for pulp in the event of routine down-time in pulp section.

### INFLUENCE OF CAPACITY UTILISATION AND PRODUCT MIX ON ENERGY CONSUMPTION

Large integrated mills using conventional raw material have capacity utilisation varying from 54 to 100%. Table 31 shows capacity utilisation data of various mills for the year 1981.

Mills have been segragated according to type of products manufactured. Table 31 also shows total energy inputs of various mills. It can be seen from the table that the energy inputs vary as per capacity utilisation and product mix.

TABLE—31

CAPACITY UTILIZATION, PRODUCT MIX AND ENERGY CONSUMPTION

| | Capacity Utiliza-tion | Energy inputs M. Kcal/Ton. |
|---|---|---|
| **PRODUCT** | | |
| **WRITING & PRINTING PAPER** | | |
| Mill No. 1 | 54.85 | 15.540 |
| Mill No. 2 | 102.70 | 11.484 |
| Mill No. 3 | 95.77 | 12.454 |
| Mill No. 4 | 66.85 | — |
| Mill No. 5 | 110.20 | — |
| Mill No. 6 | 88.20 | 12.707 |
| Mill No. 7 | 85.80 | 14.420 |
| Mill No. 8 | 80.00 | 20.378 |
| Mill No. 9 | 100.20 | 11.536 |
| **PRODUCT** | | |
| **DUPLEX BOARD, KRAFT & MLW** | | |
| Mill No. 1 | 116.90 | 13.600 |
| Mill No. 2 | 99.10 | 11.899 |
| **PRODUCT** | | |
| PACKAGING PAPER | 94.54 | — |
| **PRODUCT** | | |
| **CIGARETTE TISSUES OF** | | |
| **SPECIALITY PAPER** | 90.10 | — |
| **PRODUCT** | | |
| **MARKET GRADE** | | |
| **PULP & PAPER** | 78.74 | 9.076 for Pulp. 11.433 for Paper |

**OBSERVATIONS**

1. Energy consumption of mills producing writing and printing paper varies from 11.4 to 15.5 million kilo cals/ton.

2. Mills producing duplex board, kraft and MLW etc. energy consumption is 11.9 to 13.6 million kilo cals/ton.

In small non-integrated mills energy inputs is in range of 6 to 10 million kilo cals/ton.

Increasing prices of non-renewable resources (like, fuel, oil, coal), purchased power tariff and power cuts imposed, shortage of conventional raw materials etc., are some of the bottlenecks for improving capacity utilisation of paper industry. Capacity utilisation of paper industry in the past decade (after 1973 oil crisis) steadily declined from 95.5 to 67.9% in 1979.

**ENERGY CONSERVATION PROJECTS EFFORTS BY VARIOUS PAPER MILLS TOWARDS ENERGY CONSERVATION**

Motivation forces behind energy conservation programmes are rising energy prices and concern for future availability of fuel.

To cite recent analogy, when industries in Tamil Nadu were on the verge of closure due to water shortage, many factories made efforts to consume clarified effluent water to keep factories running.

If such attempts are made all over India we will be saving power used for pumping water and fresh water.

Projects already completed by few selected mills in India :

**STAR PAPER MILL**

a. **PAPER MACHINE SECTION**

1) 50 HP saving due to addition of forward drive roll on machine No. 3 thereby existing couch roll does not require vacuum.
2) 150 HP power saving due to replacement of 6 vacuum pump by 3 Nos. Kakati 603 pumps on machine No 4.
3) 65 HP reduction due to replacement of all centricleaner pumps by higher efficiently pumps in paper machine No. 2, 3 and 4.
4) Reduction in steam consumption per ton paper by replacement of old MG hood by new efficient hoods on machine No. 3 and 4.
5) 60 HP saving by replacing all the dryer bush bearing by antifriction bearings.
6) 40 HP saving due to replacement of old drive on machine No. 1 by new drive (Elender) complete with anti-friction bearings.

7) 40 HP saving in power and lubrication saving to the tune of Rs. 40,000 by replacing all the beater bush bearing by anti-friction bearings.

8) Reducation in power of 125 HP by installing disc refiners.

9) 15 HP saving by replacing complete line shaft drive by individual drive.

**b. PULP MILL AND RECOVERING PLANT**

1) 20 HP saving by removing of heat exchanger inlet pump and taking overflow of accumulated tank to hot water tank.

2) Reblows controlled by taking black liquor injection pump in circuit.

3) 90 HP digester circulation pump motor is replaced by 75 HP motor by altering cooking condition.

4) 10 HP saving by discarding screw conveyor of Hypo Tower 2 and pulp is taken by gravity.

**c.** ELECTICAL DEPARTMENT

1) 30 KW load saving by replacing incandescent lamps in mill and colony area by efficient flourescent tubes, mercury and sodium vapor lamps.

**d.** TURBINE AND BOILER HOUSE

1) 550 KW additional captive power generation by replacing old turbo-generators (2 Nos.) by new 5 MW condensing turbine steam extraction facility.

2) 2 Nos. of new coal fired boilers with sophisticated control system have been installed resulting in increase in efficiency by 8%.

3) After erecting DM plant for water softening, number of boiler blow-downs have reduced.

BALLARPUR PAPER MILL

1. 15 KW saving by reduction in stages of feed pump from 9 to 8.
2. 10 KW saving by installing high flow pump for black liquor in old chemical house.
3. 12 KW saving due to modification of centri-cleaners in pulp mill II.
4. Diversion of black liquor rejects to potchers (4 KW savings).
5. Power Factor improvement from 0.85 to 0.9 by installation of KVAR capacitors.
6. Introduction of high efficiency pumps in pump house.
7. Replacement of 150 HP motor in Soda Recovery Section by 100 HP. Similarly 75 HP motor of bleached stock chest No. 1 was replaced by 50 HP Motor.
8. Introduction of automatic level controller in chlorine washing stage thereby saving 16,800 units per year.
9. By installing thyrister panel on paper machine No. 1 and coating plant, 75 KW saving has resulted.
10. Excess cooling water return water pump for rectifier is eliminated (16 000 units saving).
11. 70 psi steam is consumed for Recovery Boiler, Air Heating and 5th effect evaporator by earlier 100 psig steam arrangements.
12. 600 tonnes per month steam saving by replacement of steam doctors in Dorr Oliver and Kimco Filters by mechanical discharging arrangement.
13. 51 tons/hr steam saving by addition of one more effect to existing 4 effect evaporator.

THE CENTRAL PULP MILLS LIMITED PROPOSAL ALREADY IMPLEMENTED

1) Switchover from oil to coal as fuel in the boilers.

2) Closure of oil fired lime kiln and use of purchased lime.

3) Controlled running of condensing turbine.

4) Installation of combi and fabric presses in Paper Machine.

5) Evaporator tubes changed over to stainless steel tubes from mild steel.

6) Provision of multi-purpose tanks to avoid frequent stoppage of recovery boiler.

7) Additional washing stage for Brown Stock Washer to convert into 3 stage washing.

8) Modification of refiner plates pattern & refining at high consistency etc.

9) Recycling of clarified paper machine effluent in pulp mill.

10) Lowering of cooking temperature.

11) Installation of thickner for knotter and screen rejects to reduce liquor ratio.

Apart from the above, following projects are undertaken :

1. Trials on biodegradation of bamboo dust, for hot water generation and further anaerobic digestion to recover the gases and use the residue as compost.
2. Power factor correction.

3. Replacing mercury vapour lamps by sodium vapour lamps.
4. Study of complete hydraulic system in the mill to find out potential for energy conservation.

## GOALS AND STRATEGY OF IMPLEMENTATION DURING THIS DECADE

The Indian Paper Industry is depending on the external fuel sources to the extent of 70% which is very high compared to the industry in developed countries. The pressure on conservation after the energy crisis in 1973-74 and again 1979 has changed the whole economics of utilisation of non-renewable energy sources. The developed countries took the lead in taking up energy conservation schemes in the early seventies and many of the countries have achieved these targets in energy conservation.

## AMERICAN EXAMPLE

American example can be cited in this connection. Soon after the oil embargo in 1973, the Federal Government in USA implemented a programme which sought energy conservation commitments from those industries which had the heaviest energy use, which naturally included paper industry as well. The target set for the pulp and paper industry was to reduce fossil fuel and purchased energy consumption per ton by 23% between 1972 and January 1980. This target was almost achieved by taking following measures :

1. By increasing the use of self generated and waste fuels from 41% to 47%.
2. By increasing the use of hogged wood from 2% to 5%.
3. By reducing the use of fuel oil from 22.3% to 19.1%.
4. By reducing the use of natural gas from 21.5% to 17.8%.
5. Reducing the use of coal from 9.8% to 9.1%.
6. By increasing the capacity utilisation by 7.4%.

Present purchased energy requirement of paper industry in India varies from 7.62 to 13.25 K Kcal/tonne of large mills. A few old large mills consume much more purchased energy. Process heat consumption in the large mills varies from 11.6 to 16.9 tonnes of steam per ton of paper and electric power from 1,305 to 1,873 KWH per tonne of paper. The cogeneration in large mills varies from 25% to 60% of the total power requirement.

The estimated total energy requirement of paper industry based on the installed capacity as on March 1982 and 70% capacity utilisation was 2.39 million tonnes of coal equivalent, and 1,356 million KWH of electricity. The projected energy consumption of paper industry estimated for 1,990 based on 2.8 million tonnes installed capacity and 75% utilisation will be 3.5 million tonnes of coal equivalent and 2,100 million KWH of electrical energy.

It is necessary to fix a target for energy conservation target for our paper industry. From the trend in energy conservation measures taken by Indian paper industry, it would be rational to fix a minimum target of 20% reduction in energy by 1990. This would mean a reduction of 0.7 million tonnes of coal equivalent and 420 million KWH of electrical energy by 1990.

The scope for energy conservation in our industry in excellent since,

- # there lies a scope for increasing our capacity utilisation from the existing level of 75% upwards to 90%.
- # possibilities of increased use of low energy consuming materials such as agricultural residues and waste paper.
- # possibility of increased cogeneration from existing 40 to 50% in large mills.
- # possibility of increasing cogeneration in small mills from existing near-zero level to 20% minimal.
- # possibilities of water conservation potentials.
- # possibility of improving in-plant chemical production.
- # possibility of viable recovery unit for small mills.

## RECOMMENDATIONS

Looking into the ever increasing rise in the cost of energy any investment to save energy will always have beneficial economic returns in future. It is gratifying to note that Government of India has already announced in the Budget proposal for 1983-84, a 100% depreciation in the cost of devices and systems for energy conservation (list given in Annexure 5).

With a view to achieve the objective of reducing energy usage of at least 20% by 1990 following recommendations are made :

The paper industry development cell in the DGTD should advise the present and future paper mills on energy efficient technologies, devices and systems, and should act as an information source on matters relating to energy to promote conservation.

Constitution of an apex committee consisting of members from DGTD, industry associations, professional bodies and research institutions, Government representatives and outside consultants/experts : for–

Providing information to individual mills and when requested, providing guidance to achieve targets.

— To collect basic energy consumption data on fuels and power and also production data by individuals on a monthy or quarterly basis to monitor progress in energy conservation.

— To analyse the energy data and develop energy consumption norms.

— To arrange periodic meetings and seminars to review progress and inform of the further measures needed to be taken by the industry.

— To institute industry level awards for energy efficient mills.

— To interact with the Government and mills] on matters relating to energy policy, R & D etc.

— This body should actively monitor progress, initiate action on following basic recommendations.

All steps must be taken to remove imbalance in sectional capacities to achieve capacity utilisation of at least 90%. This will instantly drop energy usage at least by 10%.

All measures should be taken to improve the thermal efficiency of boilers and other steam generating units (refer Chapter 4).

Steam generation in the recovery boiler per ton of black liquor solids fired should be stepped up. (refer Chapter 4. Committees observations).

Usage of waste fuels like bamboo dust, wood bark, bagasse pith, straw dust etc. for steam generation should be improved (refer chapter 4. Committees observations).

All steps to increase co-generation in large mills and to instal co-generation plants in small paper mills should be taken up on an emergency basis (refer chapter 4, Committees observation). To maximise the primary energy saving potential of co-generation, a liberal import policy for import efficient boilers and turbines be looked into, to remove bottleneck of power which at the moment is a great hindrance in the production efforts. The Electricity Board should also encourage the parallel operation of co-generation and other captive generation plants. This would not only improve the over-all thermal efficiency but also reduce the dependance on State Electricity Boards. This will also help to increase capacity utilisation (Annexure 6).

Efficiency use of waste heat should be given top priority. Heat from boiler flue gases, continuous and intermittent blow-downs, surface condenser etc. can be put to good use (refer chapter 4. Committee observations).

Power factor should be improved (refer chapter 4 Committees observation).

Use of waste paper and agricultural residues should be increased to reduce the overall energy requirement per ton of paper and also the load on raw material resources (refer chapter 1 Introduction). It might be desirable also to announce a long term policy of continuation of importing waste paper.

The various inplant measures as given in the check-list (Annexure) should be taken up.

Modern Technology for improving productivity, energy conservation, efficiency improvements as discussed in chapter 4 (Committees Observation) should be given top priority.

Inplant chemicals production, as practised in many developed countries, can be taken up in our paper industry also. Captive plants for Caustic and Chlorine for example are now available in smaller capacities and with new membrane technology (refer chapter 4 Commttees Observation).

Investment required for the short-term and long term energy conservation measures should be given priority by the Government.

Encouragement be given for small paper mills to install Chemical Recovery units. A unit of 50 TPD for bagasse based liquor is technically feasible and economically viable (refer Annexure 7, article by Shri N.S. Sadawarte).

Paper mills should be allowed to retain a specified proportion of excise duty payable by them in a separate account as a medium term loan at a nominal rate of interest exclusively for financing the cost of installation of energy conservation devices and systems. This scheme can be made more attractive for emerging installation of recovery units in small paper mills.

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5. Andhra Pradesh Paper Mills.
6. Nepa Paper Mills.
7. Titaghur Paper Mills.
8. Ashok Paper Mills.
9. Seshasayee Paper Boards.
10. Sirpur Paper Mills.
11. Sree Rayalaseema Paper Mills.
12. Orient Paper Mills.

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## ANNEXURE—1
## PRODUCTIVITY TRENDS IN PAPER INDUSTRY

It is worth examining

i) the productivity trends of factor inputs like labour, capital and materials including energy deployed by the industry.

ii) the linkages between factor productivity and factor substitution in the context of technological development and

iii) the impact of input cost variations on the capacity utilisation.

Capital productivity of fixed assets such as plant and machinery is closely linked to capital utilisation. The data on capacity utilisation are presented in Table Al-1. During the 20 year period, 1961-81 a general decline in capacity utilisation was registered. Capacity utilisation during the later part is extremely good reaching 99% in 1970. It fell to a mere 68% in 1981. Further decline is expected due to demand recession in 1982 The major factors responsible for this deterioration are :

i) shortage of raw materials

ii) non-availability of fuel and power

iii) poor industrial relations leading to strikes and go-slow

iv) sluggish demand caused by excessive taxes, levies, and price and production control

v) lack of financial resources as a result of credit squeeze in the recent past.

The input and output indices for the period 1960-77 are given in Table Al. 2. Capital material and labour productivity indices are combined using the weightages based on their importance during the base year 1960 in the total value of production.

The resulting total productivity index is presented in Table Al. 3. The following observations are made :

*Capital productivity increased by 9.2 percent till 1970; thereafter it declined by 5.7 percent.

*Labour productivity increased by impressive 21% per annum till 1974; followed by a sharp decline during the remaining years at 12% per annum.

*Input (cellulose materials, energy and chemicals) productivity displayed a mixed trend. During 1960-63, it declined by 2% per annum. followed by a sharp increase of 11% per annum till 1969. Input productivity fell thereafter until it reached an all time high in 1973. After 1973, productivity fell again followed by an impressive increase in 1977.

*It may be noted that paper manufacture being input intensive, the total productivity index closely followed the input productivity index Thus after an initial period of decline until 1963, total productivity index rose to 164.8 during 1970 at an annual rate of 9.5% followed by a decline to 149 in 1972. Although the index reached a peak of 196.5 in 1973, it declined to 152.6 on 1977 at 5.6% per annum The increase in capital productivity index and labour productivity index during the sixties is largely the outcome of increased capacity utilisation. It may be recalled that capacity utilisation had increased from 86 percent on 1960 to 99 percent in 1970. The impact of economies of scale due to capacity.

### TABLE A1–1

### INSTALLED CAPACITY, PRODUCTION AND CAPACITY UTILISATION OF PAPER AND PAPER BOARD IN INDIA

| Year | Installed Capacity '000 tonnes | Production '000 tonnes | Capacity Utilisation (percentage) |
|---|---|---|---|
| 1960 | 400.0 | 345.0 | 86.3 |
| 1961 | 410.0 | 364.8 | 89.0 |
| 1962 | 433.8 | 387.6 | 89.3 |
| 1963 | 502.2 | 462.6 | 92.1 |
| 1964 | 555.9 | 490.6 | 88.3 |
| 1965 | 643.9 | 537.0 | 83.4 |
| 1966 | 643.9 | 585.1 | 90.9 |
| 1967 | 701.2 | 608.7 | 86.8 |
| 1968 | 730.0 | 639.4 | 87.6 |
| 1969 | 730.0 | 701 0 | 96.0 |
| 1970 | 768.0 | 759.6 | 98.9 |
| 1971 | 900.6 | 778.8 | 86.5 |
| 1972 | 952.9 | 784.8 | 82.3 |
| 1973 | 967.0 | 775.0 | 80.1 |
| 1974 | 1009.0 | 826.8 | 81.9 |
| 1975 | 1068.0 | 812.4 | 76.1 |
| 1976 | 1127.0 | 874.8 | 79.3 |
| 1977 | 1137.0 | 919.2 | 80.8 |
| 1978 | 1265.0 | 1006.0 | 79.5 |
| 1979 | 1380.0 | 1047.0 | 75.9 |
| 1980 | 1538.0 | 1058.8 | 68.8 |
| 1981 | 1817.0 | 1235.0 | 68.0 |

Note : These exclude News Print

Sources : (1) CSO Government of India-Monthly statistics of the production of selected industries-various issues.

(2) Monthly abstract of statistics–various issues.

(3) Commerce Research Bureau data system.

## TABLE A1-2
### INDICES OF OUTPUT, LABOUR, INPUT AND CAPITAL AT CONSTANT 1961-1962 PRICES.

| Year | Production | Labour | Inputs | Capital |
|---|---|---|---|---|
| 1960 | 100 00 | 100.00 | 100 00 | 100 00 |
| 1961 | 115.15 | 97.59 | 111.84 | 110 56 |
| 1962 | 146.18 | 108 66 | 153.16 | 144.57 |
| 1963 | 188 48 | 119.82 | 203.07 | 163.27 |
| 1964 | 225.57 | 124.96 | 196.45 | 190.25 |
| 1965 | 229.63 | 129.52 | 166.82 | 202.10 |
| 1966 | 278.03 | 143.46 | 192.12 | 217.77 |
| 1967 | 308.49 | 145.45 | 226.71 | 242 11 |
| 1968 | 407.40 | 138.62 | 278.73 | 246 07 |
| 1969 | 383.04 | 159.21 | 248.31 | 273 99 |
| 1970 | 580.79 | 173.66 | 390.63 | 302.50 |
| 1971 | 602.47 | 179.06 | 429.96 | 313.72 |
| 1972 | 600.40 | 178.37 | 459.17 | 327.69 |
| 1973 | 645.76 | 177.69 | 351.36 | 340.85 |
| 1974 | 721.29 | 185.65 | 476.27 | 399.11 |
| 1975 | 646.25 | 192.31 | 542.82 | 430.68 |
| 1976 | 550.51 | 198.61 | 421.41 | 450.52 |
| 1977 | 553.49 | 217.71 | 374.55 | 479.49 |

Based on CSO Wages and Productivity in selected industries (in selected industries) in Organised Manufacturing Sector : 1900-1977 : October 1981.

## TABLE A1-3
### LABOUR, INPUTS AND TOTAL PRODUCTIVITY INDICES IN PAPER INDUSTRY AT 1960-61 PRICES

| Year | Labour Productivity | Inputs Productivity | Capital Productivity | Total Productivity |
|---|---|---|---|---|
| 1960 | 100.00 | 100.00 | 100.00 | 100.00 |
| 1961 | 117.35 | 102.68 | 103.60 | 103.76 |
| 1962 | 133.94 | 95.44 | 101.38 | 98.52 |
| 1963 | 156 67 | 92.82 | 115.33 | 98.98 |
| 1964 | 180.80 | 114.82 | 118.42 | 119.65 |
| 1965 | 176 92 | 137 65 | 113.37 | 138.46 |
| 1966 | 193.05 | 114.72 | 127.52 | 146.71 |
| 1967 | 209.52 | 136.07 | 127.27 | 140 45 |
| 1968 | 292.80 | 146 16 | 165.44 | 157.78 |
| 1969 | 240.88 | 154.26 | 139 78 | 159.10 |
| 1970 | 333.91 | 148.68 | 191.75 | 164 82 |
| 1971 | 336 87 | 140.12 | 191.72 | 157.72 |
| 1972 | 337.08 | 130.76 | 182,93 | 149.06 |
| 1973 | 362.36 | 183.79 | 189.15 | 196.53 |
| 1974 | 389.75 | 151.45 | 180.70 | 170.17 |
| 1975 | 336.45 | 119.05 | 149.88 | 136.46 |
| 1976 | 276.30 | 130.63 | 121.95 | 140.01 |
| 1977 | 254.84 | 147.77 | 115.21 | 152.62 |

Note : The Weightages for total productivity are :

Inputs Productivity = 0583
Labour Productivity = 0069
Capital Productivity = 0078

## ANNEXURE—2

### A NOTE ON PRODUCER GAS

SHRI S. RAMCHANDRAN,
NPC, MADRAS

Many alternative energy sources are being thought of to substitute oil-a depleting commodity at a faster rate. Substitution of oil by coal is gaining momentum all over the world and all the developed nations are changing their economy from oil to coal. As the scope of substitution for oil by renewable alternative energy sources is very limited, coal has to play a very important role as far as the industrial energy substitution is concerned.

It is not possible to substitute coal in its original form for oil in many applications. However, coal through producer gas is technically feasible and economically viable alternative for oil in almost all the industrial heat release applications. Coal remains paper industry's main energy feed stock. However, the industry purchases around 10% of its total energy requirements as oil by paying almost three times more cost for the same energy content when compared to that of coal. Paper industry essentially uses oil in lime kilns, as auxiliary fuel in recovery boilers and in some instances to dry the pulp. Lime kilns consume major quantity of oil purchased by a paper mill. Oil is being used in all the applications as coal cannot be used in its solid form.

Producer gas from coal is good as a liquid fuel and it can totally replace oil in the paper industry. Substitution of producer gas for oil in the paper industry economically attractive as every tonne of oil is replaced by 3 tonnes of coal based on its endure energy efficiency. Producer gas generation as well as endure technology is not new to the country and it is as simple as burning coal in its solid form. Gas producers of different sizes are available in the contry at competitive prices. Some mills in the country are already on producer gas for burning lime. It is necessary for all the mills to think of substitution of oil by coal through producer gas and initiate action plane to reduce the cost of total purchased energy.

## ANNEXURE—3

### DAILY ENERGY AUDIT

| Generating Consuming Units | Input Energy | Useful Energy Output | Wastage (Percentage) | Specific Consumption Normal | Specific Consumption Actual | Revenue Loss (Rs.) | Detailed Reasons for Deviation | Preventive Action Needed |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

## ANNEXURE—4

## CHECK LIST OF POTENTIAL PROJECTS FOR ENERGY CONSERVATION

### FIBROUS RAW MATERIAL

1. Design a system for utilising bark from hardwoods and others found waste as fuel.
2. Select chippers to reduce slivers and dust.
3. Develop system to utilise slivers and dust generated usefully as fuel or as fibre.

### BATCH COOKING

1. Use indirect steaming for digesters.
2. Design efficient blow heat recovery system and consider utilising the heat for either—

   BLACK LIQUOR EVAPORATION

   or

   WHITE LIQUOR HEATING

   or

   WATER HEATING FOR USE IN BROWN STOCK WASHING & BLEACHING

3. Optimise utilisation of energy during cooking cycles by

— minimising gas ventury

— minimising cooking temperature by balancing alkali/wood ratio.

— carry out two-stage steaming, first with low pressure steam followed by medium pressure steam

— minimising liquor wood ratio.

### WASHING AND SCREENING

1. Optimise use of wash water relative to savings from recovered cooking, bleaching and paper making chemicals.
2. Recycle all liquor spills to system.
3. Utilise recycled water for washing the pulp.
4. Consider methods and equipments for increasing consistency of brown stock at each stage of washing by higher vacuum, application of press roll on pulp mat or by use of screw presses.
5. Recycle screening back water as much as possible and utilise excess back water for chip washing/bamboos wood washing.

### BLEACHING

1. Consider methods of

— maximising pulp consistency in each stage minimising bleaching temperature.

2. Consider countercurrent reuse of wash water.
3. Use paper mill (bleached) white water on last-stage wash.
4. Design for the reuse of chlorination-stage effluent for screened pulp high density dilution.
5. Reduce fresh water utilisation to the minimum by maximum back water recirculation.
6. Consider methods for reusing alkali extraction stage effluent for caustic lye dilution or solid caustic dissolving.
7. Reevaluate energy savings compared to bleaching economy and product quality by reducing number of bleaching stages.
8. Reevaluate the need for current brightness levels to see if they can be reduced.
9. Reevaluate economics of inplant generation of chlorine, caustic soda utilising off gas $H_2$ for fuel.

### MULTIPLE EFFECT EVAPORATORS

1. Reappraise multiple effect evaporator system optimum number of stages.
2. Evaluate use of vapour compression techniques.
3. Reappraise techniques to increase overall temperature drop across the stages and also to increase overall heat transfer coefficient.
4. Collect and recycle all liquor spills.
5. Filter black liquor to reduce evaporator boil out frequency.
6. Design and operate for minimum conveyor to improve cleanliness of condensate for reuse.
7. Design multiple effect evaporator for taking out black liquor at the maximum possible concentration in order to reduce or totally eliminate evaporation in direct contract evaporator of recovery boiler.
8. Reevaluate efficiency of vacuum producing equipment, i.e. use of vacuum pumps in place of ejectors.

## RECOVERY BOILER

1. Maximise feed black liquor concentration to boiler.
2. Maximise temperature drop across boilers, higher pressures and lower coldend temperatures.
3. Utilise indirect heating of black liquor at liquor heaters.
4. Investigate uses of waste heat in pre-heating air and boiler feed water.
5. Incorporate attamperators to control superheated steam temperatures.
6. Design primary, secondary and tertiary air ducts and air ports for maximum reduction efficiency and minimum carryover.

## CAUSTICISING

1. Recover heat from slaking for reuse.
2. Evaluate all methods to reduce addition of fresh water to the system by :
   - use of mechanical seals
   - use of combine condensate from evaporators in place of fresh water for showers.
3. Collect & return all spills to system.
4. Follow counter-current washing for washing the sludge.
5. Evaluate methods to maximise concentration of white liquor.
6. Evaluate use of more number of sludge washing stages to minimise alkali.

## PAPER/BOARD MANUFACTURE

1. Design and operate saveall system to produce wash water of sufficient cleanliness and reliability for general reuse in stock preparation and paper mill for—
   - Fourdrinier showers
   - Head box showers
   - Consistency dilution
   - Broke repulpers
   - Dilution of chemical additives
   - Wash up hoses
   - Bleach plant washers
2. Optimum refiner plate design to obtain paper strength at minimum refining power.
3. Refine at high pH to reduce specific refining power.
4. Cooling, seal, gland, bearing waters etc, should be segregated for temperature and reused wherever possible.
5. Select and operate press section to reduce water content in paper rating dryers to the minimum.
6. Utilise wet and moisture gauge to maintain continuous records of moisture.
7. Use of vacuum utilising lower volume of seal water
8. Reuse vacuum pump seal water in wash water system.
9. Design and operate paper machine dryers from one overall steam usage considering—
   - Minimising the dryer pressure level required.
   - Dryer drainage system for control and economy.
   - Improved methods of utilising vapour recompression to reclaim blow through steam.
   - Positive pressure hoods.
10. Operate dryer hoods for controlled operation and recovery of heat.
11. Operate machine for—
    - maximum machine speed
    - minimum machine breaks
    - minimnm recycled broke
12. Install paper machine hood economiser.
13. Use low coefficient of friction suction box covers to minimise fourdrinier power usage and maximise wire life.
14. Establish optimum felt replacement schedule to maximise production and minimise steam for drying paper.

## POWER GENERATION

1. Install additional feed water heating.
2. Reduce excess air for combustion by $O_2$ monitoring.
3. Improve water treatment to minimise boiler blow-down.
4. Improve condensate returns.
5. Recover heat from blow down flash steam.
6. Use condensate for desuperheating.

7. Eliminate throttling of high pressure steam through pressure reducing station.

8. Use multifuel combustion zones in power boiler.

9. Use high efficiency back pressure turbo generators and avoid use of small, in efficient condensing turbines.

10 Generate steam at high pressure and temperature to generate more by product power and engage back pressure turbine for power generation.

11. Operate boiler to give colourless smoke but keeping a watch on $O_2$ at the same time as not to have excess air.

12. Check unburnt in cinder in coal fired boilers good combustion of coal.

13. Use boiler fluegases to dry pith/bark/saw dust/ bamboo dust/rice husk before firing.

**ELECTRICAL—**

**MILL LIGHTING**

1. Utilise light sources having maximum lumen watt efficiency, accepting some deficiency in colour quality if necessary.

2. Apply photocell and time dial control more strictly to out-door lighting, making sure illumination is provided only when definitely necessary.

3. In all areas. inside and out, utilise spot lighting as much as possible and avoid high level general illumination unless definitely required.

**ELECTRICAL EQUIPMENT**

1. For power factor correction, consider use of unity power factor synchroniser machines and locating capacitors at loads to reduce line and mud transformer losses.

2. Avoid 'over-motoring' pumps and other drives, Make sure motor and impellers are efficiency matched to load. Avoid energy wastage with motor driving against practically closed valves and dampers.

3. Consider automatic systems for operating equipment to avoid long periods of running with no load (Conveyors etc.). An alarm might be adequate in some cases.

4. Review cable sizing from energy loss as well as thermal limitation stand-point, particularly in low voltage high current applications.

5. Efficiencies of all electrical equipment should be given increased weight in purchasing recommendations.

6. Consider using high voltage motors wherever possible especially in higher range.

**MILL/GENERAL**

1. Maintain or replace steam trap stations that are leaking steam.

2. Eliminate leakage and misuse of compressed air.

3. Eliminate leakage and misuse of water.

4. Educate operating personnel on the costs of steam, air, power and water to encourage the elimination of wastes—

— Unnecessary operation of spare equipment.

— Use of oversize equipment, ie. pupms with oversized impellers.

— Unnecessary use of lighting.

5. Evaluate the feasibility of burning combustible mill water such as bamboo dust, saw dust, bark pith etc.

6. Evaluate feasibility of recovering spent lubrication oils.

7. Evaluate feasibility of utilising solar heat wherever possible, ie. sun drying of bambo dust, saw dust, bark, pith etc, before firing in the boilers.

## ANNEXURE—5

## DEVICE AND SYSTEMS FOR ENERGY COSERVATION ELIGIBLE FOR 100% DEPRECEATION-APPROVED BY THE GOVERNMENT OF INDIA

Group F 100 per cent

2A Energy saving devices being—

a. Specialised boilers and furnaces

i inguifluid/fludized bed boiler

ii flameless furnaces

iii fludized bed type heat treatment furnace

iv high efficiency boilers (thermal efficiency higher than 75 per cent in case of oil/gas fired boilers).

v Boilers for unconventional fuels like bark, husk, bamboo dust, saw dust and other mill waste.

vi coal gasification.

b. Instrumentation and montoring energy flows :

i automatic electrical monitoring system
ii digital heat loss meters
iii micro-processor-based control system
iv oxygen and $CO_2$ recorder controller

c. Waste Heat Recovery Equipments and co-generation System—

i Economisers and feed water heaters
ii recuperators and air preheaters
iii back pressure turbines for co-generation
iv heat pumps
v vapour absorbtion refrigeration systems
vi organic ranking cycle power system
vii low inlet pressure small steam turbines

d. Power factor correcting devices : shunt capacitors & synchronous condenser systems.

e. Pertaining to Process—

— Belt conveying system
— Blow heat recovery system
— Indirect heating of digester
— Continuous digester
— High density storages
— Centricleaner requiring low pressure drop
— Oxygen and peroxide bleaching
— Multiple effect evaporator
— Electrostatic precipitation
— Desilication of black liquor
— Lime sludge reburning
— Cascading of steam and condensate system
— Closed hood for machine
— Suction pick-up with bi/tri nip press
— Thyrostat DC drive
— Installation of disc refiners
— Waste paper treatment plant.

## ANNEXURE—6

## NOTE ON CAPTIVE POWER PLANT IN AN INTEGRATED 30 TPD WRITING AND PRINTING PAPER PLANT

### Introduction

A case study of a captive power plant in a 30 TPD integrated paper plant manufacturing writing and printing paper was presented in a paper by A Krishna and Vinay Kumar. The Philosophy of the paper has basically been that the frequent power trips are hampering the production and hence a captive power plant to match the essential process equipment and the associated services is a viable project when looked in over all perspective inspite of the fact that cost of power generation under adverse circumstances of not being able to match the steam and power requirements in the process. However, it is clearly indicated that the captive power generation, with efforts to utilise the turbine exhaust steam in the process fully, is not only highly economical but also essential to make the unit free from the vagaries of grid power.

The scheme as advocated in the said paper was in reference to a new unit under implementation. This note is basically to improve the said concept further and to evaluate the economics of such a captive power plant in an existing mill where no captive generation was envisaged in the beginning and only low pressure boilers for process steam requirements are incorporated.

### Scheme

In the scheme, for power generation, envisaged earlier, a 1.5 MW turbo alternator with boilers to generate steam at 30 kg/cm²g and 400°C were conceived. The excess steam beyond the process requirement was condensed in a Dump Condenser and process water was used in the Condenser prior to using in the process.

It is accordingly observed that at a level of 1050KW power generation the excess steam varies between a maximum of 6000 kg/hr to 2000 kg/hr minimum. In order that the excess steam be reduced to a minimum, it is now envisaged that the boiler conditions be changed although it certainly increase the cost further. A scheme is accordingly suggested as indicated in fig. No. 1 for an existing mill. In this scheme the steam load is distributed between the proposed new high pressure power boiler and one of the existing small boilers. The general pattern of process steam requirement is assumed same as in the earlier referred paper.

### Economics

Economics of the proposed captive power plant are elucidated in tables I & II. The total investment of the proposed power plant is estimated at Rs. 1.5 crores. Coal cost is assumed as Rs. 600/- per tonne delivered at site and over all steam generation efficiency is assumed as 70%.

## Conclusion

It is recommended that the HP boilers should be of minimum 44 kg/cm²g pressure and 425°C and 12 TPH capacity power generation should be aimed at 1300 KW.

The power generation cost is estimated as 50 P per unit. However as the interest and depreciation burden goes down over the years, the cost of power generations after 7 years will be as low 25 to 30 P per unit which is very attractive.

TABLE—I

**PROJECT COST :**

Boiler 12 Tonnes/hr 44 kg/cm² g & 425°C

| | Rs lakhs |
|---|---|
| Boiler instrumentation and auxiliaries as installed | 75.00 |
| Modifications in the existing system | 5.00 |
| Turbine and auxiliaries | 50.00 |
| Modifications in the electricals | 10.00 |
| Contingencies | 10.00 |
| Total : | 150.00 |

**FIXD COSTS :**

| | Rs. in Lakhs |
|---|---|
| Wages and salaries | 1.00 |
| Repairs % of cost attributed for power generation | 1.50 |
| Depreciation 7% of project cost | 10.50 |
| Interest (soft loans) 12% | 18.00 |
| Total : | 31 00 |

$$\therefore \text{ Fixed cost } = \frac{31,00,000}{330 \times 1300 \times 24} = \text{Rs. } 30/-$$

$$\therefore \text{ Total Power Generation cost } = 50 \text{ paise/KWH}$$

TABLE—II

| | 30 kg/cm² 370°C | 44 kg/cm² 370°C | 44 kg/cm² 400°C | 44 kg/cm² 425°C |
|---|---|---|---|---|
| H1 $\frac{KCals}{Kg}$ | 755.5 | 748 | 764 | 779.5 |
| $\Delta H \frac{KCals}{Kg}$ | 66.0 | 90 | 93 | 99.0 |
| $H_2 \frac{KCals}{Kg}$ | 689.5 | 658 | 671 | 680.5 |
| Sat temp $T_s$ °C of exhaust steam | 148 | 148 | 148 | 148 |
| HP steam flow rate $\frac{S.\ Kg}{hr}$ | 17000 | 12500 | 12100 | 11400 |
| Heat for power generation Q $\frac{KCals}{hr}$ | 4,422,000 | 1,902,000 | 1,709,000 | 1,341,200 |
| Coal equivalent W coal $\frac{kg}{hr}$ @ 4500 K Cals/kg and 70% overall efficiency | 1405 | 605 | 545 | 430 |
| Cost of coal C Power Paise/KWH @ Rs. 600/tonne | 65 | 28 | 25 | 20 |
| C Fixed : Fixed cost $\frac{Paise}{KWH}$ | 30 | 30 | 30 | 30 |
| C Total Generation cost $\frac{Paise}{KWH}$ | 95 | 58 | 55 | 50* |

* Recommended scheme

ANNEXURE—7

# SCOPE FOR INSTALLATION OF SODA RECOVERY SYSTEM IN MINI PAPER MILLS

BY

N. S. SADAWARTE

## INTRODUCTION

The Pulp and Paper Industry in India has developed over the years through a number of units. The individual mills very in size from 2 TPd to 250 TPD. Whatever be the size, a paper mill is a high quantity consumer of water, of chemicals, of energy, and of fibrous raw materials. It also has to discharge almost 25% of its water back to the source and pollution abatement has today assumed a greater responsibility.

Though large mills have an integrated chemical recovery system, the total absence of recovery section or suitable pollution treatment methods in small mills has become a topic of discussion of every one within the industry as well as out of it.

Every body is quite concious of the fact that this situation can' no longer continue. Different ways and means have to be found out to enable these mills to treat their effluents and to establish recovery systems. This is the need of the time. We must, therefore, compliment I.C.I.C.I. for organizing this Seminar and thus focussing all attention towards this attempt to evolve possible solutions.

That installation of recovery units by medium or small paper mills is a must will be realised when we consider the consequence of not doing so.

Of the 100 odd medium/small mills, accounting for production of about 2.40 lac tons of paper and board in 1979, atleast half are expected to have used agricultural residues as their fibre source. Based on this assumption in cooking these fibres, they used an estimated 36,000 M.T. Caustic Soda valued at estimated Rs. 18.00 Crores which was let off in drains as effluents because no chemical recovery system exists for these mills.

Again one cannot stop only after considering the loss of this quantity of Caustic Soda, staggering as it is at Rs. 18.00 Crores. But one has to go beyond and consider the inputs which have gone in the manufacture of this quantity of Caustic Soda. Almost 2000 KWH are required to manufacture one ton of Caustic Soda. Thus, precious power alone to the extent of about Rs. 2.52 Crores was lost with the Caustic in the effluent drains. It is this magnitude that prompts us to give so much importance to installation of Chemical Recovery Units by small paper mills and further necessitates a meaningful dialogue among all the experts in this field.

## DISTRIBUTION OF SMALL, MEDIUM AND LARGE PAPER MILLS.

The total annual installed capacity of 121 Paper Mills in the country is 15.:8 tons with the actual production in 1979 at 10, 44, 868 tons (Table No. 1) Daily production in the different units shows over a hundred fold variation; plant capacity ranges from 2 tons per day (TPD) for the smallest units to about 250 tons per day (TPD) for the largest paper mill in the country.

The installed capa city of the paper mills can be broadly grouped in two categories according to the source of fibre. There are 21 mills above 60 T. P.D. capacity, centered around forest resources like Bamboo and mixed Hardwoods. These large units account for 70% of the total paper production and remainder of the production comes from the 100 smaller units within capacity range of 2 to 60 T.P.D. The main source of fibre for the small unit is a blend of two or more pulps derived from diverse non-wood materials such as bagasse, agricultural residues such as rice straw and wheat straw, Jute, sabai grass, cotton waste, cotton rags, cotton linters, waste paper, hessian etc. depending upon local availability. Paper mills are located in nearly all the states in the country as shown by the statewise distribution in Table 2. The location

TABLE—1

SUMMARY OF INSTALLED CAPACITY OF PAPER AND PAPER BOARD INDUSTRY (CATAGORYWISE) AS ON JANUARY 1,1980.

Scope for Recovery in Mini Paper Mills

| Name of Category | Capacity Range | No. of Units | Annual Installed Capacity. | % to total installed Capa. | Actual Production in 1979 | Capacity Utilisation (I) |
|---|---|---|---|---|---|---|
| Large I | above 20,000 | 21 | 1075460 | 69.92 | 7,64,894 | 71.11 |
| Medium II | 10,001–20000 | 8 | 112500 | 7.31 | 75,417 | 67.04 |
| Small III | 5,001–10000 | 24 | 185900 | 12.09 | 92,505 | 49.76 |
| IV | 2,001– 5000 | 31 | 111160 | 7.23 | 74,543 | 67.06 |
| V | 500– 2000 | 37 | 53146 | 3.45 | 37,509 | 70.58 |
| | Total | 121 | 1538165 | 100.00 | 10,44,868 | 67.93 |

TAALE—2

STATEMENT DISTRIBUTION OF INSTALLED CAPACITY OF PAPER & PAPER BOARD MILLS

Scope for Recovery in Mini Paper Mills

| State/Union Territory | No. of Units | Installed Capacity (Tonnes) | % of total installed capacity in the state or Union Territory | 1000-2000 No. | 1000-2000 Installed capacity | 2000-5000 No. | 2000-5000 Installed capacity | 5000-10000 No. | 5000-10000 Installed capacity | 10000-20000 No. | 10000-20000 Installed capacity | 20000 & above No. | 20000 & above Installed capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Andhra Pradesh | 8 | 256100 | 16.64 | 1 | 1500 | 1 | 2500 | 2 | 19000 | — | — | 4 | 233100 |
| Assam | 2 | 28000 | 1.82 | 1 | 1000 | — | — | — | — | — | — | 1 | 27000 |
| Bihar | 3 | 76500 | 4 97 | — | — | 1 | 3000 | — | — | — | — | 2 | 73500 |
| Chandigarh | 1 | 1500 | 0.09 | 1 | 1500 | — | — | — | — | — | — | — | — |
| Gujarat | 21 | 95490 | 6.20 | 9 | 11990 | 6 | 23000 | 4 | 27000 | 2 | 33500 | — | — |
| Haryana | 10 | 89800 | 5.84 | 3 | 5300 | 5 | 18500 | — | — | 1 | 15000 | 1 | 51000 |
| Karnataka | 9 | 110770 | 7.20 | 1 | 1950 | 2 | 7920 | 2 | 15500 | 1 | 10300 | 2 | 84000 |
| Kerala | 2 | 35700 | 2.32 | — | — | 1 | 2700 | — | — | — | — | 1 | 33000 |
| Madhya Pradesh | 5 | 120900 | 7.86 | 1 | 1200 | 1 | 3000 | 1 | 6000 | — | — | 2 | 110700 |
| Maharashtra | 22 | 190620 | 12.40 | 5 | 6960 | 9 | 33700 | 4 | 26400 | 2 | 25200 | 2 | 89460 |
| Orissa | 3 | 129500 | 8.42 | — | — | — | — | — | — | — | — | 2 | 129500 |
| Pondicherry | 1 | 9000 | 0.38 | — | — | — | — | 1 | 9000 | — | — | — | — |
| Punjab | 1 | 9000 | 0.58 | — | — | — | — | 1 | 9000 | — | — | — | — |
| Tamilnadu | 4 | 75000 | 4.88 | — | — | 1 | 4000 | 1 | 6000 | 1 | 15000 | 1 | 50000 |
| Uttar Pradesh | 17 | 100905 | 6.56 | 10 | 15865 | 3 | 9840 | 3 | 29000 | — | — | 1 | 46200 |
| West Bengal | 14 | 209380 | 13.61 | 4 | 5880 | 1 | 3000 | 5 | 39000 | 1 | 13500 | 3 | 148000 |
| Total | 123* | 1538165 | 100.00 | 36 | 53145 | 31 | 111160 | 24 | 185000 | 8 | 112500 | 22 | 1075460 |

*Titaghur and Ashoka two locations each.

pattern and capacities of the different mills are governed mainly by the availability of fibre resources and finance. Paper mills with a capacity below 30 T.P.D. are presently classified as mini paper plants.

The conventional raw material for paper making in this country is Bamboo, which on account of non-availability of pulp woods (pine, spruce etc.) is the preferred long fibre pulp source. Thus paper production in the large units was based on bamboo, a major non-wood source in this country. However, in the past two decades, efforts to conserve available bamboo resources have necessitated the use of mixed hardwoods and plantation grown eucalyptus which constitute upto 50-60% of the digester furnish in some mills.

Among the medium/small units there is one mill in this country based on bagasse with integrated chemical recovery operations (30-35 T. P. D.) and another mill based on rice straw (30-35 T.P.D.) without recovery units making bleached pulp for printing and writing grade. Technology for the utilization of non-wood fibre resources for paper making is quite well developed as illustrated by the trend in utilisation of bamboo, bagasse, reeds and straw in developing countries in Table No (3). Bagasse is the dominent raw material and bagasse pulp represents over half of the total world wide production of non-wood pulps, with mill capacity in the ranges of 40 to 300 T. P D. An increasing quantity of straws is also used now for paper making in some countries in 30 to 80 T. P. D. units.

Thus, Bagasse and straw are the principal fibre resources available for medium paper plant. Sufficient straw will be available to the plants (20 to 30 T. P. D.) located near rural collection centres. Bagasse becomes available at the sugar mills after cane crushing and juice extraction steps. Sugar Mills use the bagasse as fuel to obtain a steam for mill operations. However, with an improvement in thermal efficiency of bagasse boilers, surplus bagasse can be made available to an adjoining paper mill. Bagasse paper mills can also be located in regions having several sugar mills, each releasing a certain amount of surplus bagasse. Additional bagasse quantity can be released further by substituting coal fired boilers in sugar mills especially in stages like Andhra Pradesh, Bihar where collieries are nearby and road transportation is economical.

Paper mills can thus be classified as large units based mainly on bamboo and mixed hardwoods, medium/small units based on bagasse, straw and secondary fibres and small units dependent upon locally available fibrous materials. This paper deals with the medium /small paper mills based on srraw/ bagasse.



TABLE—3

TREND IN THE USE OF NON-WOOD FIBRES IN DEVELOPING COUNTRIES (MILLS INSTALLED AFTER 1965)

| Country | Rice Straw | Other Straws | INSTALLED CAPACITY TPD (No. of) MILLS) | | | MISC. | TOTAL |
|---|---|---|---|---|---|---|---|
| | | | Reeds | Bagasse | Bamboo | | |
| Bangla Desh | — | — | — | 60(1) | 100(1) | 160 | 160(2) |
| Brazil | — | 25(1) | — | 40(1) | — | 200(1) | 265(3) |
| India | 65(2) | 65(2) | 150(2) | — | 175(2) | — | 390(6) |
| Indonesia | 60(2) | — | — | 160(1) | 30(1) | — | 250(4) |
| Iraq | — | — | 120(1) | 220(2) | — | — | 340(3) |
| Mexico | — | — | — | 660(4) | -- | — | 660(4) |
| Pakistan | — | — | — | 90(1) | -- | — | 90(1) |
| Philippines | 30(1) | — | — | 50(1) | 40(1) | 20(2) | 140(5) |
| Sri Lanka | 70(2) | — | — | — | — | — | 70(2) |
| Other (16 countries) | 300(4) | 330(4) | — | 1460(8) | 225(2) | 345(3) | 2660(21) |
| Total | 525(11) | 355(7) | 270(3) | 2740(19) | 570(7) | 565(6) | 5025(51) |

Note : No. of mills in each categories indicated in the parenthesis.
Data on India is not very comprehensive.

## PROCESS TECHNOLOGY FOR PULPING OF BAGASSE, STRAWS AND BAMBOO

### CONVENTIONAL BAMBOO PULPING :

Bamboo based paper mills adopt the kraft pulping processes and use bleached (4-stage CEHH Bleach plant) or unbleached pulp for paper production and chemical recovery is an integral part of the mill operations with the dual role of reclaiming the inorganic pulping chemicals, and energy (power and steam) from the organics dissolved in the spent pulp liquor. All the operations of bamboo processing pulping, bleaching, paper making and chemical recovery are quite satisfactory and similar to the wood based paper mills.

### CHEMICAL COMPOSITION AND MORPHOLOGY OF BAGASSE & STRAWS

Bagasse and straws differ substantially from bamboo and woods in chemical composition and fibre morphology (Table No. 4). These are short fibre resources and generally require blending with a long fibre (10 to 30%) depending upon the type of machine and the desired properties. Satisfactory printing/writing paper has also been claimed to have been made from bagasse pulp without any inclusion of long fibre pulp. Lignin content of straws/bagasse is low and is easily delignified requiring only caustic soda and less severe pulping conditions. Impregnation of straws/bagasse with pulping liquor is relatively easy due to their open and porous structure and can be adopted easily for short cycle continuous pulping processes.

TABLE—4

CHARACTERISTICS OF NON-WOOD FIBROUS RAW MATERIALS COMPARED TO WOOD

Scope For Recovery In Mini Paper Mills

| Sr. No. | Raw Material | Fibre Characteristics Avg. Length 9 (mm) | Avg.Dia (Microns) | Ratio L/D | Ash | Lignin | Pen-tosan. | Cross & Bevan Cellulose. |
|---|---|---|---|---|---|---|---|---|
| 1. | Rice Straw | 1.4 | 8.5 | 170 | 14-18 | 12-14 | 22-25 | 46-49 |
| 2. | Wheat Straw | 1.1-1.5 | 9-13 | 110-120 | 6-8 | 16-17 | 27-20 | 52-54 |
| 3. | Jute | 2 | 20-25 | 80-100 | 0.5 | 21-39 | 18-19 | 57-58 |
| 4. | Sabai Grass | 2 | 9 | 231 | 6 | 22 | 23.9 | 54.5 |
| 5. | Bagasse | 1.7 | 20 | 85 | 2-3 | 18-22 | 28-32 | 46-55 |
| 6. | Bamboo | 2.7-3.0 | 14 | 192-214 | 3-5 | 24-30 | 16-21 | 60-63 |
| 7. | Hardwood | 0.7-1.6 | 20-40 | 35-40 | 0.2 | 23 30 | 19-26 | 34-61 |
| 8. | Softwood | 2.7-4.6 | 32-43 | 7[illegible]-90 | 0.2 | 23-34 | [illegible]7-14 | 53-62 |

## RAW MATERIAL PREPARATION SUCH AS CLEANING AND DEPITHING AHEAD OF COOKING

Two-thirds of both bagasse and rice straw consist of fibres useful for pulp production and the remaining constituents disintegrate readily to fine material during processing. The clums of rice straw containing the useful fibres are suitable for paper pulp and it is desirable to remove the leaf blades and leaf sheath from rice straw. Similarly bagasse consits of useful fibre (two thirds) which are preferably removed in a pretreatment operation. The leaf portions of rice straw and pith content of bagasse are relatively easily separated by mechanical abrasion or hammering action from the useful fibres. Leaf and sheath can be separated satisfactorily from rice straw in two steps. These consist of a first stage cyclone for the separation of foreign matter from chopped dry straw and a second stage of wet cleaning for the disintegration of leafy portions by mild abrasion and screening for obtaining the useful fibres. Efficient methods are available for depithing bagasse in one or two stages with hammer mills and/or hydrapulper by moist and wet depithing techniques. Efficient removal of the leaf/pith constituents from rice straw/bagasse significantly improves pulp yield, quality and strength properties besides substantial improvements in drainage characteristics of the pulp suspension during pulp washing, stock preparation and paper machine operation. Another major advantage is the significant reduction in pulping chemical demand associated with the elimination of leaf/pith from the input to the digester. Cleaning and washing removes extreneous grity material which helps in reducing wear and tear during further processing.

## CHEMICAL USAGE

Chemical pulping of rice straw and bagasse requires about 10 per cent and 12.5 per cent Caustic Soda respectively (oven dry basis) for satisfactory delignification and defibring of the fibrous raw material to produce a pulp suitable for making printing and writing variety. The chemical requirements are less while making packaging grade pulp by the high yield semi chemical process, suitable for flutting media and wrapping (kraft) papers. These processes combine a mild chemical (alkali) pretreatment and mechanical defibering of the straw/bagasse. Chemical pulp production from rice straw or bagasse requires 225 or 275 kg. NaOH per ton of pulp with unbleached pulp yield of 43% and 47% respectively. The remaining organic constituents dissolve as sodium salt in the spent liquor-black liquor.

## NATURE OF BLACK LIQUOR

The economic viability of the paper mills based on straw/bagasse requires a serious consideration of the recovery of pulping chemicals and pollution abatement aspects associated with the handling/disposal of the black liquor.

The black liquor from soda pulping of rice straw/bagasse differ substantially in the physico-chemical properties. The sillica content of rice straw is high and will occur in the black liquor to the extent of 10 to 15 g/l (as $SiO_2$), while the silica content of bagasse black liquor is comparable to bamboo black liquor (weak black liquor-5 to 6 g/l) The Viscosity of bamboo black liquor is comparable to pine (softwood) black liquor while the bagasse and straw black liquors are relatively more viscous and increrse sharply above a concentration of about 35% (Figure 1).

## ALTERNATE SCHEMES FOR PROCESSING BLACK LIQUOR

There are three possible alternatives for processing the black liquor from the mini paper plants based on straw/bagasse (Figur 2).

### SCHEME : 1

### EFFLUENT TREATMENT : METHODS FOR BLACK LIQUR DISPOSAL AND THEIR LIMITATIONS

Lime addition–Acidification-primary clarification-Aeration-secondary clarification-disposal of treated effluent to inland streams or for land irrigation.

### SCHEME : 2

### WET AIR OXIDATION

Air Oxidation of black liquor organics (150-200 atm 300-500°C) followed by green liquor causticization and regeneration of white liquor for cooking.

### SCHEME : 3

### CONVENTIONAL CHEMICAL RECOVERY

Evaporation-combustion-causticization regenerated white liquor to be sent for cooking.

## EFFLUENT TREATMENT METHODS FOR BLACK LIQUOR AND THEIR LIMITATIONS.

### EFFLUENT CHARACTERISTICS

For different level of production, water requirement, effluent discharge as well as BOD load are given in Table-5. As can been seen, the pollution load far exceeds the prescribed Indian Standards IS : 2490 (Discharge into river water) and IS : 3307 (Inland irrigation). Treatment and disposal of waste water from pulp and paper industry are fo

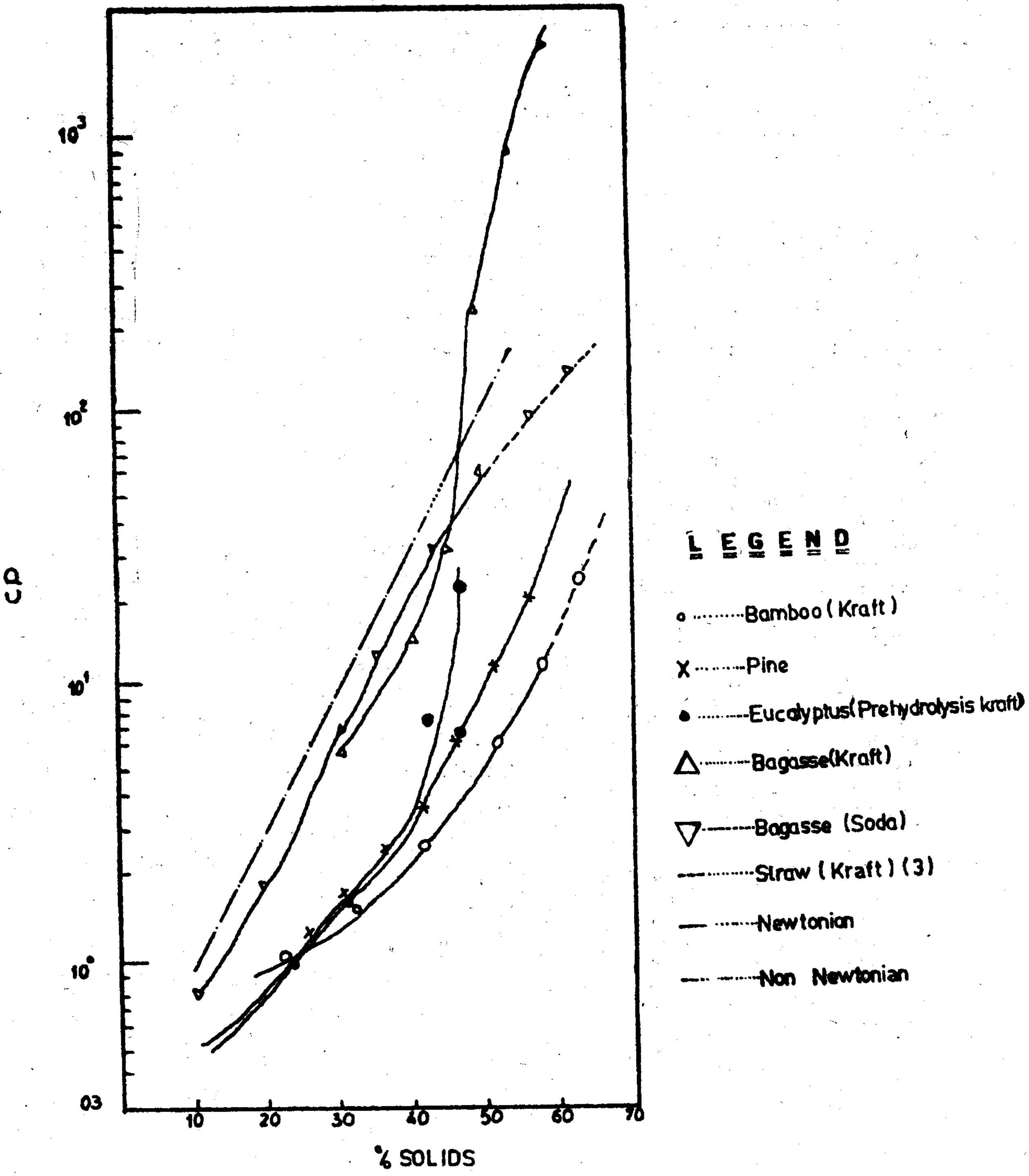



Figure-1 **VISCOSITY OF BLACK LIQUORS AT 90°C**

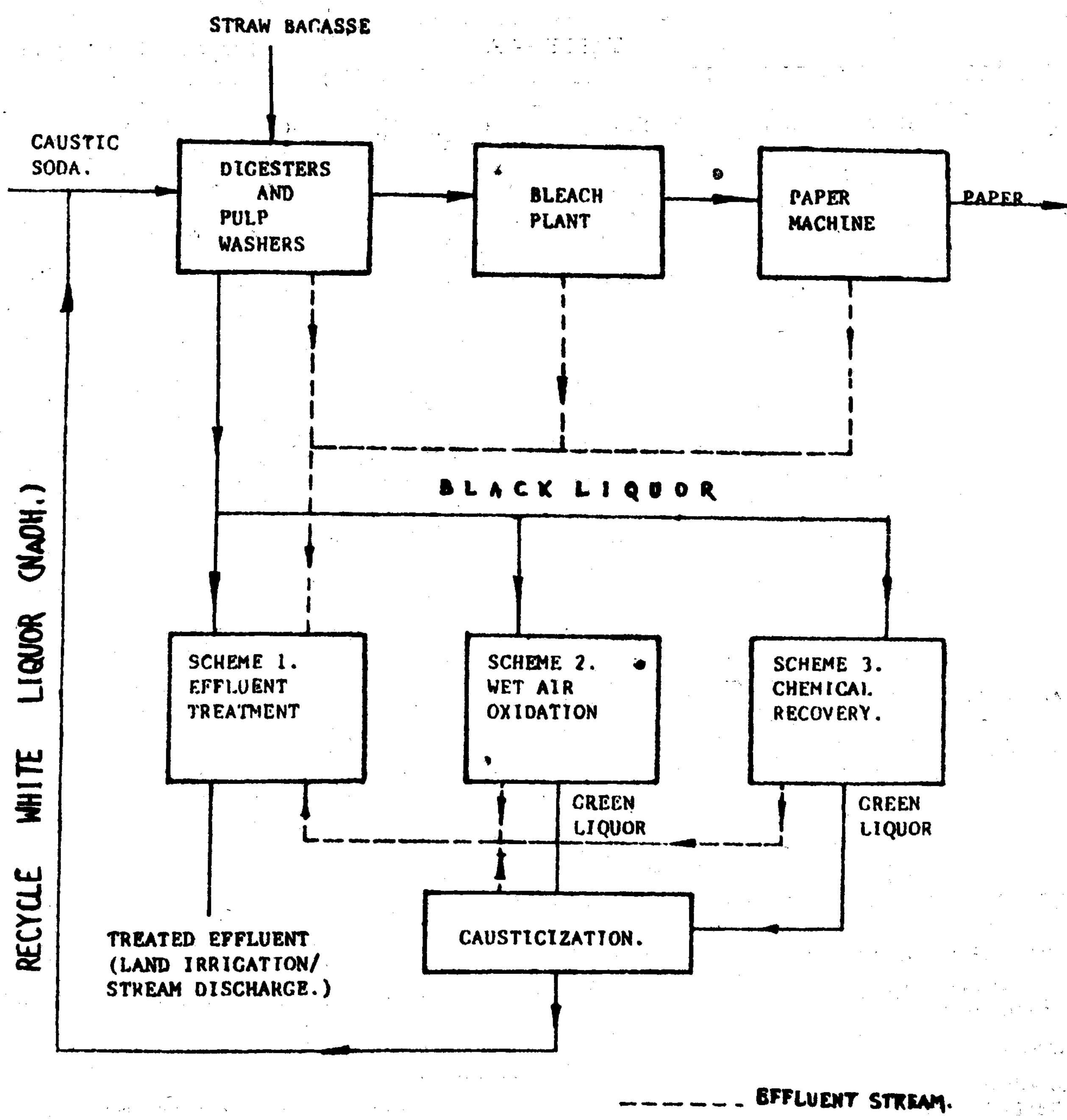



FIGURE 2 : ALTERNATE SCHEMES FOR HANDLING BLACK LIQUOR FROM STRAW/BAGASSE PAPER MILLS.

TABLE—4 A

CHARACTERISTICS OF BLACK LIQUOR SOLIDS (APPROXIMATE)

Scope For Recovery In Mini Paper Mills

| Sr. No. | Raw Material | $SiO_2$% | Organics% | Calorific Value Kacl/Kg of Black liquor Solids. |
|---|---|---|---|---|
| 1. | Rice Straw | 15–17 | 58–65 | 2600–2800 |
| 2. | Wheat Straw | 4–8 | 54–58 | 2800–3000 |
| 3. | Bagasse | 1.2–3 | 56–60 | 3200–3400 |
| 4. | Bamboo | 2–4 | 52–54 | 3200–3340 |
| 5. | Softwood | 0.1 | 55–60 | 3800–4200 |

TABLE–5

Scope For Recovery in Mini Paper Mills

WATER REQUIREMENT, EFFLUENT DISCHARGE AT DIFFERENT LEVEL OF PRODUCTION

| | Production Capacity TPD | Product | Water Requirement (m3/Ton) | Effluent discharge (M3/Ton) | Main Effluent Characteristics | | |
|---|---|---|---|---|---|---|---|
| | | | | | pH | Suspended (ppm) | BOD (ppm) |
| | 20 | Unbleached | 230 | 195 | 7–9 | 600–1000 | 300–400 |
| | 30 | 3—stage bleached (CER) | 378 | 320 | 9–10 | 800–1000 | 600–800 |
| | 40 | -do- | 470 | 400 | 8–9 | 600–800 | 800–1000 |
| | 50 | -do- | 484 | 412 | 8–9 | 400–800 | 1000–1200 |
| Mill A (*) | 15 | Unbleached | 180 | 135 | – | 860 | 320 |
| Mill B (*) | 15 | Unbleached | 230 | 167 | – | 780 | 375 |
| Mill C (*) | 20 | Bleached | 400 | 325 | – | 1320 | 1300 |

Note (*) Water consumption, effluent discharge, suspended solids and B.O.D. characteristics are of some of the medium size paper mills located in Gujarat.

very complex nature. The choice of the method to be adopted and degree of treatment will depend upon tha geographical location and local environment,

## EFFLUENTS TREATMENT METHODS

Different types of treatment alternatives are worked out for various production levels.

### CASE I.

### 20 TPD PLANT (SODA PROCESS–UNBLEACHED PAPERS)

With limited production and low cooking chemical requirements, resultant effluent volum is low and can be tackled easily for treatment purpose. The mill effluent can be rendered suitable to meet IS : 3307 by simply providing primary treatment facility and treated effluent can be used for irrigation purpose in the adjacent land for various crops. (Scheme A.)

### CASE II.

### 20 TPD PLANT (SODA PROCESS—BLEACHED PAPERS)

As the effluent will contain more pollutants from bleaching section, both primary and secondary treatment will be required. Scheme B.

### CASE III.

### 30 TPD TO 50 TPD CAPACITY SODA PROCESS BLEACHED PAPERS.

Mills producing paper at 30, 40 and 50 TPD level will discharge effluent at the rate of 2.0, 2.5 and 3.5 MGD. Since, BOD is more than 500 ppm and suspended solids in the range of 600 to 1000 ppm the effluent in all the cases needs suitable treatment both primary and secondary. Different types of treatment suggested including costing at various production levels, are listed in Table (6) (Scheme C.)

## TABLE—6
## COMPARATIVE COST OF EFFLUENT TREATMENT.

| Production Capacity TPD | Effluent Volume MGD | Treatment Scheme Is : 3307* | Cost of Treatment Rs. lacs: Case I (Unbleached) | | Casr II (bleached) Is : 2490* |
|---|---|---|---|---|---|
| 20 | 1.5 | A | 10 | B | 30 |
| | | | Case I (Suitable for irrigation.) | Case II (suitable for discharge in river) | |
| 30 | 2.0 | B | 25 | C | 35 |
| 40 | 2.5 | B | 30 | C | 45 |
| 50 | 3.5 | B | 37 | C | 54 |

Scheme A. Primary clarifier, to reduce suspended solids, sludge to be dried in lagoon.

B. Primary clarifier to reduce suspended solids, sludge to be dried in lagoon. Partial secondary treatment for 50% BOD reduction.

C. Primary clarifier to reduce suspended solids, sludge to be dried in lagoon, complete secondary treatment for 95·/. BOD reduction. Secondary clarifier to remove suspended solids.

* Details are given in table 6 A.

## TABLE—6 A

Scope For Recovery in Mini Paper Mills

### ISI SPECIFICATIONS : TOLERANCE LIMITS FOR INDUSTRIAL EFFLUFNTS

Values are subject to relaxation or tightening by local authorities.

| Sr. No. | Characteristics | Discharged into inland surface water Is : 2490 | Discharged on land for irrigation proposed Is : 3307 |
|---|---|---|---|
| 1. | Temperature | 40° C | — |
| 2. | pH | 5.5—9. | 5.5—9. |
| 3. | Total suspended solids mg/l | 100 | — |
| 4. | Total dissolved solids mg/l | — | 2100 |
| 5. | B.O.D. mg/l | 30 | 500* |
| 6. | C.O D. mg/l | 250 | — |
| 7. | Total residual chlorine. mg/l | 1 | — |
| 8. | Total sodium% | — | 60** |

* 500 mg/l—can have adverse effect on soil.

** 60—75% can have adverse effect on soil or aquatic life.

Table (7) indicates anticipated pollution loads in case of plant of 30 TPD capacity, with and without chemical recovery unit.

## LIMITATION OF TREATMENT METHODS

In general when effluent meets IS: 3307 i.e. Irrigation Standards, every effort should be made to use this water to increase agricultural production.

Black liquor having high alkali content may pose a problem of high salinity of soil after a prolonged usage in agricultural field. One of the ways to tackle the problem is to segregate, and store black liquor in lagoon and to control its discharge in river during the highest dilution periods such as Monsoon period wherever possible.

Another way of reduciug salinity problem is to neutralize black liquor with the help of hydrochloric acid or gypsum.

Thus, it will be seen that beyond the capacity of 20 TPD bleach paper, it will be necessary to have some sort of chemical recovery plant.

## WET AIR OXIDATION.

Wet Air Oxidatian (Zimmerman Process) developed for the effluent sludge handling has been adopted successfully by a few paper mills abroad for recovering pulping chemicals. Oxidation of the organic constituents of black liquor by air under high pressure and temperature conditions gives green liquor. The proponents of this process (ZIMPRO) advocate its use particularly for handling the sulphur free non-wood soda black liquor. The weak black liquor is essentially directly converted to green liquor eliminating the conventional evaporation and combustion steps. The intial investment appears to be higher than conventional chemical recovery equipment. However, the ZIMPRO method appears to be quite satisfactory for handling the viscous straw/bagasse black liquors and the silica presumably poses no problem during the conversion of black liquor into green liquor. The wet air oxidation technique is new to the Indian Paper Mills and requires sophisticated imported equipment. Even though, the above method appears very promising, a detailed study is recommended to assess the role of the various parameters associated with indigenous bagasse/straw soda black liquors.

## CONVENTIONAL CHEMICAL RECOVERY

The sequence of conventional chemical recovery operations in bamboo based mills consists of multiple effect evaporation, forced circulation/cascade/cyclone/venturi scrubber finisher evaporation, recovery furnace and causticization. Most of these steps are satisfactory except the evaporation plant becoming bottle-neck in some mills due to reduced efficiency from the silica scale deposits. Some paper mills have also increased the pulp production beyond the design capacity of the recovery units. In such case, the profile of black liquor concentration during processing has been modified to accommodate the extra black liquor by installation of additional cyclone type evaporators and roaster/smelter units to generate green liquor. This has been accepted as a reasonably good solution for handling the extra black liquor.

The basic concepts of evaporation-combustion-causticization though same, will have to be used in a simpler modified way for processing the black liquor from bagasse/straw in case of small mills.



TABLE—7

EFFLUENT CHARACTERISTICS AND TREATMENT REQUIRED FOR A 30 TPD PLANT WITH AND WITHOUT CHEMICAL RECOVERY

| Capacity | Product | Alkali Requirement Tons/Day | Qty of effluent $M^3$/Ton. | Effluent Characteristics BOD ppm | S.S. ppm | pH | BOD LOAD kg/T. | Suggested Treatment IS 3307 | IS 2409 |
|---|---|---|---|---|---|---|---|---|---|
| 20 TPD | Unbleached | 3.05 | 195 | 300–400 | 600–1000 | 7–9 | 50–60 | A | C |
| 30 TPD | Bleached without recovery | 6.52 | 320 | 600–800 | 800–1000 | 9–10 | 230–270 | B | C |
| 30 TPD | Bleached with recovery | 1 9 | 340 | 300–400 | 600–800 | 7–8 | 80–120 | C | C |

NOTE : BOD load in case of 20 TPD is very low, mainly due to soda process without bleaching. Less Chemical consumption in cooking 8-20% NaOH on OD material as against 10-10% NaOH in cooking besides 1-1.5% caustic requirement in bleaching.

## RELATIVE EVALUATION

1. Black liquor from mills larger than 30 TPD capacity cannot be combined with the mill effluent for treatment prior to disposal to receiving streams or land irrigation. Further the effluent treatment schemes to handle black liquor would drain the costly caustic soda required for pulping processes and suitable chemical recovery schemes must be developed.

2. In some locations like, Vapi Gujarat it may be feasible to combine the black liquors from a select group of paper mills and devise a common chemical recovery plant.

3. Wet Air Oxidation as technique to recover alkali from black liquor requires a detailed study and technology is not readily available for use by the medium paper mills.

4. A low cost recovery scheme for medium size straw/bagasse paper mills with the basic steps of evaporation–causticization–combustion–causticization at present seems to be the feasible solution.

## REVIEW OF RECOVERY UNITS IN INDIA AND ABROAD FOR STRAWS AND BAGASSE. RECOVERY UNITS IN INDIA.

The concept of installing a small recovery unit for around 30 TPD pulping capacity is quite old. In fact many of the old mills started as small units and were subsequently expanded. They are today's some of the large units. The concept of recovery of pre-war period (or 1940's) continued even in 1950's. Many large mills have supplemented their recovery section capacity in sixty's and seventy's with modified designs but on a smaller scale. These units have been operating with reasonable efficiency. It may be noted that the operation of these units was simply based on conventional raw materials like, bamboo. In recent years, these mills are also doing pioneering efforts in treating mixed liquors from bamboo and mixed tropical hardwoods and to some extent agricultural residues.

## CONSTRAINTS FACFD BY SMALL MILLS

The smaller paper units could not come up with the installation of recovery units mainly because of a wide variation in use of secondary fibres (waste paper) and a mixture of unconventional fibrous materials.

Although the broad outline and some basic parameters required to design such small units are known in our country, recovery concepts have not been established so far in the small sector.

Small scale units will need help from both technical as well as financial angles. This is an area where experience gained by large mills in running small scale recovery units, can be transmitted to small mills with a mutually beneficial proposition. Both the financing institution and the government can play a vital role in bringing about this horizontal transfer of technology.

It can be mentioned here that Mandya National Paper Mills is operating a small recovery plant based on 30 TPD bagasse pulp.

Recently, JK Papers have also come up with a small scale design of 30 TPD incorporating a small recovery boiler with an accent on thermal efficiency.

## RECOVERY UNITS ABROAD

Some of the straw/bagasse based paper mills abroad have developed suitable chemical recovery methods.

1. Conventional recovery schemes for soda bagasse black liquor from Pandia continuous digesters :

100 T.P.D. — Ledesma, Argentina (1972)
250 T.P.D. Columbia S.A. (1978)
300 T.P.D. — (Market Pulp Mill) Taiwan (1978).

2. Wet Air Oxidation method proposed for 100 TPD bagasse mill based on satifactory commercial operating experience with eucalypt soda black liquor (Australia. 1973)

3. Pilot plant test results (35 tons black liquor solids per day. i. e. about 25 TPD pulp mill) for combustion of 60% black liquor spray in a vertical smelter (Fnland 1979).

4. Conventional chemical recovery system for wheat straw black liquor (100 TPD mill Greece, 1972).

5. Low cost modified chemical recovery system quadruple effect evaporation, cyclone evaporator, rotary kiln with waste heat boiler (12 arm steam) causticization for handling black liquor from a 35 TPD rice straw paper mill (Sri Lanka. 1980)

6. Table 8 gives comparison of extent to which chemical recovery is done by some typical units based on agricultural residues in other developing countries.

## A PLAUSIBLE SCHEME FOR SMALL CHEMICAL RECOVERY SYSTEM

When planning a small pulp and paper mill it would be a mistake to just scale down larger unit. The technologically best process and most modern equipment are not necessarily the most

TABLE—8

COMPARISON OF CHEMICAL RECOVERY, MAKE UP AND LOSSES AS PRACTICED IN DEVELOPING COUNTRIES USING AGRICULTURAL RESIDUES

| Alkali loss in | CLEANED WHEAT STRAW Kg/ADT Pulp. | 1 | DEPITHED BAGASSE MILL I Kg/ADT Pulp | % | MILL II % |
|---|---|---|---|---|---|
| Washing ... | 17.67 | 5.7 | 3.22 | 5.7 | 8.4 |
| Evaporator ... | 1.55 | 0.5 | 1.16 | 0.5) | 3.12 |
| Recovery Boiler ... | 4.65 | 1.5 | 3.5 | 1.5) | |
| Causticizing ... | 7.13 | 2 3 | 5.36 | 2.3 | 2.3 |
| Total losses ... | 31 | 10 | 23.24 | 10 | 10 |
| Recovery Efficiency ... | 90 I | | 90 I | | 84.8% |

All the mills are in 100–150 T.P.D. range and use sophisticated instrumentation and technology.

economic solution for such a small unit It is however, essential to keep such units as simple as possible and to use conventional, sturdy and well established equipment and to do every thing to keep investment cost as low as possible.

With the above concept in mind, the experience gained, technology known and equipment building facility available within the country, the following plausible scheme emerges and is discussed below (Figure 3 outlines a brief flow diagram).

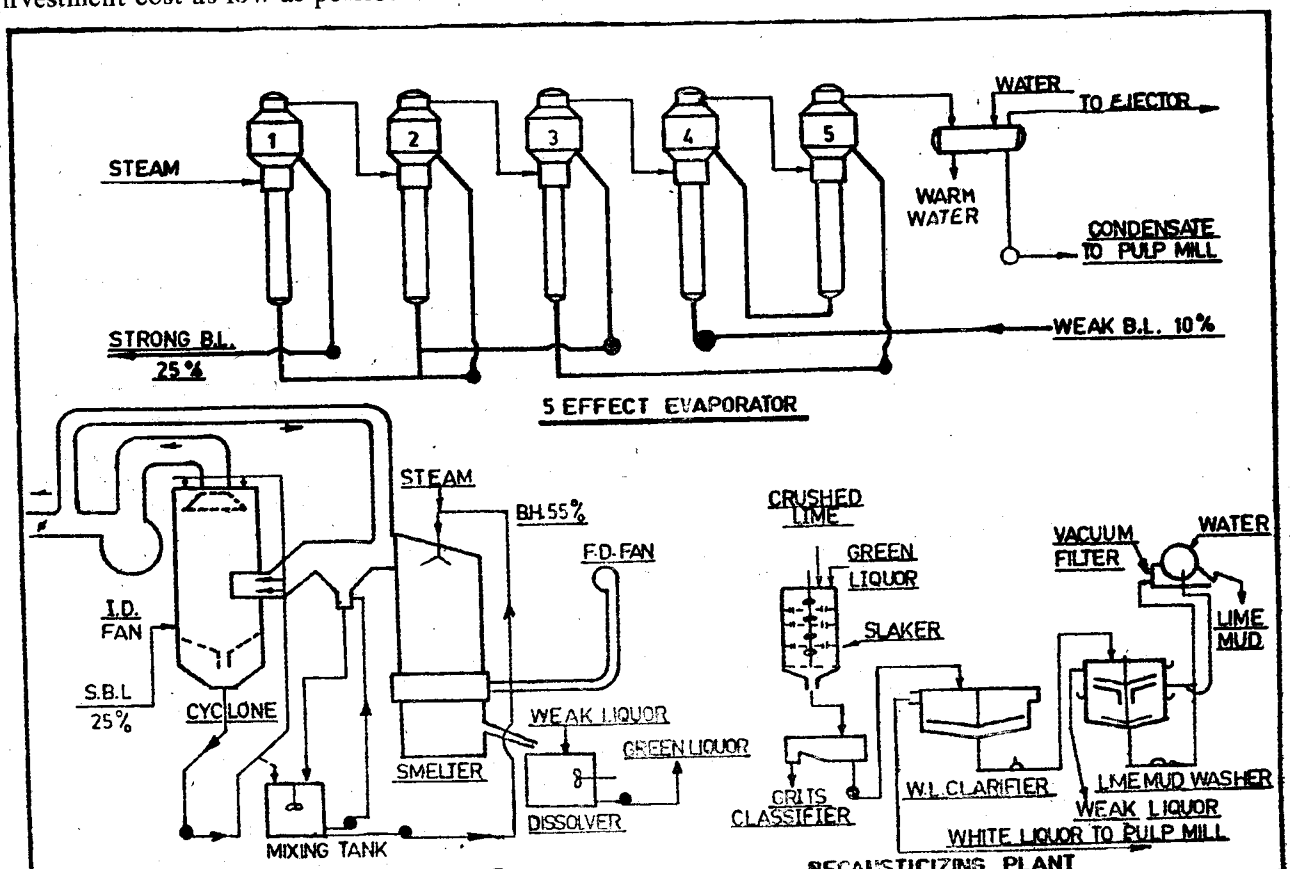



FIGURE 3 : RECOVERY UNIT A BRIEF FLOW DIAGRAM

It is generally believed that the chemical recovery operation begins from evaporators and ends with the white liquor production through the recovery furnace and causticizing plant. It may be true to some extent, but the chemical recovery performance and efficiency depends to a great extent, on the raw material prepa ation such as dry and wet cleaning, depithing and properly controlled pulping and pulp washing operation as weil.

## COOKING

In view of less cooking time required and bulky nature of the raw material, continuous cooking system is preferred to batch digestors.

Both Soda and Sulphate process can produce bleached pulp quality where the difference will be only marginal. Soda process is mainly considered advantageous due to the fact that it will be easier to handle black liquors in Recovery Plants Also the sulphate make up is likely to be more expensive.

The absence of sulphur will also be beneficial for less corrosion and will decrease equipment cost in Recovery section.

## PHYSICO-CHEMICAL CHARACTERISTICS OF STRAW/BAGASSE NEEDS DIFFERENT APPROACH

In view of the slow drainage and silica characteristics of straw-bagasse, the sizing of equipment required for washing, evaporators to causticizers will have to be enhanced atleast by 35 percent, compared to equipment needed for bamboo.

## WASHING

It is worthwhile to explore installation of a screw press ahead of 2 stage vacuum washer system to achieve higher concentration of weak black liquor above 10% with washing loss around 5 to 7%.

## BLACK LIQUOR FILTER

A black liquor filter is necessary for removal of pulp fines in the feed to evaporator plant to reduce the scale deposition problem in units handling higher concentration of black liquor.

## EVAPORATORS

The evaporator plant will raise the concentration of the weak black liquor from 10 to 25 30 per cent unlike the 45-50 per cent level obtained in convetional evaporation plants. This is primarily due to higher viscosity and/or concentration of silica in straw/bagasse black liquors. An increase in free alkali concentration by caustic dosage to black liquor reduces the severi ty of these limitations during processing.

It will be possible to achieve higher concentration of bleach liquors upto 45-50 per cent needed where heat recovery by waste heat boiler is considered. Suitable arrangements have to be incorporated when more rice straw is used as rice straw contains almost 3-4 times more silica compared to other raw materials.

A quantiple-effect evaporation plant (long tube vertical evaporators) is recommended for straws/bagasse black liquor. A cyclone type flue gas direct contact evaporator can be used to increase the concentration to 55 to 67 per cent level suitable for self sustained combustion in a smelter.

## SMELTER-CYCLONE EVAPORATOR

In view of high capital investment, high silica content and lower calorific value of back liquor solids, installation of a conventional recovery boiler may not prove to be economic on plants of 30 TPD capacity.

A Roaster Smelter where 50-55% solid concentrated black liquor can be directly fired seems to be a proven alternative both investmentwise and operationwise.

The resulting hot flue gases at a temperature around 700 to 900°C will be combined with exhaust flue gas and will be directed to a cyclone evaporator cum scrubber where the heat of flue gases will be utilised to concentrate the black liquor, from 25% to 55-58% solids. The smelt comes out from a spout at the bottom of the smelter unit.

The auxilary fuel like wood and oil is expected to be required during start up and shut-downs otherwise the combustion will be self sustained.

In view of energy conservation inclusion of waste heat boiler should be given due consideration.

## RECAUSTICIZING SECTION

The smelt from smelter is dissolved to form green liquor.

With a view to reduce investment, a simpler plant will consist of a multi-compartment slaker causticizer followed by a grits classifier where finally crushed lime is treated with green liquor to complete the causticizing reaction.

Raw white liquor thus produced is settled in a white liquor clarifier. The sludge with residual white liquor is washed in a single two compartment clarifier and thus mud is futher separated in a vacuum filter for disposal.

## STORAGE TANKS

The above proposed recovery system can operate continuously for a period of 30 days. A monthly shut-down of 2/3 day will be necessary for mechanical cleaning of evaporator tubes and deposits in smelter-cyclone unit.

A multi purpose liquor storage tank system to store black and white liquors to accommodate the above shut down will be needed.

## DISTRIBUTION OF OVERALL CHEMICAL LOSSES.

The distribution of alkali loss at the various locations in rhe proposed chemical reocvery scheme is given below :

| | |
|---|---|
| Pulp Mill and Brown stock Washerlosses. | 7% |
| Evaporator losses | 1% |
| Smelter—Cyclone stack loss | 10% |
| Causticizing section losses. | 5% |
| Total | 23% |
| Overall chemical recovery | 77% |

## PROCESS CALCULATIONS

Table 9 shows the alkali requirement and alkali recovered for straw pulping. However, the requirement of alkali per ton of bagasse bleached pulp will not be far different than that of straw.

Table 10 also shows details of black liquor process steam, lime and power requirement in recovery section.

Table 11 highlights the need to install a 5 effect evaporation system from economic advantage.

## ECONOMIC VIABILITY

Based on the above scheme an economic viability is prepared and presented in Table 12.

TABLE—9



ESTIMATION OF ALKALI REQUIREMENT, RECOVERED ALKALI AND BLACK LIQUOR SOLIDS

| | Units | Paper Mill Size | | | |
|---|---|---|---|---|---|
| Capacity of Paper Mill | TPD | 20 | 30 | 40 | 50 |
| A.D. Bleached Pulp to Paper | Ratio | 1.1 | 1.1 | 1.1 | 1.1 |
| A.D. Bleached Pulp Requirement | TPD | 20 | 30 | 40 | 50 |
| Pulp furnish from Agricultural Residues | % | 75 | 75 | 75 | 75 |
| A D. Bleached Pulp from Agricutural Residues | TPD | 15 | 22.5 | 30 | 37.5 |
| Bleached Pulp yield (on raw material) | 33.33 | 33.33 | 33.33 | 33.33 | 33.33 |
| Straw required A. D. | TPD | 45 | 67.5 | 90 | 112.5 |
| A. D. | TPD | 40.5 | 60.7 | 81 | 101.2 |
| Alkali used (on BD raw material) | % | 10 | 10 | 1p | 10 |
| Caustic Soda used | TPD | 4.05 | 6.07 | 8.1 | 10.12 |
| Caustic on Bleached A. D. Pulp | Tons/Ton | 0.270 | 0.270 | 0.270 | 0.270 |
| Average B. L. solids on Bleached AD pulp | Tons/Ton | 1.60 | 1.60 | 1.60 | 1.60 |
| B.L. solids to Recovery | Tons/Day | 24 | 36 | 46 | 60 |
| Overall Caustic recovery efficiency | % | 77 | 77 | 77 | 77 |
| Qnantity of alkali recovered. | TPD | 3.12 | 4.67 | 6.24 | 7.79 |
| Yearly (300 working days) | Tons/Yr | 936 | 1401 | 1872 | 2337 |
| Equivalent value of recovered | Rs/Day | 15600 | 23350 | 31200 | 38950 |
| alkali at purchase caustic | Rs. (lacs) | | | | |
| rate of Rs. 5000 per ton | Year | 46.8 | 70.05 | 93.6 | 116.85 |

## TABLE—10
### RECOVERY SECTION STEAM, AND POWER REQUIREMENT

| | Units | | | | |
|---|---|---|---|---|---|
| Paper Mill Capacity | TPD | 20 | 30 | 40 | 50 |
| Pulp from Agricultural Residues | TPD | 15 | 22.7 | 30 | 37.5 |
| B.L. solids to evaporators | TPD | 24.0 | 36.0 | 48.0 | 60.0 |
| Concentration | % | 10 | 10 | 10 | 10 |
| B.L. concentration from evaporators | % | 25 | 25 | 25 | 25 |
| Evaporation | TPD | 144 | 216 | 288 | 360 |
| Evaporator economy (evaporation/ton steam) | Tons/Ton | 3.5 | 3.5 | 3.5 | 3.5 |
| Steam for evaporation Add 5% for water boiling. | TPD | 41.1 | 61.7 | 82.2 | 103 |
| Steam consumed in evaporators | TPD | 43.2 | 64.9 | 86.5 | 108 |
| Steam for disolver & causticizing | TPD | 5.0 | 7.0 | 9 5 | 11.6 |
| Recovery total steam consumption | TPD | 48 | 72 | 96 | 120 |
| Lime required (60% purity) per | Tons/Yr. | 14,600 | 21,600 | 28,800 | 36,000 |
| Per ton of NaoH recovered | Tons/Ton | 1.3 | 1.3 | 1.3 | 1.3 |
| Caustic recovered | TPD | 3.12 | 4.67 | 6.24 | 7.79 |
| Lime required | TPD | 4 05 | 6.07 | 8.10 | 10.1 |
| | Tons/Yr | 1.215 | 1,821 | 2,430 | 3,030 |
| Electric power Load (recovery section) | KW | — | 350 | 400 | 450 |
| Units consumed per day | KWH/Day | — | 8,400 | 9,600 | 10,800 |
| Total power consumed on 300 days (with 10% losses) | KWH/Yr | — | 2800000 | 3200000 | 3600000 |



## TABLE—11
### COST BENEFIT COMPARISON FOR INCREASE IN EVAPORATOR EFFECTS
(Illustration for a 40 TPD Paper Plant 30 TPD Agricultural Pulp)

| | Unit | 3 Effects | 4 Effects | 5 Effects |
|---|---|---|---|---|
| B.L. solids processed (10% to 25% concentration) | Tons/Year | 14,400 | 14,400 | 14,400 |
| Total evaporation | Tons/Year | 86,400 | 86,400 | 86,400 |
| Steam Economy (Evaporation/ Ton steam) | Tons/Ton | 1.8 | 2.8 | 3.5 |
| Steam required | Tons/Year | 47,778 | 30,857 | 24,685 |
| Cost of steam @ Rs. 100/Ton | Rs. lacs/Yr. | 47.78 | 30.86 | 24.68 |
| Saving in steam cost compared to 3 effect operation. | Rs. lacs/Yr. | — | 16.92 | 23.1 |
| Addition of cost of evaporator bodies compared to 3 effects. | Rs. lacs | — | 7.0 | 14.0 |

TABLE—12

ECONOMICS OF INSTALLATION OF A RECOVERY UNIT

Scope For Recovery In Mini Paper Mills.

| | Units | | | |
|---|---|---|---|---|
| Capacity of Paper Mill | TPD | 30 | 40 | 50 |
| Capital Investment Required | Rs. lacs | 120 | 140 | 160 |
| Amount of Caustic recovered | Tons/Day | 4.67 | 6.24 | 7.79 |
| | Tons/Year | 14401 | 1,872 | 2,337 |
| **Cost of Production of Alkali Caustic in Recovery Section.** | | | | |
| Steam consumed | Tons/Year | 21,600 | 28,800 | 36,000 |
| Seam cost @ Rs. 100/Ton | Rs. lacks | 21.60 | 28.80 | 36.00 |
| Lime consumed | Tons/Year | 1,821 | 2,430 | 3,030 |
| Lime cost @ Rs. 450/ton | Rs. lacs/Yr | 8.19 | 10.93 | 13.63 |
| Power consumed | KWH(Lacs)/Yr. | 28.0 | 32 0 | 36.0 |
| Power cost @ Rs. 0. 40/KWH | Rs. lacs/Yr | 11.2 | 12.8 | 14.4 |
| Auxiliary fuel | Rs. lacs/Yr | 2.0 | 3.0 | 4.0 |
| Maintenance | Rs. lacs/Yr | 1.0 | 1.5 | 1.75 |
| Wages | Rs. lacs/Yr | 0.75 | 0.85 | 1.00 |
| Total operating cost | Rs. lacs/Yr | 44.74 | 57.88 | 70.78 |
| Cost of Recovered Caustic (Before Interest & Depreciation) | R./Ton | 3,193 | 3,091 | 3,028 |
| Interest @ 13% | Rs. lacs/Yr | 15.6 | 18.2 | 20.9 |
| Depreciation @ 7% | Rs. lacs/Yr | 8.4 | 9.8 | 11.2 |
| Total Interest & Depreciation | Rs. lacs/Yr | 24.0 | 28.0 | 32 0 |
| Interest & Depreciation per ton of Caustic recovered | Rs. /Ton | 1,713 | 1,495 | 1,369 |
| TOTAL COST OF RECOVERED CAUSTIC | Rs./Ton | 4,906 | 4,586 | 4,397 |

The tentative investment in a recovery section for a 30 TPD mill will be Rs. 120 lacs and Rs. 160 lacs for 50 TPD mill (Table 13) The cost of regenerated caustic before interest and depreciation will be Rs. 3193 per ton. When the cost of interest and depreciation are added the cost of generated caustic will be Rs. 4906 per ton and Rs. 4397 per ton for 30 TPD anc 50 TPD level respectively.

The prevailing purchased caustic price is more than Rs. 5000 per ton (delivered).

It will be seen that recovery section at a mill capacity of TPD is marginally viable and the viability improves at 40 and 50 TPD levels.

The cost of financing will play an important role in deciding the viability. Soft loans scheme if made applicable to introduce installaiion of recovery unit in small mills, will play a major role in the final analysis.

MAJOR R & D ASPECTS

Some of the major areas requiring R and D efforts are identified below-especially with regard to chemical recovery in rice straw based paper mills, besides the specific requirements for bagasse processing.

1. Equipment development for the preparation of straw feed to the digester—removal of leaf blades and leaf sheath.
2. Depithing methods and indigenous equipments for the medium size bagasse paper mills.
3. Indigenous development of continuous digesters for the pulping of straws/bagesse in medium size paper mills.
4. Further studies on viscosity characteristics of straw and bagasse black liquors for design of evaporation plants.
5. Combustion characteristics of straws/bagasse black liquors for efficient low cost roaster/smelter units.
6. Desilication methods for straw/bagasse black liquors to adopt conventional chemical recovery concepts and large scale utilization of these materials for paper making.

AABLE—13 DETAILS OF APPROXIMATE BREAK OF CAPITAL INVESTMENT REQUIRED (FOR CHEMICAL RECOVERY SECTION)



| PAPER MILL SIZE | TPD | 30 | 40 | 50 |
|---|---|---|---|---|
| ITEM | | | | |
| 1. Evaporation Plant. | Rs. lacs | 35 | 40 | 45 |
| 2. Smelter Cyclone Unit. | Rs. lacs | 40 | 45 | 50 |
| 3. Causticizing Plant. | Rs. lacs | 35 | 40 | 45 |
| 4. Tankages, Civil etc. | Rs. lacs | 10 | 15 | 20 |
| TOTAL | Rs. lacs | 120 | 140 | 160 |

7. Brown stock washers will be a major source of alkali loss from straw/bagasse paper mills improvements in washer design criteria and operation of the units.

8. Causticization cfficiency and settling characteristics of lime sludge.

9. Lime sludge calcination and reuse with desilication of black liquor.

10. Strength characteristics of blends of straw/bagasse soda pulp and various long fibre pulps.

11. Efficient storage of annual requirements of straw/bagasse without biodegradation.

12. Scale-up of the paper machine operating experience of the existing small/medium mills for large scale utilization of straws/bagasse.

13. Study of process parameters to asses the techno-economic feasibility of processing straw/bagasse black liquors by wet air oxidation (Zimmerman process.)

14. Techno-economic analysis of the Copeland process based on fluidized bedcombustion for handling the soda black liquor from pulping straws/bagasse.

## SUMMARY

1. Black liquor from the straw/bagasse mills beyond a 20 TPD capacity cannot be combined with the mill effluent streams for treatment.

2. There is a great need to evolve an economically viable simple system to recover chemicals from small/medium paper units.

3. Tecchnology and experience in this field available ia India and abroad is given.

4. Straws and bagasse have different morphological characteristics compared to bamboo and woods regarding a prepatory stage to obtain the digester furnish.

5. The chemical composition (high pentosans) and silica content can lead to some processing difficulties during recovery operations.

6. Problems associated with the high silica content of rice straw will require development of suitable desilication methods for efficient chemical recovery.

7. Larg paper mills in our country have considerable experience in the field of operating small scale recovery units on bamboo and mixed hardwoods black liquor.

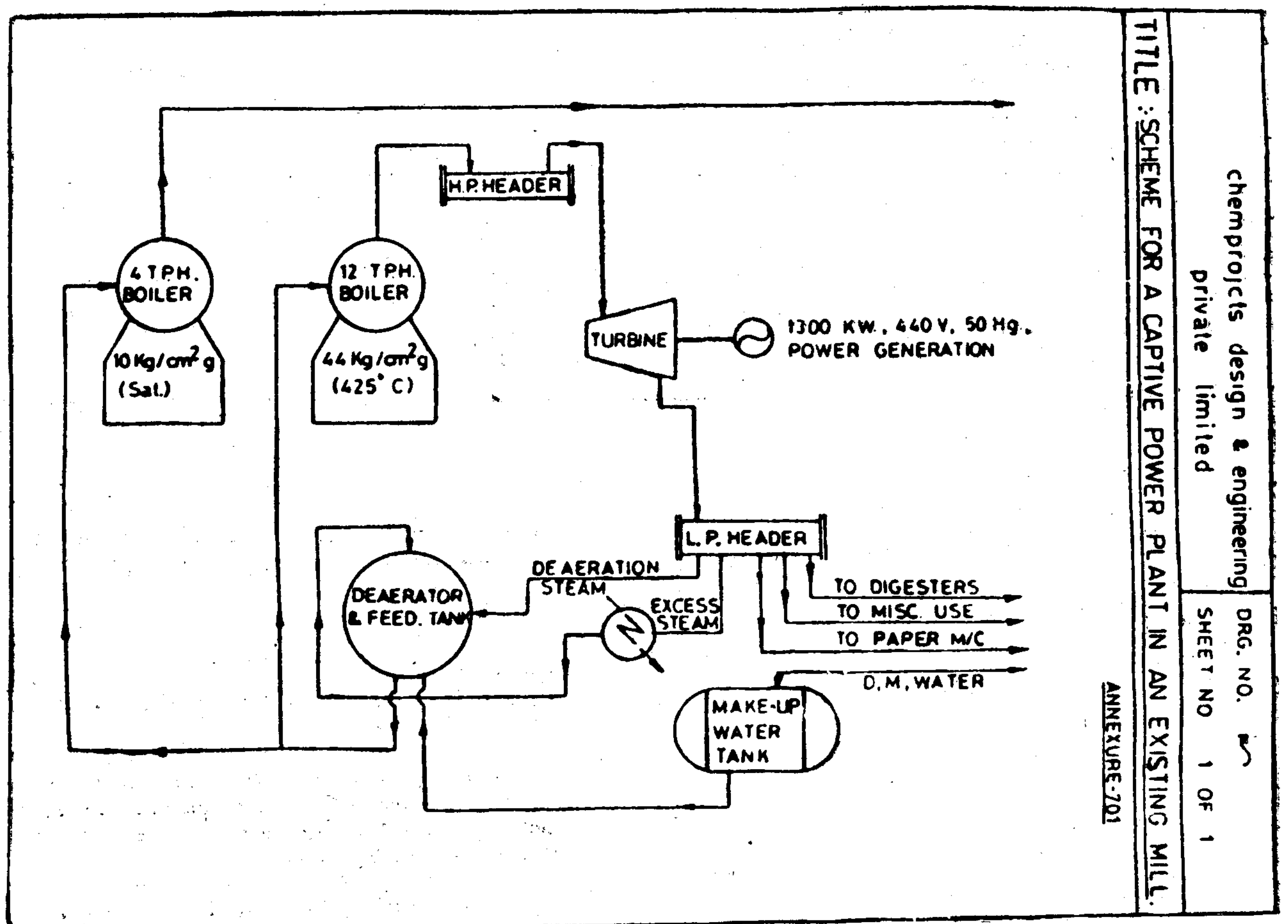
8. There is a need to have interaction between large and small units to solve the problems together.

9. Fnancial Institutions and government may iake the initiative in bringing about this interaction.

10. Technology can be adopted to develop satis factory low cost chemical recovery schemes for handling bagasse, wheat or rice straw black liquor.

11. A simple and indigenously feasible scheme is described which indicates a marginal viability at 30 TPD level which improves at 40 TPD and 50 TPD levels.

12. A common chemical recovery plant can be considered in some regions for treating the black liquors from a select group of straw/bagasse mini paper plants.




13. It is recommended to explore further wet air oxidation method (Zimmerman) for high viscosity silica liquor in Indian conditions.

14. Major areas of R and D efforte are indentified for, chemical recovery in straw based paper mills besides the specific requirements of bagasse mills.

15. A full scale workshop is recommended on this subject when both the chemical recovery and thermal recovery aspects of processing straw/bagasse black liquors can be discussed.

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