Provision of captive power generation in a 30 TPD agro-based paper plant as a means of improving capacity utilisation (A Case Study)

KRISHNA, A.,* KUMAR, VINAY**

SUMMARY

Small Paper plants of 30 TPD and below based on agricultural residues and rags generally depend for power on the grid supply. It is, however, observed from the past performances of these paper plants that their capacity utilization has been heavily curtailed in view of irregular power supply. To have a reliable power supply for very essential loads, it is proposed to incorporate a high pressure boiler and a multistage back pressure turbine for captive power generation in the plant.

The addittonal investment of the captive power plant is Rs. 50 lakhs which provides for the differential cost of high pressure boilers and 1500 KV turbo generator. The power generation cost varies between 36 paise to 86 paise per unit depending on the extent of exhaust steam utilization.

The pay back period taking into cosideration increase in production capacity and the benefits thereof after providing for the excess power generation cost is 2.15 years.

The password of the Indian economy has been the mixed economy with a judicious mixture of public and private sectors and large, medium and small scale sectors. Paper plants with conventional forest raw materials have fallen to large scale sectors in view of their viabilities and investments, while those with unconventional raw materials such as straw and other agricultural residues have fallen to small and Medium scale sectors. Although these small and medium sector plants have in fact been found unviable, they have been made otherwise by the various fiscal incentives such as excise benefits, tax holidays, etc., offered by the Government. However, of late, the capital investment of these plants have jumped by leaps and bounds. A 30 TPD integrated pulp and paper plant required an investment of Rs. 5.0 crores in the year of 1975 as against Rs. 8.0 crores at present. The high capital, coupled with other high fixed costs, has pushed up the break even capacities of these plants to beyond 75% of the rated capacity as against the norm of around 50% for the older plants. This high level of capacity utilization has become a battle of survival for the recent plants.

CAPACITY UTILIZATION

The main factors affecting the capacity utilization of a plant in the present context of Indian economy are—

i) Availability of raw materials and other inputs
ii) Availability of power and fuel
iii) Non-availability of equipment due to breakdown and maintenance
iv) Market fluctuation
v) Labour situations.

*Director Engineering,
**Project Engineer.
Chemprojects Design & Engg. Pvt. Ltd.,
17 Panchshila Shopping Centre,
New Delhi-110017.

In this paper we are analysing and trying to find a solution to the problem of non availability of power.

POWER AVAILABILITY

It may be noted from Table-I II, III and IV that the 30 TPD range plants, which are presumably totally dependent on grid power, could achieve a capacity utilization of about 50%. As per our information in one of these plants as much as 150 manhours per month were lost only due to power trippings. In a paper plant the paper machine and its auxiliaries require uninterrupted power supply. Every tripping of power would entail at least an hour's loss of production on the paper machine in view of its cleaning and re-starting procedures. In view the deficit conditions are likely to prevail, grid trippings are unavoidable. It is, therefore, essential to have a captive power plant to meet the certain demands of essential uninterrupted power supply. Various alternatives such as diesel generator sets, thermal power plants based on either condensing type turbine, bleeding cum condensing turbine or straight back pressure turbines are available for captive power generation.

TABLE—I SUMMARY OF CAPACITY OF PAPER AND PAPER BOARD AND THEIR CAPACITY UTILISATION

Sl. No.	Name	Range of capacity TPA	No. of units 1979	Installed capacity TPA	Installed capacity %	Production 1979 TPA	Production 1979 %	Capacity utilisation
I	Large	Above 20,000	21	10,75,460	69.92	7,64,894	73.2	71.2
II	Medium	10 001 — 20,000	8	1,12,500	7.31	75,417	7.2	67.04
III	Small	5,000 — 10,000	24	1,85,900	12.09	92,505	8.9	49.76
IV	Small	2,001 — 5,000	31	1,11,160	7.23	74.543	7.1	67.06
V	Small	Below 2,000	37	53,146	3.45	37,509	3.6	70.58
TOTAL			127	15,38,165	100	10,44,868	100	67.93

NOTE : i) Total No. of units installed as on 1.1.80 is 136 and installed capacity is 16,41,230 Tonnes Per Annum.

ii) At present there are approximately 142 units.

iii) There are 24 units having capacity below 7500-15000 TPA.

Ref : Based on the data available from D.G.T.D.

TABLE—II PROJECTED DEFICIT IN POWER GENERATION AT THE END OF SIXTH PLAN (1980-85)

REGION	As on 31/3/80 installed capacity MW	AT THE END OF SIXTH PLAN Installed Capacity MW	Demand MW	Deficit MW
Northern	8248.22	8937.00	10463.0	—1526.0
Western	7834.34	8532.50	8907.0	— 374.5
Southern	7207.11	7733.90	8149.0	— 415.1
Eastern	4865.76	4713.20	4741.0	— 27.8
Northeastern	334.28	666.70	434.2	+ 233.5
Total	28489.70	30584.30	32694.2	—2109.9

Ref : Special edition of 'Hindu' and the Govt. Publication on 6th Five Year Plan.

TABLE—III CAPTIVE POWER GENERATION BY INDUSTRIAL UNIT WITH CAPTIVE PLANT OF MORE THAN 100 MW EACH

S. No.	Year	No. of units	Installed Capacity MW (10^6 Watt)	Gross power generation GWH (10^6 Watt Hrs.)
1.	1974-75	639	1964	6452
2.	1975-76	740	2071	6657
3.	1976-77	879	2225	7240
4.	1977-78	1010	2444	7519
5.	1978-79	1039	2555	7573
6.	1979-80	1181	2799	8157

Ref : "Captive capacity and output up" The Economic Times dated 8-2-82.

TABLE—IV CAPTIVE POWER GENERATION, ENERGY PURCHASED & POWER CONSUMED BY SELECTED INDUSTRIES (GWH)

	NET CAPTIVE GENERATION	Energy purchased from utilities	Energy used by industry	Ratio of net captive power generation to Industry used by Industry.
	1978-79	1978-79	1978-79	1978-79
1. Iron & Steel	1732	4327	6056	28.6
2. Aluminium	972	2886	3856	25.2
3. Sugar	776	159	933	83.2
4. Paper	573	1016	1552	36.9
5. Mineral Oil & petroleum	535	275	743	72.0
6. Textiles	516	5234	5750	9.0
7. Fertilizers	479	3938	4418	10.8
8. Chemicals	408	3641	4047	10.1
9. Cement	363	2111	2473	14.7
10. Collieries	159	727	885	18.0
11. Jute	76	597	673	11.3
12. Non-ferrous metals	23	1662	1685	1.4
Total (1-12)	6612	26573	33071	20.0
C. Others	164	3333	3500	4.7
C. Grand Total	6776	29906	36571	18.5
D. Percentage share of (1-12) in Grand Total	97.6	88.9	90.4	--

NOTE : Data relate to selected industrial units with captive plants each with capacity exceeding 100 KW.

Ref : "Captive capacity and output up" The Economic Times, Dated 8-2-82.

The choice, however, depends on the consideration of capital investment, power generation cost and sutability to the specific working proposals of the plant.

It is generally accepted that the cost of captive thermal power generarion is certainly going to be far more expensive than the grid power in as much as the thermal power station can achieve an efficiency of 20% only in converting the thermal energy of the steam to power. The balance is wasted in the condensor. A captive power generation can be competitive if, instead of wasting the remaining heat of steam, it is utilized in the process heating. It is not always possible, however, to balance the power and requirements, and unfortunately the small paper mills have to face this. However, if the cost of power generation and the productivity (or production losses) are compared then it becomes obvious that a captive power plant with a pseudo power cum process heating cycle becomes viable and essential.

CAPTIVE POWER PLANT

Recommended Scheme

The installed and essential power requirements of a specific 30 tpd plant are listed in table V. Classification of essential load is based on the premise that the paper machine should run uninterruptedly and so also all those asscciated equipment to runthe paper machine continuously. A diversity factor of 0.75 is assumed in arriving at the continuous running load of these equipment.

The Steam requirement and its distribution in paper plant is shown in figure-1. It is proposed to meet these requirements from the exhaust of turbine after generating power. This revised scheme of steam and power generation for the specific plant is shown in figure-2. It may be noted that the steam generation in the latter case is governed by the minimum power requirement to maintain the continuity of production during unscheduled power tripping. Thus the power scheme is designed to generate 1050 KW at the minimum level.

Features of the scheme

In this scheme it is proposed to generate steam at 30 Kg/cm²g and a temperature of 370°C and expand the same to 4.0 Kg/cm²g in a turbine of 1500 KW turbine to generate the requisite essential power (1050KW). The low pressure steam is then distributed in the plant for process heating. A small quantity of steam is directly fed to the digesters at a pressure of 6.5Kg/cm²g. of course, the exhaust steam from the turbine is duly desuperheated to meet the process requirements.

The steam balance under these revised conditions is shown in Table-VI. It may be observed that in order to maintain a constant power generation of 1050 KW the steam requirement is 14 TPH whereas the process requrements vary between 12.3 to 7.15 tonnes per hour exclusive of the small quantity of high pressure steam. The excess steam is proposed to be condensed in a dump condenser which utilizes the process water as the cooling medium.

Cost of the Scheme:

The cost of scheme is calculated based on actual investments as the differential cost ot the total power plant as envisaged and the simplified steam generation scheme as practised normally. This includes the cost difference between low pressure and high pressure boilers, turbine, additional instrumentation and pipe and pipe fittings. The additional investment amounts to Rs.50 lakhs and is detailed in Table No. VII.

Cost of the scheme:

The cost of power generation in the captive power plant is assessed under two heads viz. Fixed costs and variable costs.

Fixed Costs:

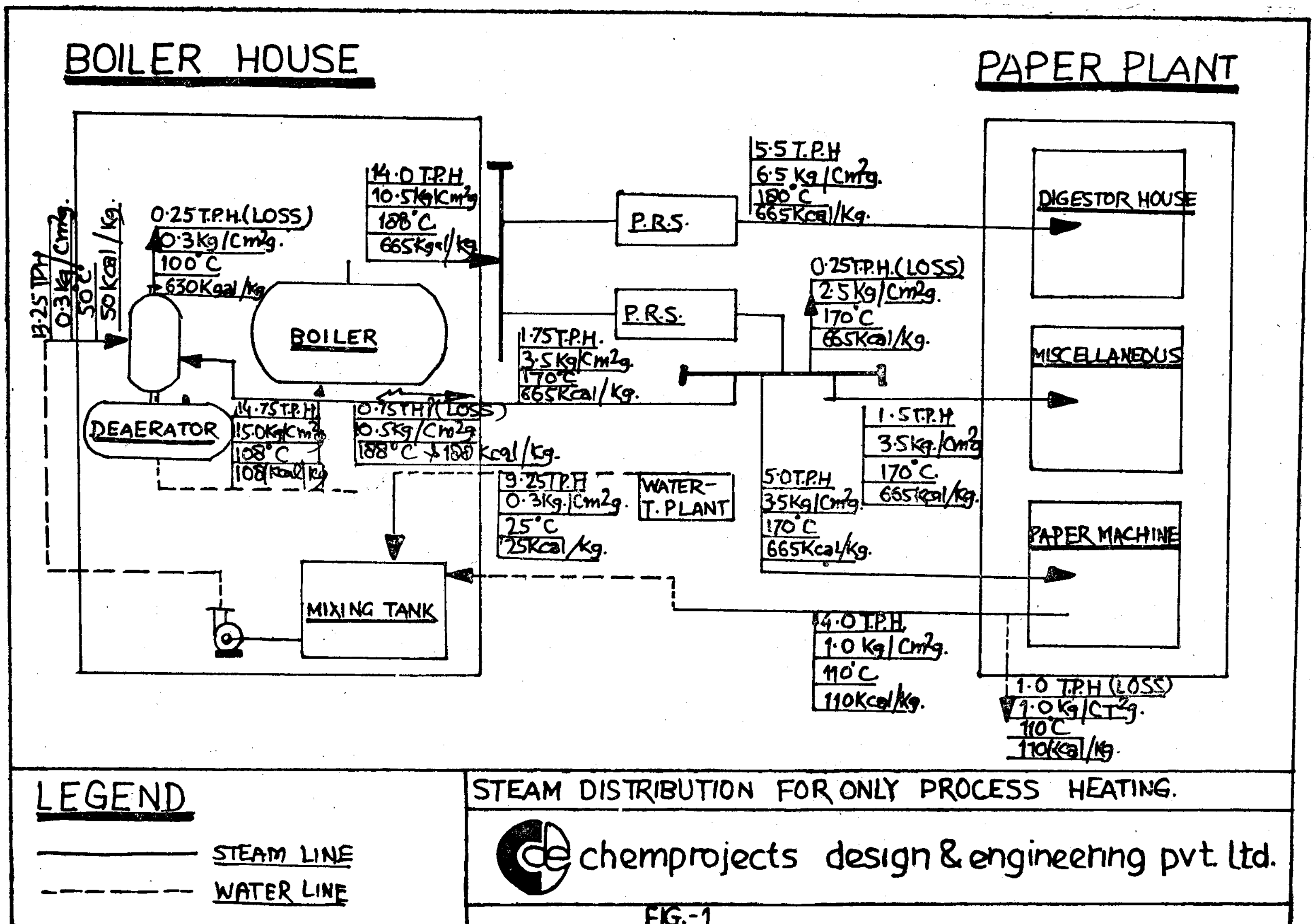
Fixed costs include on the depreciation on the machinery and buildings, interest on the soft loans for the power plant, labour and supervision costs etc. The incidence of these costs on unit power basis vary depending on the level of power generation.This is illustrated in table No. VIII and varies between 10.4 paise per unit to 19.4 paise per unit between 1400 KW to 750 KW power generation.

Variable Costs:

Variable costs are basically on the coal consumption in providing for the extra heat in the steam which is duly converted to power. This varies on the efficient utilization of the exhaust steam in the process heating. The variable cost power generation comes to 19 paise when all the exhaust steam is used for process heating to 71 paise when 6.85 tonnes per hour is condensed in the condensor as shown in Table IX. Credit was taken for the return of condensate at 4.0 Kg/cm²g back to boiler.

Average cost of power generation:

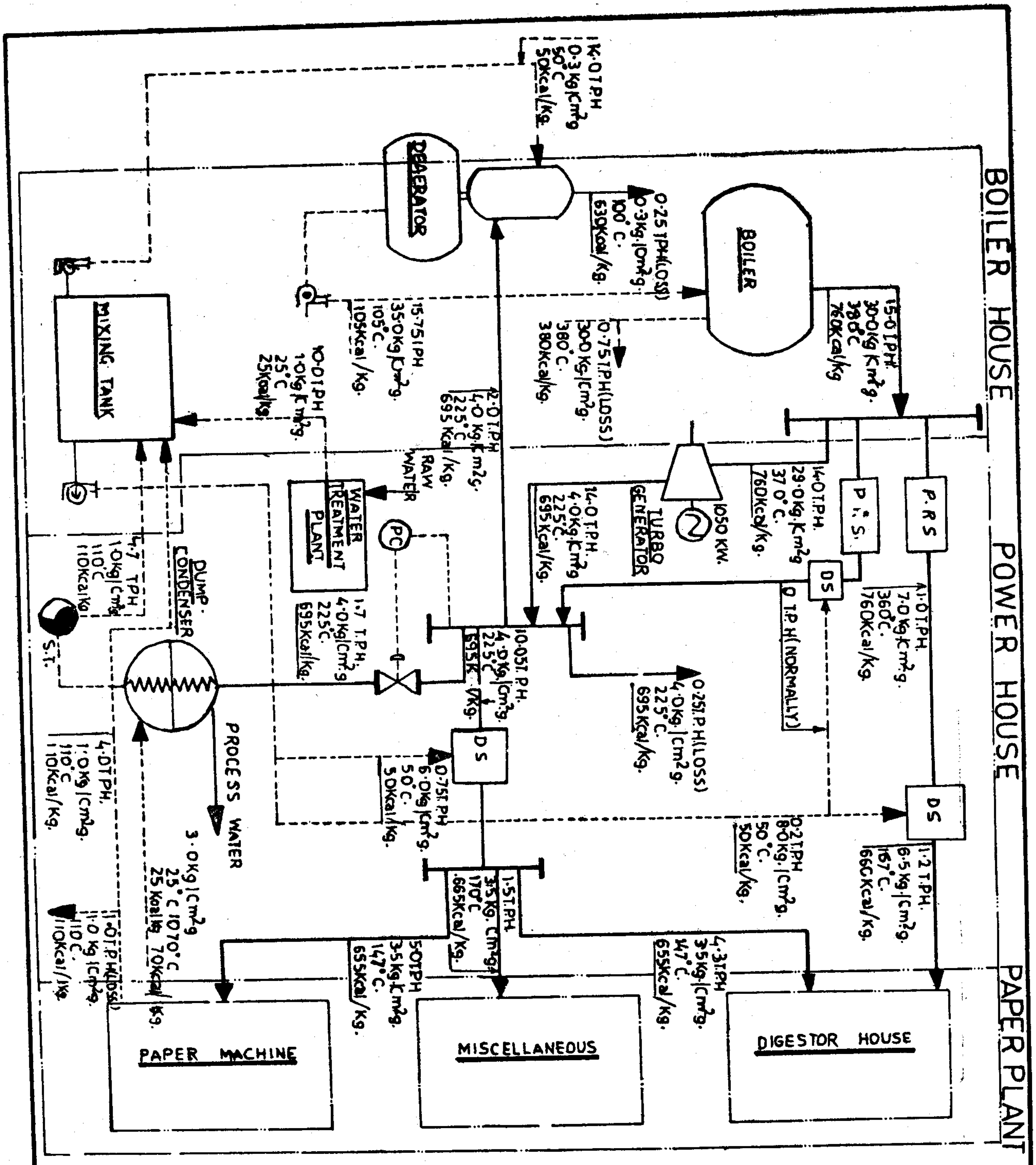
In assessing the average power generation st it is assumed that a minimum of 1.7 TPH of



STEAM DISTRIBUTION FOR ONLY PROCESS HEATING.

chemprojects design & engineering pvt. ltd.

FIG.-1



LEGEND:

—————— STEAM LINE.

- - - - - - - - - WATER LINE.

PROPOSED STEAM DISTRIBUTION WITH CAPTIVE POWER.

chemprojects design & engineering pvt. ltd.

FIG.-2

TABLE—V SECTIONWISE ELECTRICAL LOADS FOR 30 TPD PLANT

S. No.	Section	Total installed load		Essential load to be put on turbine	
		No. of Motors	H.P.	No. of Motors	H.P.
1.	Digester house	6	120	—	—
2.	Rag Pulping	42	1530	—	—
3.	Straw Pulping	80	2050	—	—
4.	Wastepaper pulping	17	560	—	—
5.	Stock preparation	24	720	12	500
6.	Paper machine & Finishing house	39	1410	30	1100
7.	Chemical preparation	27	130	—	—
8.	Boiler House	19	360	12	200
9.	Pump House	3	180	1	60
10.	Tube well	4	170	—	—
11.	Effluent treatment	14	270	—	—
12.	Lighting DB's	—	50	—	10
13.	Total installed H.P.	275	7550	55	1870
14.	Total installed KW	—	5630	—	1400
15.	Diversity & Load factor	—	65%	—	75%
16.	Total Running load	—	3660	—	1050

Note : T.G. will be able to sustain production only for 2 hours maximum. If any production beyond 2 hours is to be sustained certain amount of diesal generator power is essential.

TABLE—VI PROCESS REQUIREMENT OF STEAM UNDER VARIOUS OPERATING CONDITIONS

S. No.	Section	Steam pressure Kg/cm²g	Without power generation			With power generation		
			i Max. TPH	ii Normal TPH	iii Min. TPH	i Max. TPH	ii Normal TPH	iii Min. TPH
1.	Digester House	6 5	5.5	3 0	—	1.0	0.5	0.5
2.	Digestor House	3.5	—	—	—	4.0	3.0	—
3.	Paper Machine	3.5	5.0	5.0	—	4.65	4.65	4.65
4.	Miscellaneous	3.5	1.5	1.5	—	1 40	1.40	0.50
5.	Deaerator	3.5	1.75	1.5	—	2.50	1.75	1.75
6.	Various losses	—	0.25	0.25	1.00	0.25	0.25	0.25
7.	Total Process Requirement	6.5	5.5	3.0	—	1.00	0.50	0.50
8.	Total Process Requirement	3.5	8.5	7.75	1.00	12.30	11.05	7.15
9.	Steam to T G	28.0	—	—	—	14.00	14.00	14.00
10.	Steam to Condensor	5.0	—	—	—	1.70	2.95	6.85
11.	Duration hrs/day	—	8	12	4	8	12	4

TABLE—VII EXTRA EXPENDITURE INCURRED FOR CAPTIVE POWER GENERATION (INSTALLED EQUIPMENT COST)

S. No.	Item	Case of pressure steam generation Fig. 1 (Rs. in lakhs)	Case of high pressure boiler with TG (Rs. in lakhs)	differential cost (Rs. in lakhs)
1.	Boiler,	25.00	35.00	10.00+
2.	Turbogenerator with auxiliaries	—	23.50	23.50@
3.	Building & Foundation	3.00	5.50	2.50
4.	Dump-condensor & Desuperheater	—	3.50	3.50
5.	Pipes, fitting, valves and pressure reducing stations for steam and water lines	16.00	21.00	5.00
6.	Electrical	—	5.00	5.00*
	TOTAL	44.00	93.50	49.50

Say — Rs. 50.00 Lakhs

* Provided for flexibility in the main LT panel, modification in MCC and extra cabling etc.

\+ Ex-works price with CST and excise duties has been taken.

@ Turbine ex-work price 19.5 lakhs.

TABLE—VIII
CALCULATION OF FIXED COSTS OF CAPTIVE POWER GENERATION

A) **TOTAL FIXED COST OF GENERATION:**

BASIS
i) 30 TPD Paper Plant, no recovery
ii) 330 days per annum, continuous operation
iii) Power generated Max/normal/min. =1400/1050/750 KW.
iv) Capital expenditure—See Table VII

Sl.No.	Item	Details	Amount cost Rs. in lakhs
1.	Wages & Salaries	One turbine incharge and one operator are required extra per shift.Superivision cost is marginally increased	1.00
2.	Repairs &Maintenance	@2% of extra capitalised cost	1.00
3.	Depreciation	@7% of capitalised cost	3.50
4.	Interest	@12% on capitalised cost	6.00
	TOTAL FIXED COST		11.50

B) UNIT FIXED COST OF GENERATION AT VARIOUS LEVEL

Sl.No.	Level KW	Cost Rs. KWH
1.	750	0.194
2.	1050	0.138
3.	1400	0.104

TABLE–IX

Calculation of variable generation cost based on the various load conditions in Hybrid captive power plant.

Basis : i) 30 TPD Paper Plant
ii) 330 days/annum continuous operation.

Sl. No.	Item	Condition when no steam is sent to condenser	Condition I Ref. Table VI.	Condition II Ref. Table VI.	Condition II Ref. Table VI.
1.	Power generated KW	750	1050	1050	1050
2.	Steam generated TPH	13.30	15.00	14.50	14.50
3.	Steam through T. G. TPH	12.30	14.00	14.00	14.00
4.	Steam through condenser TPH	—	1.7	2.95	6.85
5.	Heat used for power K Cal/hr*	865	1900	2640	5180
6.	Cost of Coal Rs/hr.**	138	286	398	741
7.	Power cost paise/KWH	19	28	40	71
8.	Duration hr/day	—	8	12	4

Note: i) Average cost based on condition I, II & III

$$= \frac{28 \times 8 + 40 \times 12 + 71 \times 4}{24} = \frac{988}{24} = 41.2$$

ii) Total average cost paise/KWH

Fixed cost	13.8
Variable cost	41.2
Duty	3.0
Total	58.0 paise/KWH

*@65 KCal/TPH to turbine and 525 KCal/TPH to condenser

**@ Rs. 550/tonne of 4800 KCal/Kg GCV coal, 72% boiler efficiency.

exhaust steam is wasted in the condenser, for about 8 hrs., 2.95 TPH for 12 hrs and 6.85 TPH for four hours in a day. The most adverse situation arises only when there is power tripping and only power machine and boiler house are in operation. This situation prevails actually during grid trippings only. If the number of trippings in a day is more, then the occurance of this situation is also more frequent.

ECONOMICS AND DISCUSSION:

The average cost of power generation based on the hybrid captive power plant scheme as suggested is 58 paise per KWH.

It may be noted that if the exhaust steam utilization is improved and the power generation is maintained not lower than 1100 KW the unit cost will be 33 paise.

The economics of such a captive plant can be realised only in relation to the production loss if no captive power plant is installed is worked out as below :

	Rs. in Lakhs/Year
Cost of Captive power generation @ 58 paise (1050 KW for 330 days)	48.23
Cost of purchased power @ 40 paise (1050 KW for 330 days)	33.26
Excess cost incurred	14.97
Increased production 2340 TPA @ 150 hrs. in a month) Sales realisation @ Rs. 6000/-per tonne ex-works	140.40
Profit @ 25% of sales realisation which includes the excise rebate and incidence of fixed cost	35.10
Net Savings (35.10–14.97)	20.13
Add depreciation	3.50
Net Cash accrual	23.63

Pay back period for
Rs. 50.00 lakhs = 2.15 Years.

Captive power plant economics will however look poor if the grid power is available continuously. However, the necessity for inclusion of the power plant will be essential if the production loss due to power trippings account to even 70 hours in a month,

If the mill has any future plans to expand 50 TPD then this captive power plant as envisaged can become very attractive and essential without considering the "crisis economics".

If a 30 TPD mill is combined with an alkali recovery unit then the unit can become stabilised at 1400 to 1500 KW power generation and be made viable.

The economics as worked out is applicable on smooth sailing on the other fronts of plant operation and marketting.

CONCLUSION :

Under the present day power availability situation, it is observed that a captive power plant of 1000 to 1500 KW capacity based on multistage back pressure turbine with a dump condenser system is essential to maintain a reasonable capacity utilisation. Inspite of its high unit power generation cost the same becomes a sole surviving factor of a new mill. In fact after 3 years when the investment is recovered and loans are cleared the cost of power generation may be equal to the grid cost and become self sufficient to a large extent.

ACKNOWLEDGEMENT :

We acknowledge with thanks our esteemed clients M/s. Zenith Papers (Division of Zenith Steel Pipe Industries Limited, Bombay) for letting us use the data from their mill which is presently ready to go on trial production.