# Co-Generation and feeding of excess power to Grid-Triveni experience

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## Introduction

The industrial growth and the consequent spurt in economic activity in our country over the last four decades has resulted in the continuous rise in demand for power and the power sector has registered a phenomenal growth rate. Power shortages, however, continue unabated inspite of growth of the power sector. It is the considered opinion of the experts in our country that the power shortage is here to stay in the forseeable future. Considering that the power situation in India has been rather dismal especially since the fuel crisis of 1973 and there are yet no signs of any major change in the position, it is high time, co-generation is considered as a means, to substantially ease the situation. The industry which can generate more electricity than it consumes can feed the excess power into state grids. The economics of using co-generation, ensures that the additional financial requirement to a new plant or the existing one, is generally recovered within a reasonable time (from 1 to 5 years). This option will be still more attractive when the industry has waste heat resources such as furnace gases, exhaust from gas turbines or fuel input from agricultural waste, i.e. non-conventional source such as bagasse and rice husk.

In a co-generation concept it is possible to bring together a fuel, a need or use for heat and a place to use excess power generated. This can make tremendous economic and environmental sence in the present subject of co-generation in any country's power situation.

## Co-Generation Defined (Refer Fig.1)

Co-generation is most simply. the co-incident generation of process steam-heat energy and electricity by an industry with or without the involvement of electricity board. In the 'Topping cycle' (Fig.2) steam is pressure reduced through a steam turbine generator set before being used for a heating or process work. In the 'Bottoming cycle' (Fig. 3) waste heat available as a by product of a process is used to produce the steam that runs the turbogenerator sets. In either case, co-generation can provide electricity at a fraction of the cost of purchased power.

Co-generation can provide the much needed relief to state owned central power stations and to the benefits of industry, agriculture and national development as a whole. The accepted advantages of co-generation by industry are:

a) Ability to generate power at a lower cost than possible by electricity boards.

b) The ability to use bio-mass extensively and thus reduce dependence on conventional fuels.

c) The ability to place co-generation plants on grids with no restraints from various factors which is presently affecting power generation at central power stations.

d) Provides a technically and commercially viable project with short and predictable pay back periods.

e) Provides an economical and timely solution to energy problems facing the country.

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In order for a co-generation project to be successful, one has to conduct a technical and economic feasibility study. An over view of technical and economic feasibility assessment is given in fig-4.

Technical and economic assessment in Co-generation involves basically 3 steps.

I. Collection of Data
II. Technical Feasibility
III. Economic Aspects

**Collection Of Data:**

a) **Electricity Board Data:**

— Standard electricity tariffs

## How Co-Generation Works ?

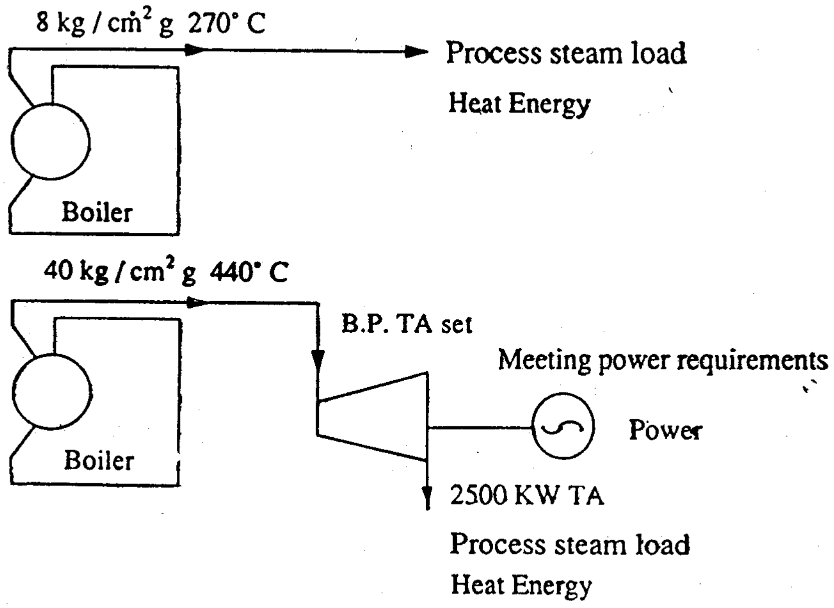


FIG. 1

## Topping Cycle

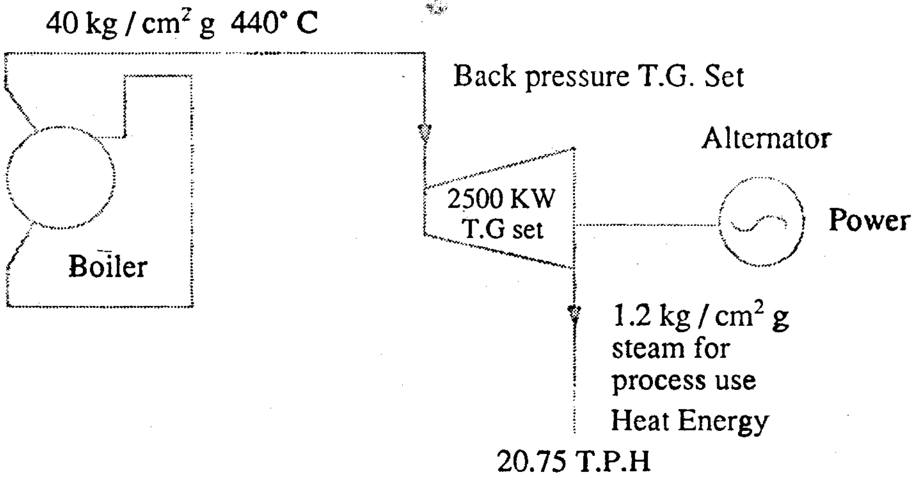


FIG. 2

## Bottoming Cycle

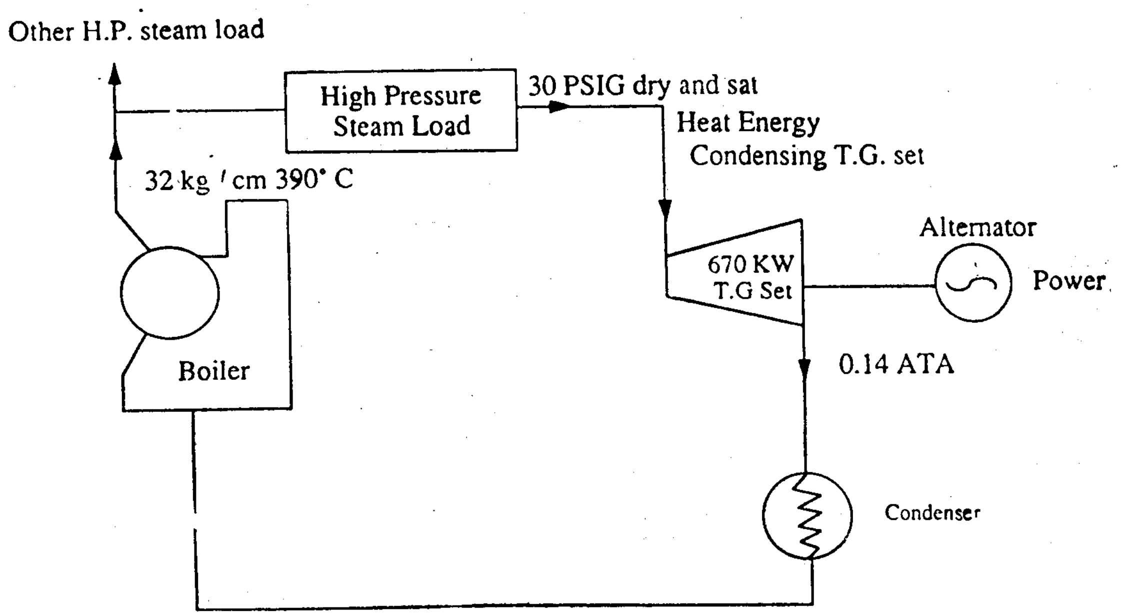


FIG. 3

## Overview of Technical and Economical Assessment in a Co-Generation Project

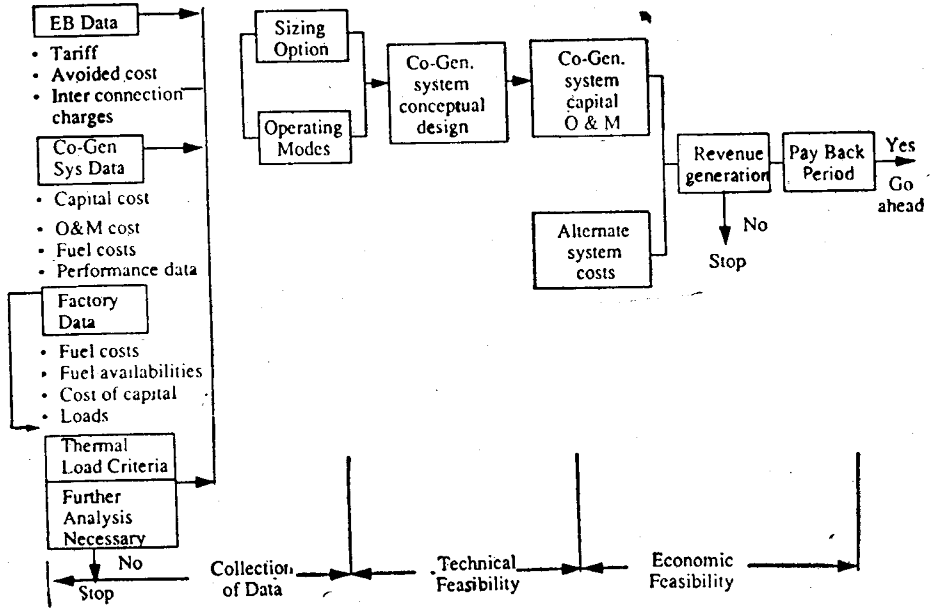


FIG. 4

— Tariff which an EB is prepared to pay to a co-generation facility. In India, many of the EBs are accepting Banking and Wheeling concept whereby a cogenerator is directly billing to the ultimate client and giving a certain percentage of bill to the EB as banking and wheeling charges.

— **AVOIDED COST:**

Avoided cost means the incremental costs to an electricity board for electrical energy or capacity or both which but for the purpose from the co-generator would be generated by the electricity board itself,

In our opinion, avoided costs should generally come into picture where supply of electricity is more than demand. In India, where demand is many times more than supply, the talk of avoided cost need not exist. The effort of all involved agencies must be generate, transmit to and supply cogenerated power through EB lines as the only agency available for this purpose. In India, EBs suffer from shortage of both capacity and energy, and at the same time, they are strapped for funds for capacity expansions.

— **Interconnection :**

It is the most vital link between the co-generation plant and electricity board. This allows co-generation plant to sell excess power to grid and in return EB/Nation gains additional capacity from interconnecting.

The protection standards/requirements for the tie-up or interconnection are presently not defined anywhere and are primarily dictated by EB. Most commonly EB distribution systems are not designed to accommodate interconnection of generation. Some typical complications which can arise include voltage control, faults currents, over voltages, harmonics, unbalance and other characteristics of the generation may cause complications.

EB normally advice after studying the co-generator's system any modifications/inclusion of equipments necessary for the purpose of interconnections and all these interconnection changes between co-generation and EB will have to be borne by cogenerator.

### b) Co-Generation system data

1 Capital Cost :

- Hardware costs :
  - prime mover
  - electrical generation and control
  - boilers and heat recovery equipment
  - fuel storage requirements
  - pollution control
  - backup systems
- installation cost
- operating and maintenance (O&M) costs
- Fuel cost and availability of fuels
- Performance data
  - power generated
  - operation at part load
- Expected service life

### C) Factory Data :

Process steam requirement/heat energy—should be large enough to justify the construction of capital intensive co-generatian plant rather than relying on less expensive (but also less efficient) conventional system.

For example, it is known that big hotels in India use steam for many purpose, but hourly steam demand and the quantity is not large enough to justify a cogeneration plant using steam turbine topping system. Perhaps, a Diesel engine topping system, wherein, hot water derived from water cooled exhaust manifold of the Diesel engine should work. At present, these hotels are operating on stand alone Boilers and generate steam at the required pressure for their use as and when demand exists in a particular day.

Further information includes process steam usage per hour, monthly steam usage, peak steam demands as well load profile data, load magnitute and timing.

Projections of future etectricity and process steam demand will also be required. These projections will be important in sizing the co-generation system or allow its expansions to satisfy future as well as current demands.

An analysis of the above data collected will lead us to the following:

- i) Possible size of the Co-generation plant
- ii) Type of Prime Movers required
- iii) Possible choice of fuel

In addition to the above. the following elements should be obtained.

- a) Fuel cost
- b) Cost of capital

## II. Technical Feasibility :

After collecting the above data, in order to evaluate engineering feasibility of cogeneration plant, a cogenerator has to go through a design selection process involving two basic steps;

- a) Determining appropriate size
- b) Operation mode.
- c) Identifying prime mover type.

### a) Sizing option:

Has to necessarily cater for process steam requirement/power integration and should answer critical duty requirement of dependability, reliability and flexibility. Sizing option primarily depends on the portion of thermal needs, that is to be met by the co-generation systems.

An optimal sizing of Co generation plant makes maximum sequential use of heat input starting from Boiler. All heat is added at the beginning of co-generation Cycle and flows through the power generating and heat using equipment before being rejected from the system.

For example, in a typical sugar factory it is a foregone conclusion that the cogeneration system must be such that the heat energy recovered from the prime mover will meet the entire thermal load. Further, the next option is that after meeting the entire thermal load of the plant, if extra live steam is available the same can be sent through a condensing TG set to generate further power.

### b) Operating modes :

**3 basic modes are available :**

### i) Thermal despatch mode priority :

In this mode thermal despatch is the main inten as in a sugar plant and when the thermal demand of the plant is met and any excess cogenerated power is sold to EB

### ii) Electric despatch mode priority :

In this mode electric despatch gets priority and the plant may have to dump the excess steam at times of low thermal demand operation. This mode is not usually cost effective.

### iii) Hybrid strategy :

Hybrid strategy means operating the cogeneration plant to produce maximum electricity output during the EBs peak requirement and thermal following mode during the other times. If the cogenerator has a contractual obligation to deliver a minimum amount of power to the EB ultimate client during peak periods, then a hybrid strategy shall be followed.

### c) Identifying Prime mover type : (Refer Fig.5)

### a) Gas Turbine topping system :

In this system Gas turbo generator is first used to generate power and the high temperature (800-1000 °F) exhaust heat from the gas turbine can be used as a heat source for waste heat boiler to generate steam for the use in the process.

### b) Diesel engine topping system :

In the system shown above, the high temperature exhaust from the Diesel engine is passed through waste heat recovery boiler and the process steam or the hot water (depending upon the heat input available from the exhaust gas from the Diesel engine), can be made available for use in the process.

### C) Steam turbine topping system :

Steam turbine topping cycles represent the most widely used method accounting for about 80% of

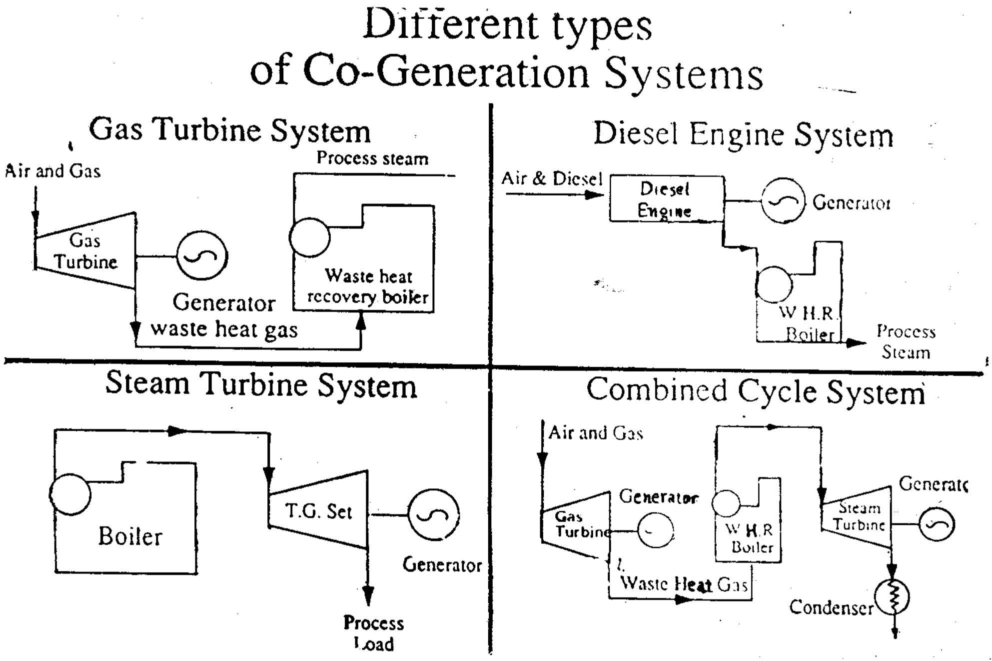


FIG. 5

electric power generated in co-generation system. The projected sketch gives the necessary information.

**b) Combined cycle system**

In a combined cycle co-generation, a gas turbine with a waste heat boiler is combined with a steam turbine generator. In a combined cycle system, the Gas turbine drives an electrical generator and the rejected heat is recovered by a waste heat boiler. The recovered steam is used in a steam turbine driving a generator to produce additional power.

Further the back pressure steam from the turbine is then used directly in the industrial process or for heating,

At Triveni, we have been supplying steam turbines for cogeneration duty in the last few years for sugar, chemical, petrochemical, fertiliser, paper and other allied industries. In the last four years, there have been some interesting examples of which the following is worthwhile to be mentioned.

a) A 6 mw cogeneration plant including for feeding of excess power to Grid in Tamilnadu Sugar Corporation at their Chidambaram plant. This is an example from Sugar industry and other schemes for 2500 TCD and 3500 TCD Sugar Factory. (Refer Fig. 6. 7. & 8.).

b) 4 to 5 mw TG set for Carbon Black plants at Phillips Carbon Black Ltd. Durgapur and Oriental Carbon and Chemicals Ltd. Ghaziabad where our condensing TG sets have been put in operation in bottoming cycle mode. In these projects. special boilers are installed to burn carbon monoxide and produce steam. This is an example wherein waste heat is recovered and power is generated. These are examples from Carbon black industry. (Refer Fig. 9)

c) M/s. Sesa Goa Ltd. has set up a pig iron plant at Goa wherein the gas from the Mini-blast furnace is passed through boiler and steam geneated which is passed through a condensing turbo generator supplied by us. This is an example from Pig/Sponge Iron industry wherein power is generated through bottoming cycle mode. (Refer Fig. 10)

d) For M/s. Harshavardhan Chemicals, we have supplied low pressure condensing TG set and the input steam for the same is supplied through waste heat recovery system of the plant itself. This is an example from Chemical industry. (Refer Fig. 11)

e) For M/s. Atul Products Ltd. Gujarat, we have supplied a 5000 kw pass-out back pressure turbo—alternator for steam conditions of 64 ATA and 500 Deg.C with facility for controlled extraction and back pressure. The TG Set will be run in parallel with the State Grid. (Refer Fig. 12 & 13).

## Co-Generation for 2500 TCD Sugar Factory

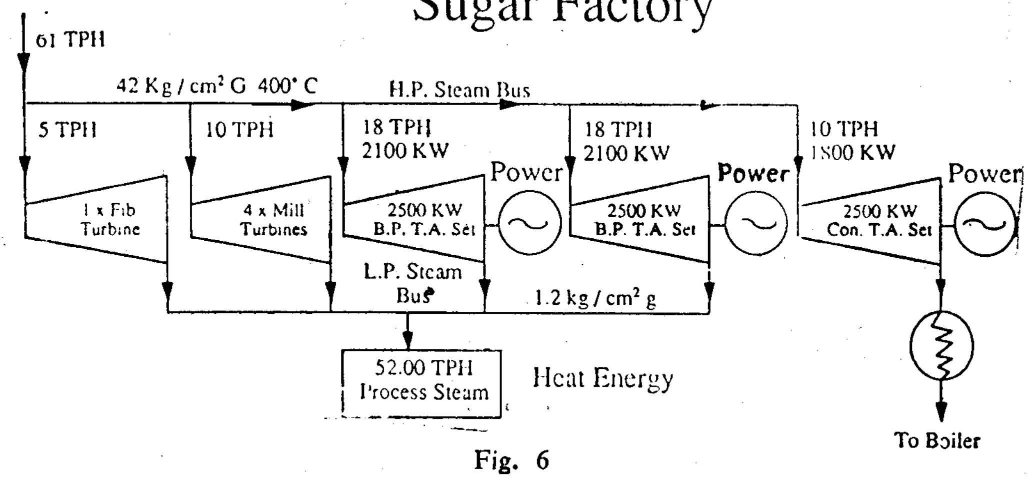
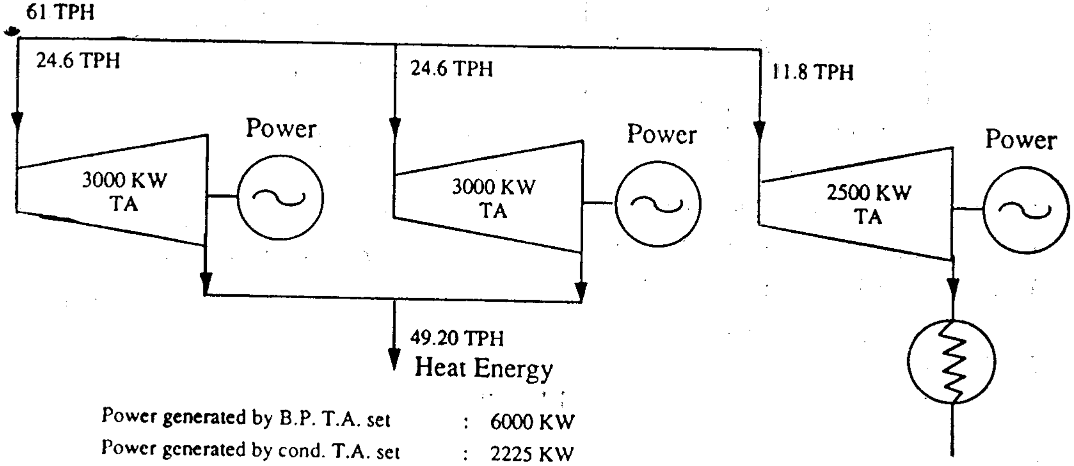


Fig. 6

| | | |
|---|---|---|
| **Power generated by B.P.T.A. set (2 nos.)** | : 2100 KW | : 4200 KW |
| **Power generated by cond. T.A. set (1 no.)** | : | : 1800 KW |
| **Total** | : | : 6000 KW |
| **Less power to sugar plant/Aux.** | : | : 2000 KW |
| **Power to grid** | : | : 4000 KW |

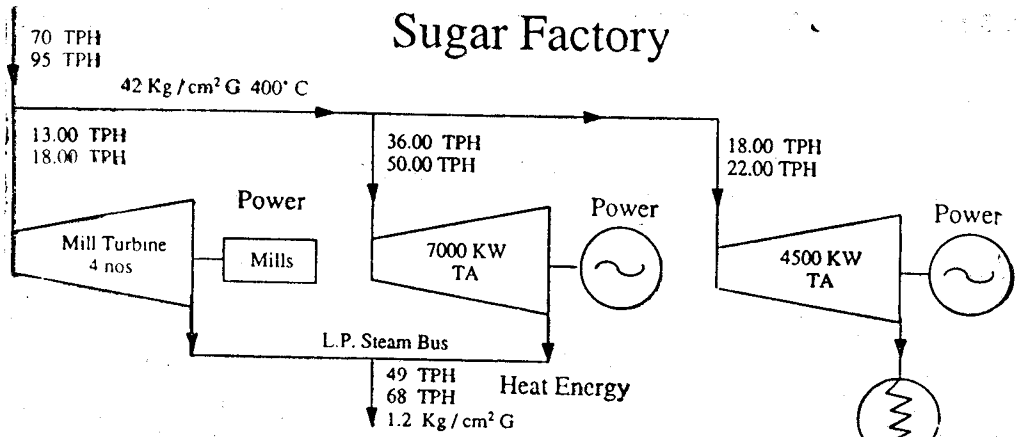
## Co-Generation for a 2500 TCD Sugar Factory with DC Motor Drives



| | |
|---|---|
| Power generated by B.P. T.A. set | : 6000 KW |
| Power generated by cond. T.A. set | : 2225 KW |
| Total | : 8225 KW |
| Less power to sugar plant / Aux. | : 3850 KW |
| Power to grid | : 4375 KW |

Fig. 7

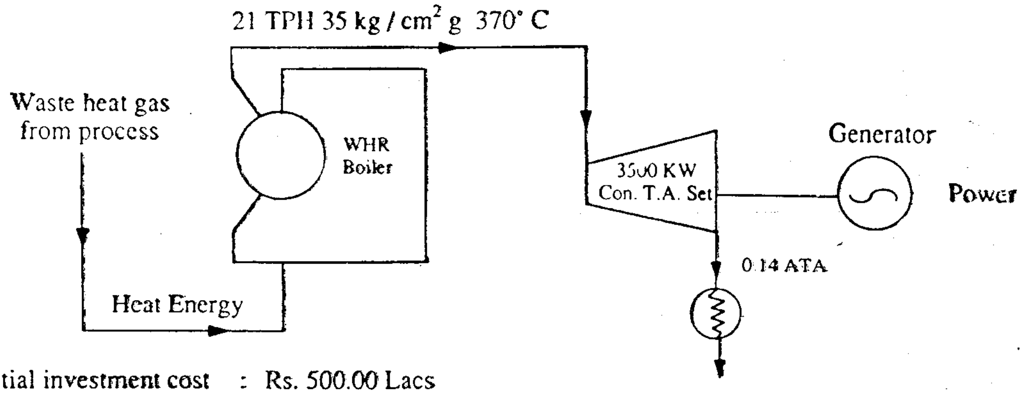
# Co-Generation for 3500 TCD Sugar Factory



| | | For 3500 TCD | 2500 TCD |
|---|---|---|---|
| Power generated by B.P T.A. set | : | 6552 KW | 4784 KW |
| Power generated by cond. T.A. set | : | 4074 KW | 3333 KW |
| Total | : | 10626 KW | 8117 KW |
| Less power to sugar plant / Aux. | : | 3567 KW | 2567 KW |
| Power to grid | | 7059 KW | 5550 KW |

**FIG. 8**

# Bottoming Cycle Co-Generation for Carbon Black Project

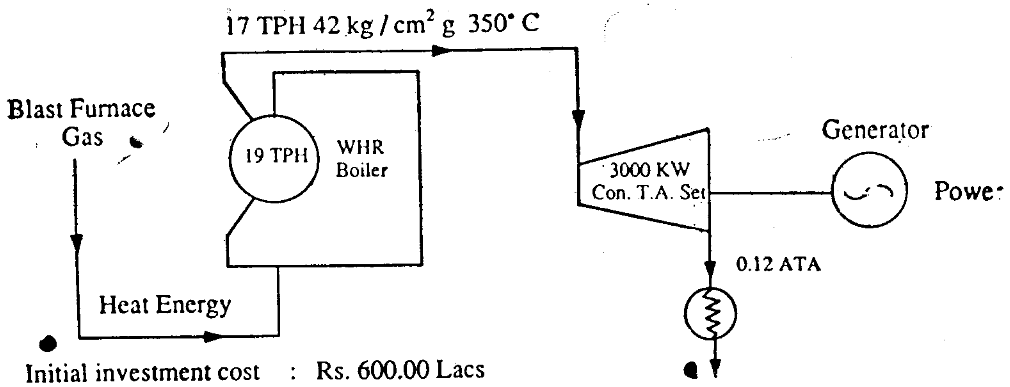


Initial investment cost : Rs. 500.00 Lacs
Cost per unit : 80 paise
Power generated : 2500 KW
Client is self sufficient in power. No export to grid
Pay back period : 4 / 5 years

Current Generation
Steam Quantity – 15 TPH
Power Generated – 2500 KW

**FIG. 9**

# Bottoming Cycle Co-Generation for Pig-Iron Project

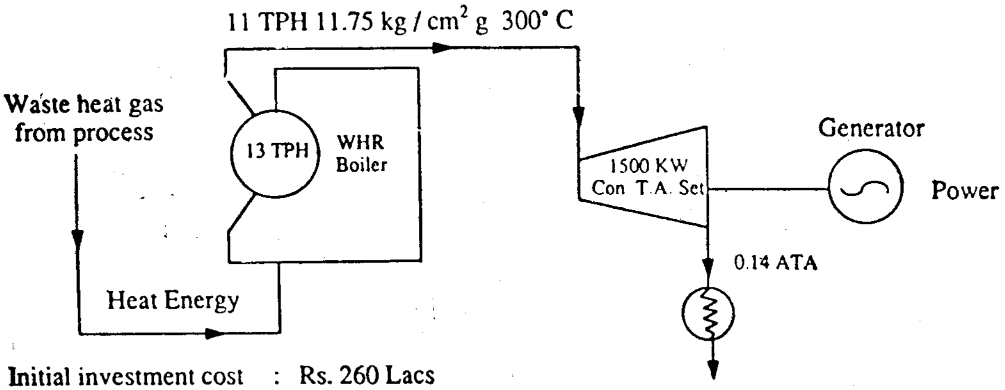


Initial investment cost : Rs. 600.00 Lacs
(with boiler)
Cost per unit : 60 paise
Power generated : 3000 KW
Client is self sufficient in power. No export to grid
Pay back period : 3.5 years

Current Generation
Steam Quantity – 17 TPH
Power Generated – 3000 KW

**FIG. 10**

# Bottoming Cycle Co-Generation for Chemical Project

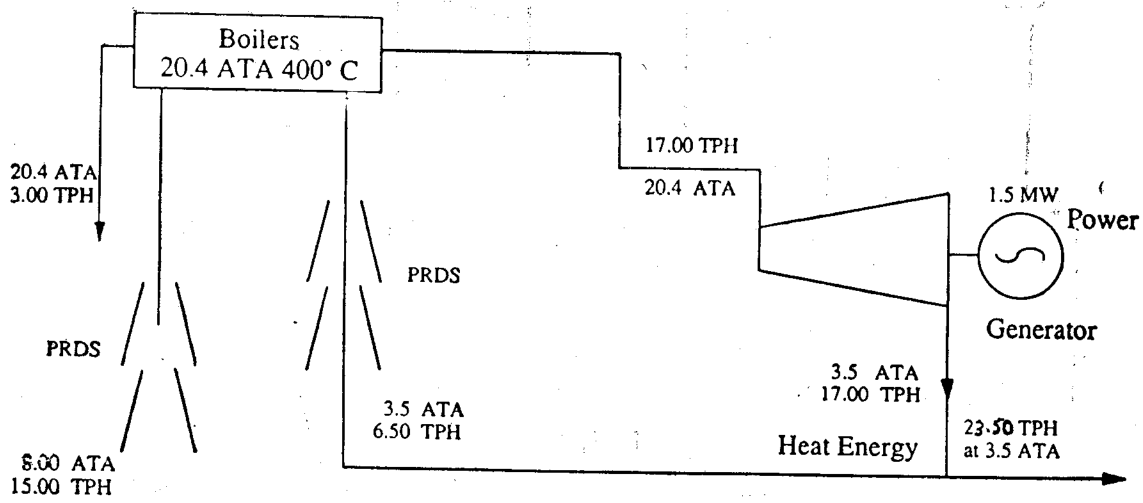


Initial investment cost : Rs. 260 Lacs
(with boiler)
Cost per unit : 46 paise
Power generated : 1500 KW
Client is self sufficient in power. No export to grid
Pay back period : 2.5 years

Current Generation
Steam Quantity – 11 TPH
Power Generated – 1500 KW

**FIG. 11**

## Topping Cycle Configuration (Old Scheme) for Chemical Project



EIG. 12

## Topping Cycle Configuration (New Scheme) for Chemical Project

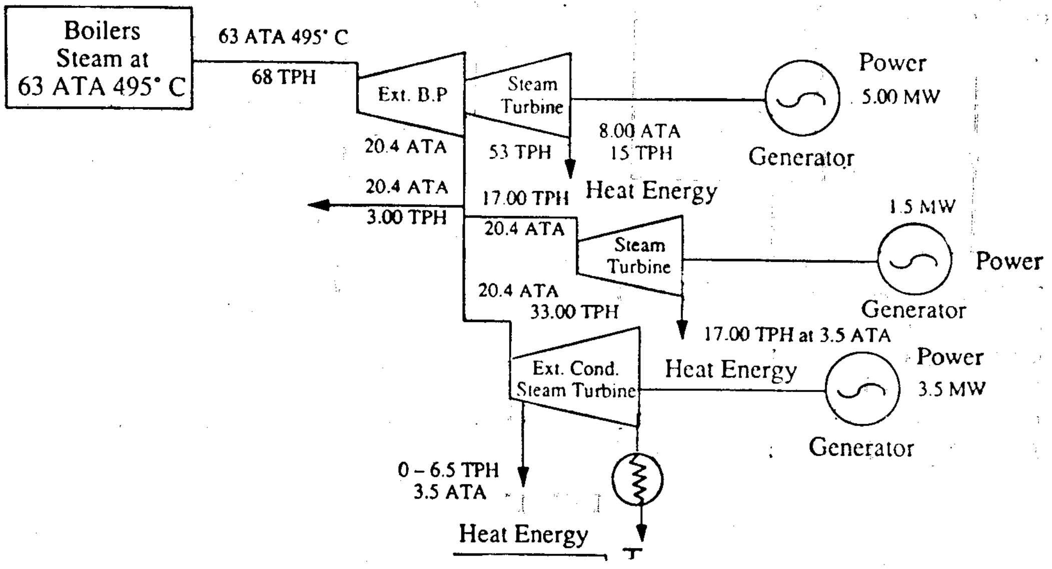


FIG. 13

f) For M/s. The West Coast Paper Mills Ltd., Dandeli, Karnataka and Satpuda Pulp & Paper Project, Maharashtra. We have supplied a pass out back pressure 5.3 MW and straight back pressure 3 MW TG sets respectively for steam conditions of 39 ATA 390°C±10°C and 45 kg/cm$^2$ 440°C respectively. This is an example from the paper & pulp industry (Ref. Fig. 14 & 15).

### Fuels :

Various different types of fuels especially alternative fuels should be of interest to us. Given below are some of the typical fuels :

a) Bagasse
b) Corn husks
c) Cotton seed hulk
d) Municipal refuse
e) Crop residuals
f) Rice husk
g) Peanut hulk

Apart from the above, conventional fuels like Coal and Fuel Oils are already known two the industry.

### Performing the Energy Analysis :

After completing the above collection of data plus technical feasibility, it would be necessary to do an analysis of all energy inputs and outputs.

Enclosed herewith in Fig 16 is a simple energy balance diagram for a sugar factory which indicates excess power available after meeting the factory demand for a conventional sugar factory operating at 18/21 kg/cm$^2$ g. 340 Deg. C and for a factory operating at 45 kg/cm$^2$ g 440 Deg. C.

As you can see excess power available in the region of 2200 kw for 45 kg/Cm$^2$ g 440 Deg. C steam condition sugar factory and NIL power for a conventional 18 kg/cm$^2$ g steam condition sugar factory.

### III Economic Feasibility Concepts in Co-generation

The aim of this exercise is to determine whether investment in a co-generation plant would be a cost-

The West Coast Paper Mills Ltd.

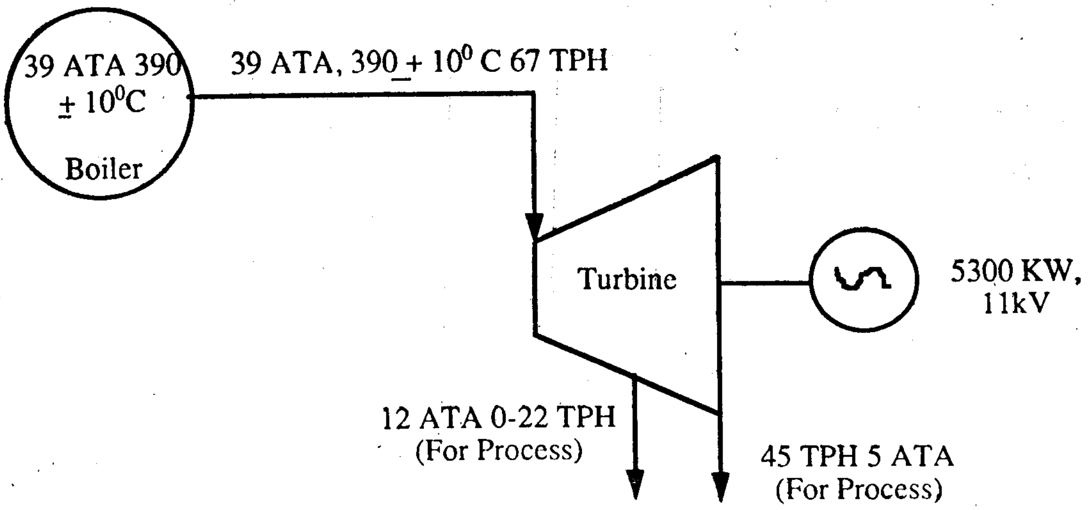


FIG. 14

# Satpuda Pulp & Paper Project

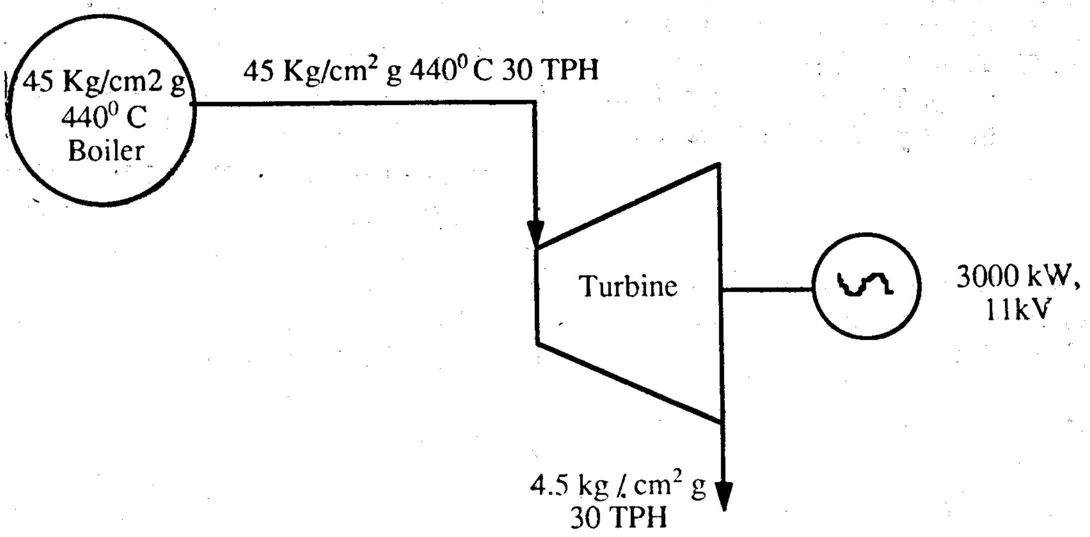


FIG. 15

# Energy Balance Diagram for a 2500 TCD Sugar Factory

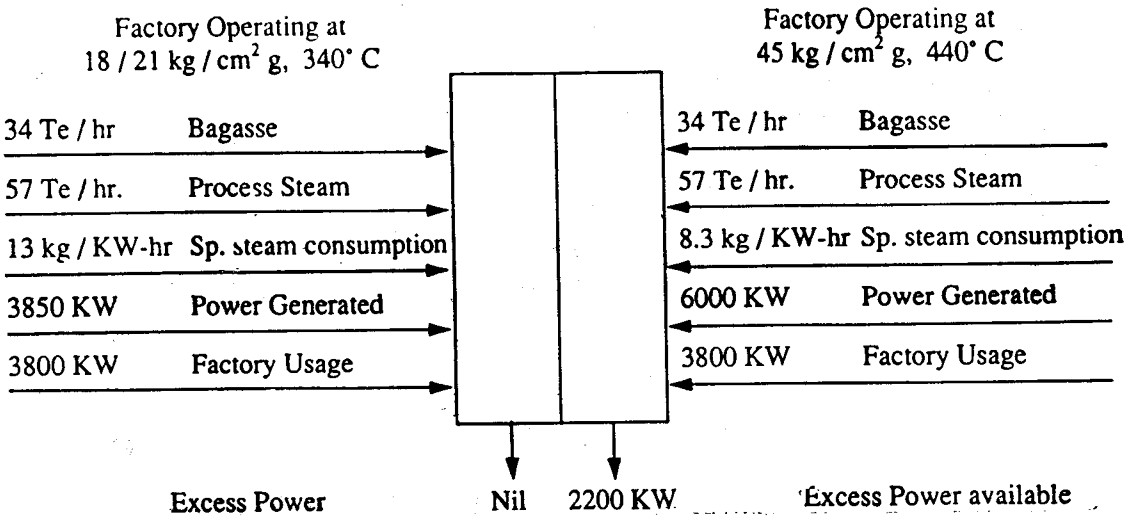


FIG. 16

effective means of meeting a particular site's energy requirement. Any industrial plant can be supplied with energy using conventional methods. For cogeneration to be feasible, the long-run costs of reliability meeting the energy needs of a particular plant through co-generation must be less than the corresponding cost of conventionally provided services. For example, in a sugar factory the conventional method of meeting both power and heat energy has already been existing in India in the last many decades (18 kg/cm² g steam condition ). However, the intent should be able to examine whether investment in a new breed of cogeneration plant for both meeting the energy needs of factory and also feeding of any excess power to grid can be economically feasible. The 45 kg/cm² g 440 Deg,C. co-generation plant in a sugar factory generates direct revenue through the sale of excess power to grid and thus enhancing the total revenue of the sugar plant through the sale of both sugar and power Similar analysis about projections of return could be done for cogeneration plant as applicable to any particular industry.

Economic feasibility study should establish two important criteria for making co-generation plant investment decisions.

i) Co-generation plant operations must produce cost savings and/or additional direct revenue that exceed the incremental investment and operations cost incurred to construct and operate the plant.

ii) Revenue or benefits must exceed incremental investment and these must be equal to or greater than similar measure on alternative application of such funds.

A number of methods can be used to evaluate the feasibility of Co-generation investments. Commonly used methods are discounted cash flow analysis (DCF) and play back analysis.

## Sensitivity Analysis :

Economic feasibility study often depends largely upon assumptions used in the business environment in which the co-generation plant will operate. There can be substantial uncertainity sorrounding the values of key parameters in the future periods.

It is possible that alternative configurations of a co-generation project may alter the economics of co-generation system significantly.

The following parameters can substantially alter the economics due to their variation in cost, availability etc.

1. Fuel
2. Electricity Board Tariff
3. Capital cost based on different types of prime mover size used for particular project.

For a specified cogeneration sytem configuration, it is very important to predetermine how well the system could perform if everything goes " right" and how poorly it could perform if everthing goes "wrong" This analysis will provide both the opportunities and the risks that are being assumed. These are three steps:

i) Fuel costs, size of load and load profile, operating conditions in the plant and day to day working relations with EB, etc.

ii) Identifying the most extreme conditions for each of the above. This step requires considerable judgement to determine extreme values that may be reasonably expected to occur.

iii) After the above analysis, one has to recalculate the cash flow analysis. The best or worst rasults obtained will indicate the levels of opportunities or risk involved.

## Pay back analysis:

Fig.7 is a model of cogeneration plant in a sugar factory which has been selected by us to give an idea about pay back analysis. The model is from sugar industry wherein a cogenerated equipment cost has been worked out at a figure of Rs. 439.38 lakhs making certain assumptions.

| S.No. | Co-generation equipment | Cost Rs.lakhs |
|---|---|---|
| 1. | Project cost | 439.38 |
| 2, | Power to grid in kw | 4750 kw |
| 3. | Power to grid in units considering 4000hours per annum as the season for sugar plant | 190 lakh (units) |
| 4. | Revenue from power (190 × Rs.1.25 per unit) | 237.50 |
| 5. | Expenditure per annum (excluding depreciation) | 96.81 |
| 6. | Net cash revenue. | 140.69 |
| 7. | Pay back period in seasons | |

$$\frac{\text{Increment cost}}{\text{Net cash revenue}} = \frac{439.38}{140\ 69}$$

=3 12 Seasons

From the above figures. the cost of generation per unit can be arrived by considering variable costs like labour. stores, consumables, fuel, etc. and various fixed costs and the figure is O 63 paise per unit.

### Critical Factors Effecting Viability of Co-generation Projects:

1. **Realisation of surplus power:**

   In developing countries, this would play key role in the development of co-generation schemes. Realisation against energy sold by a factory could be on two lines, i.e.

   a) Direct sale of Electricity Board

   b) Through Banking and Wheeling sold to 3rd party.

   In our opinion Banking and Wheeling will be the best option available to our country wherein a co-generator can bank-in and wheel the power through the EBs transmission lines to the 3rd party.

   For example, a co-generator in a remote sugar factory in Karnataka State of India can sell his co-generated power through Banking and Wheeling concept using EB transmission lines to an industry in Bangalore at a unit cost which can be less than the Diesel Energy cost.

In the Banking and Wheeling concept, the most attractive part is that a co-generator and the buyer of power can negotiate and enter into an agreement regarding cost of power per unit This means power will become a commercial commodity using EB transmission lines.

Of course, a co-generator will have to pay wheeling charges to Electricity Board.

It would be of interest to note that M/s. Mysore Paper Mills Ltd. Bhadravati and M/s. Mangalore Chemicals and Fertilizers Ltd., Mangalore, have sold excess of power available to them from their plants through Banking and Wheeling scheme of Karnataka Electricity Board and are supplying to various other firms.

### Incentives From Financial Institutions:

Co-generation schemes must receive special attention from financial institutions in the form of concessional loans to enable quick returns and to attract more entrepreneurs to venture for such projects.

### Future Of Co-generation

Co-generation has extensive future potential technical and institutional barriers have to be closely studied in the context of the present power scenario and removed. This is one of the major constraints standing in the way of active implementation of co-generation projects in India. The relevance of removing institutional barriers need to be discussed at all levels and decisions, ensuring promotion of power generation taken.

Co-generation by industry is a very meaningful and natural economic activity and no attempt must be spared by all leading institutions involved to make this concept a total success.

It is an exciting field calling for attention from Government, Institutions, manufacturers, Electricity Boards, Consultants and Bankers. They have to interact with each other and produce legislation which will give co-generation of power by industry its right place in the economic activity of the nation. ◆