Cogeneration associated with cane sugar mills in Réunion

Thirty percent of the electricity in Réunion is now generated at a power plant that burns two types of fuel — including bagasse, a by-product of a local cane sugar refining industry. Another similar plant will be put into operation in July 1995, and the two plants will jointly generate 55% of Réunion's electrical needs. In addition to electricity, the plants generate steam required to operate the cane sugar mills that supply bagasse.

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On average, Réunion produces 2 million t per annum of sugarcane, which is currently processed in three cane sugar mills: Le Gol, Bois-Rouge and Beaufonds (Figure 1). The Beaufonds mill will be shutdown at the end of the 1995 sugarcane processing period, leaving the other two to handle the island's entire sugarcane production.

Bagasse is a fibrous residue by-product of cane sugar refining; about 320 kg of bagasse is derived from one tonne of processed sugarcane, i.e. 650 000 t per annum in Réunion. This by-product is burned in special furnaces in the mills in order to generate the steam and electric power that they require. However, this does not utilize all of the bagasse produced by the mills. Other uses have been proposed to reduce the bagasse surplus, e.g. manufacturing fibre panelling, paper pulp, plastic materials, solvents, etc.

In Réunion, at power plants adjoining the Bois-Rouge and Le Gol cane sugar mills, the solution has been to use all of the bagasse as fuel to cogenerate steam and electricity with high energy yields. The Bois-Rouge plant has been running since 1992 and the Le Gol plant became operational in July 1995.

Efficient use of bagasse

Bagasse has a low specific weight of about 120 kg/m^3, with a moisture content of 46-48%. It tends to ferment under storage conditions and is highly inflammable. It has a calorific value of 1 850 kilocalories/kg, which is quite close to values obtained with many lignites mined throughout the world at high costs expense.

Bagasse has low ash content (about 3% dry wt.) and almost no sulphur, which is of particular interest in terms of air pollution and solid waste problems.

What is "cogeneration"?

The high energy efficiency required is obtained as a result of three important features. First, the steam pressure and temperature at the furnace outlet valve are

Lignites

Lignites, as coals, were formed by compaction of decomposed ligneous plants in the secondary era. The consistency of this product can vary, depending on the compaction conditions and time elapsed, from a completely transformed rock (coal), to an intermediate form (lignite), to a relatively untransformed form (peat).

much higher than operational levels normally adopted in sugar mills. Secondly, the furnaces are designed to obtain complete combustion. Thirdly, the power stations operate in the "cogeneration" mode throughout the sugarcane processing period.

Cogeneration involves producing steam at much higher pressures and temperatures than required for running the sugar mill. The steam pressure is expanded in a turbo generator to the levels required for the sugar mill. High quantities of electrical power are produced during this operation.

With total cogeneration in modern power stations, 85% energy efficiency (ratio between generated energy and that contained in the fuel) is commonly obtained, as compared to 25-40% with a conventional generation mode.

Fuel complementarity

Such power stations are, of course, expensive. Skilled operators are required, along with special treatment of the water used in the furnaces. The stations have to run year-round to justify the economic and technical expenses.

Since it is not cost-effective to store bagasse, this material has to be burned just after it is produced during the sugarcane processing period (56 months in Réunion). Hence, an alternative fuel must be used during the rest of the year (e.g. coal, lignite, fuel oil and gas). Quantitatively, about half of the electricity-generated in Réunion is obtained by burning bagasse, the other half with the local alternative fuel, which is coal.

Guiding principles of the project

The bagasse-fueled power station is an industrial complex adjoining the cane sugar mill. However, the station remains a separate entity, with its own staff. A special company was set up to finance, construct and run the power station. The sugar mill delivers all of the bagasse it produces to the station in exchange for low-pressure steam and electricity it requires to operate the mill, i.e. 400-450 kg steam at 3 bar and 30 kWh electrical power per tonne of processed sugarcane, no funds are exchanged for any of these services.

The power station recovers 90% of the steam weight from the sugar mill in the form of condensates at 90°C.

The power company's resources are based on sales of electricity over and above that produced to operate the sugar mill. The project is thus based on long-term contracts between the power company and electricity clients.

The power plant is designed to be able to burn a week's quantity of bagasse produced by the sugar mill. It is thus equipped with a fully mechanized bagasse storage unit — which disconnects the two operations of bagasse production and furnace burning. For operational safety purposes, the plant has two identical production lines that operate in parallel. Each line includes a furnace, a turbogenerator, a condenser and a cooling tower. Many different combinations are possible with this design, e.g. to switching furnace n°1 to turbogenerator n°2, and vice-versa, thus markedly enhancing operational flexibility. It is therefore possible to burn coal in one furnace and bagasse in the other. This also guarantees a steady supply of power to clients (sugar mill and the Réunion electrical network) from at least one of the lines.

Figure 1. Cane sugar mills and power cogeneration stations in Réunion.

Bois-Rouge power station.
Photo B. Robert

Power production line operation

Operations of one of the two power production lines at the Bois-Rouge station are graphically shown in Figure 2. The abscissa (Qb) on the graph represents quantities of steam (t) used in the low pressure part of the turbine. The ordinate (Qh) corresponds to quantities of steam (t) produced in the furnace for use in the high pressure part of the turbine. The second vertical scale (B) gives the quantities of bagasse burned (t) relative to quantities of vapour produced in the furnace (t). The third vertical scale (C) indicates (as a ratio of 320 kg bagasse per t sugarcane) the relation between the quantity of sugarcane processed in the mill (t) and the quantity of bagasse produced (in fact, this quantity is exactly half that of the sugarcane processed as the graph represents only one of the station's two power production lines, not both). On the graph, the corrected extraction curves Qs (Qs = constant, in t/h) are straight lines with a 45° slope. The corrected power curves W (W = constant, in megawatts) at the generator terminal are comparable to negative angular coefficient lines. If the network requests a quantity of power Wi and the sugar mill and power station request a quantity of extracted vapour Qsi, the working point I will occur at the intersection of the lines W = Wi and Qs = Qsi. Consider an example of hourly operations for a power production line at full load:

The power station and sugar mill require 180 t of steam (Qs = 90 per line). The station can then supply the network a maximum of 26.2 megawatts per line (W = 26.2). The quantity Qh produced by the furnace to supply the high pressure part of the turbine would thus be 130 t steam. The quantity Qb of steam produced to supply the low pressure part of the turbine would then be 40 t per line. This corresponds to 55 t bagasse burned in each of the two furnaces, i.e. 172 x 2 = 344 t sugarcane initially processed in the sugar mill.

The grate furnaces used include fuel injection. When ascending primary air passing through the furnace grate meets secondary air derived from different stages of the combustion chamber, 70% of the bagasse is burned in suspension and the rest on the grate. The following features enable very complete combustion of the bagasse fuel (up to 50% moisture):

– a very large combustion chamber, so the fuel can be burned over a sufficiently long period of time;

– high temperature combustion air (up to 220°C) obtained with three air heaters;

– high velocity injection of secondary air at several levels;

– reinjection, into the combustion chamber, of ash collected under the multicyclone dust precipitator and economizers.

Finally, the furnaces can be automatically switched from one type of fuel to another, either when decided by the operating staff or when a fuel shortage is detected. For instance, when the bagasse fuel supply to the two fuel injectors halts, the furnace automaticlally switches to the alternative fuel. The system is automatized with respect to various combustion parameters so as to maintain a qualitatively/quantitatively steady steam supply to the turbine.

Applications at the Bois-Rouge and Le Gol power stations

The above-defined guiding principles were applied in two projects in Réunion, near the Bois-Rouge and Le Gol cane sugar mills. South African coal is used as the alternative fuel in these two projects.

The Bois-Rouge power station was put into service in July 1992. It has supplied the sugar companies with electricity and steam since that time. By late February 1995, it had been in operation for 21 000 h, and supplied 825 million kWh of electricity (30% of the total electricity generated in Réunion over this period).

Le Gol power station is quite similar to that of Bois-Rouge. It is currently being tested and is supplying the island with electricity until July 1995. These two power stations should be able to absorb all of the bagasse produced in Réunion, i.e. 650 000 t/annum on average, and 310 000 t coal.

Description of the Bois-Rouge power station

The Bois-Rouge power station has two identical power production lines (Figure 3).

Each furnace has a steam capacity of 130 t/h (at 82 bar and 525°C). It includes a 30 megawatt turbo-generator.

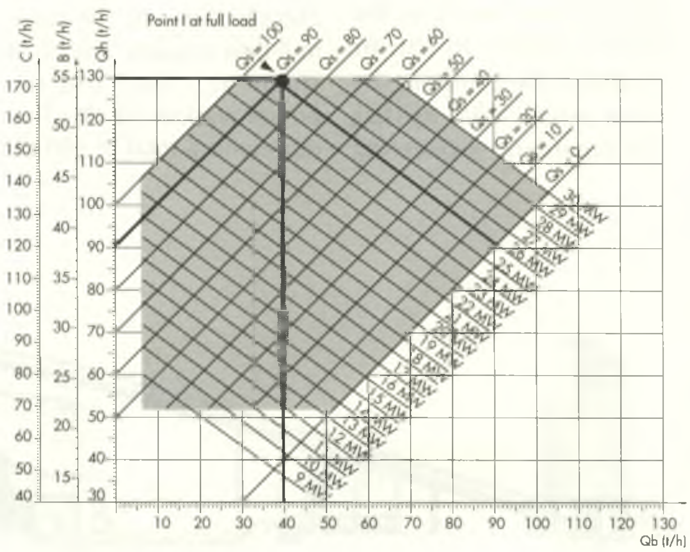


Figure 2. Graph of operations of the Bois-Rouge power station during the sugarcane processing period.

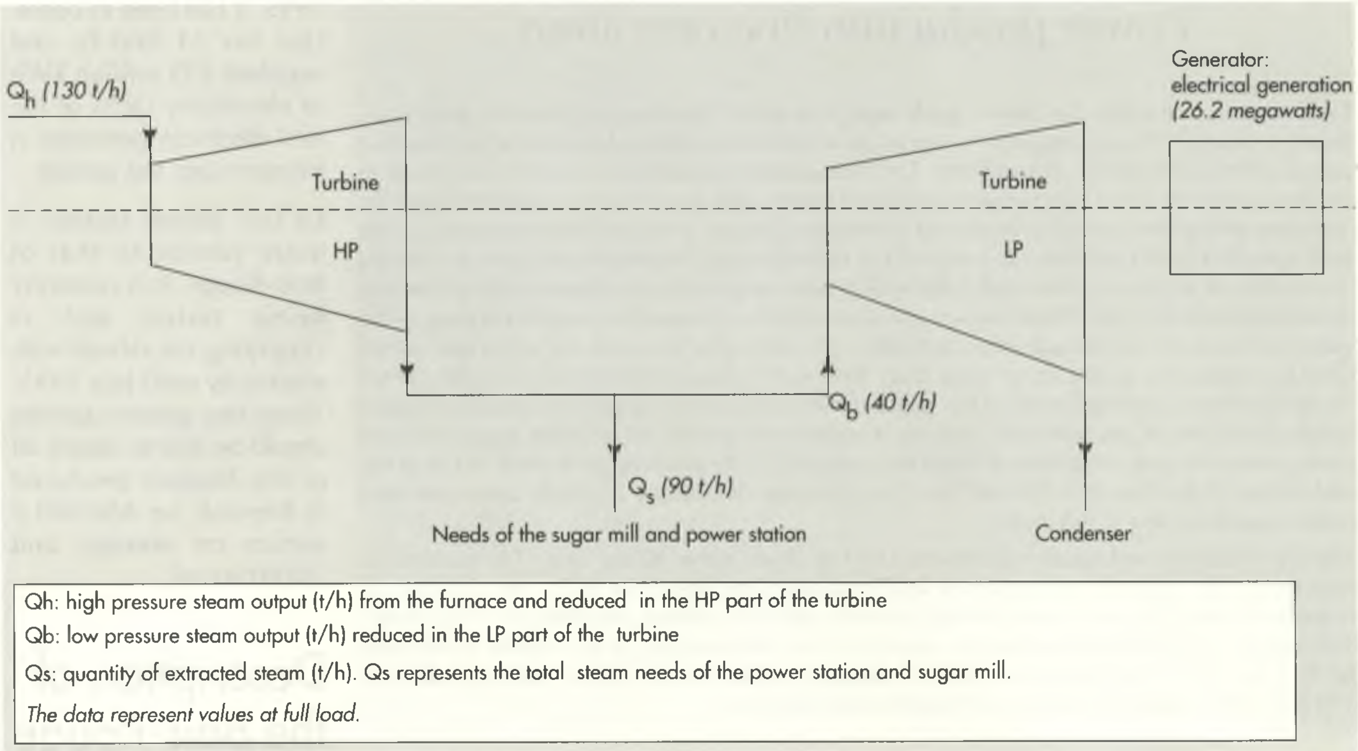


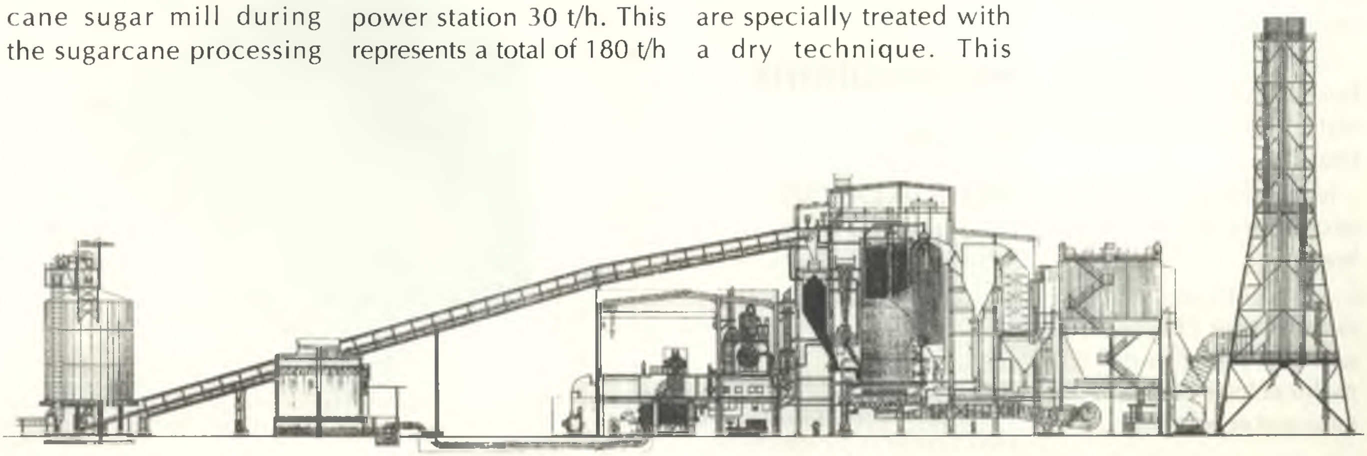
Figure 3. Steam circuit through a power production line of the power station.

The turbines (6 200 rpm) have a high-pressure part, where the steam pressure is reduced from 82 to 3 bar, and a low-pressure part, where it drops from 3 bar to the condenser pressure (about 125 mb). Between these two parts of the turbine, steam at 3 bar is extracted to provide a steady steam supply for the station itself (30 t/h, or 15 t/h/turbine), and for the cane sugar mill during the sugarcane processing period (75 t/h/turbine on average, maximum 85 t); this represents a maximum steam output of 100 t/h turbine.

In practice, at full load, the sugar mill processes 340 t/h of sugarcane and produces 110 t of bagasse, which is burned in the two power station furnaces to generate 260 t/h of steam. The sugar mill thus requires 150 t/h of steam at 3 bar, and the power station 30 t/h. This represents a total of 180 t/h steam reduced from 82 to 3 bar for cogeneration uses. The remaining 80 t/h are targeted to Réunion's power network and reduced a second time from 3 bar to 125 mb in the low-pressure part of the turbine. The cogeneration rate is thus defined as follows:

(180/260) x 100 = 70%.

Fumes ejected through the outlet valves of the furnace are specially treated with a dry technique. This treatment is performed with a multicyclone dust precipitator and then a electrostatic dust precipitator. Excellent results are obtained: fume dust levels are lower than 30 mg/m^3 for coal (environmental protection regulations stipulate that dust waste must be lower than 100 mg for bagasse and 50 mg for coal).



Elevation view of the furnace and peripheral elements. Supplied by the Compagnie thermique de Bois-Rouge.

Conclusion

The results for the Bois-Rouge power station, after 30 months of operations through three sugarcane processing periods, confirm that high quantities of electricity can be generated from bagasse fuel at competitive prices.

During the reference period, the power station availability was 90% (including regular annual shutdowns). Energy efficiency, as measured by an official organization, was 65% for a cogeneration rate of 70% during the sugarcane processing period.

Cogeneration has obvious benefits for the sugar industry: free energy supply (no investments or operational costs). Moreover, automatic switching from one fuel source to another is very convenient for sugar mill operations since there is a steady supply of steam regardless of operational variations. Finally, efficient use of local renewable energy is a prime asset.

The Saint-Pierre highlands (Southwest).
Sugarcane field in Réunion.
Photo R. Fauconnier

Abstract... Resumen... Résumé

B. ROBERT — **Cogeneration associated with cane sugar mills in Réunion.**

The Bois-Rouge and Gol power companies in Réunion have commissioned two generating stations fuelled by coal and bagasse, the fibrous residue of sugar cane refining. Each station uses special furnaces to burn bagasse thus producing the electricity and water vapour required by the mill and feeding electricity into the island network. The installations use the cogeneration principle, that is to say that electricity is produced by successive reductions in water vapour at high pressures (82 bar) and high temperatures (525°C) to low pressures (3 bar and 125 mb) and low temperatures (45°C in the condenser). From 1996, the two power installations will use all the bagasse produced by the Réunion sugar industry (650,000 tonnes) and will provide 55% of the island's power supplies.

Keywords: sugarcane, bagasse, fuel, electricity, Réunion.

B. ROBERT — **La cogeneración eléctrica en los ingenios de azúcar de caña de la isla de la Reunión.**

En la isla de la Reunión, las Compañias térmicas de Bois-Rouge y de Gol han puesto en servicio dos centrales eléctricas que utilizan como combustibles el carbón y el bagazo, residuo fibroso del procesamiento de la caña de azúcar en los ingenios. Cada central quema en calderas especificas el bagazo producido por una fábrica de azúcar. A cambio de éste, ofrece la electricidad y el vapor de agua que el ingenio necesita y también produce electricidad para la red de la isla. La central funciona según el principio de cogeneración eléctrica, es decir que fabrica la electricidad por expansiones sucesivas del vapor de agua a alta presión (82 bars) y temperatura elevada (525°C) hacia presiones bajas (3 bars y 125 milibares) y una temperatura también baja (45°C en el condensador). A partir de 1996, los dos centrales tratarán todo el bagazo resultante de la industria azucarera reunionesa (650 000 toneladas) y suministrarán el 55% de la electricidad de la isla.

Palabras clave: caña de azúcar, bagazo, combustible, electricidad, isla de la Reunión.

B. ROBERT — **La cogénération électrique dans les sucreries de canne de l'île de la Réunion.**

Sur l'île de la Réunion, les Compagnies thermiques de Bois-Rouge et du Gol ont mis en service deux centrales électriques utilisant comme combustibles le charbon et la bagasse, résidu fibreux du traitement de la canne à sucre dans les sucreries. Chaque centrale brûle dans des chaudières spécifiques la bagasse fournie par une sucrerie. Elle offre en échange l'électricité et la vapeur d'eau dont cette dernière a besoin, et produit également de l'électricité pour le réseau de l'île. Elle fonctionne sur le principe de la cogénération électrique, c'est-à-dire qu'elle fabrique de l'électricité par détentes successives de la vapeur d'eau à haute pression (82 bars) et température élevée (525 °C) vers des basses pressions (3 bars et 125 millibars) et une température faible (45 °C dans le condenseur). A partir de 1996, les deux centrales traiteront l'ensemble de la bagasse issue de l'industrie sucrière réunionnaise (650 000 tonnes) et fourniront 55 % de l'électricité de l'île.

Mots-clés : canne à sucre, bagasse, combustible, électricité, île de la Réunion.