John Thompson Mono-drum Industrial Watertube Boiler

Background

Early in industrialised sugar production, it was discovered that the biomass waste generated during the sugar milling process (bagasse) had potential as fuel to generate steam for prime movers and process requirements.

Prime movers evolved from basic steam engines, to more efficient steam turbine drives, and finally to steam turbine drives with electrical drives powered from turbo-alternators.

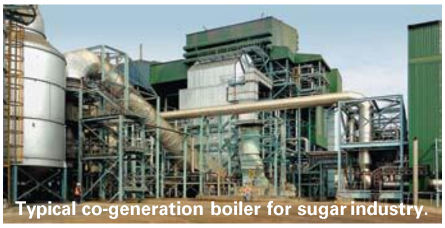
The negative environmental impact (and finite supply) of fossil fuels as a power-source has made "renewable energy" topical buzzwords, resulting in biomass fuels with low SOx and NOx emissions such as bagasse becoming increasingly desirable.

The feasibility for sugar mill power station projects is improving, due to legislation changes and market-driven incentives. Global interest has sparked a drive to develop the traditional sugar boilers into small-scale power utility units.


Sugar cane being processed.

Many sugar mills are located on tropical and sub-tropical islands, or in remote parts of developing countries, where a national electrical grid is either not available or notoriously unreliable, resulting in a discernable increase in dependence on electrical power from sugar mills in recent years.

Over the last three decades, the optimisation of power generation via biomass waste has been the focus of several feasibility studies, with some resulting in successful, lucrative sugar mill power station projects (e.g. in Reunion and Mauritius), which were designed to exploit the co-generation capabilities of sugar factories during crop season, and to generate power via supplementary fuel sources, e.g. coal, during off-crop.


Typical co-generation boiler for sugar industry.

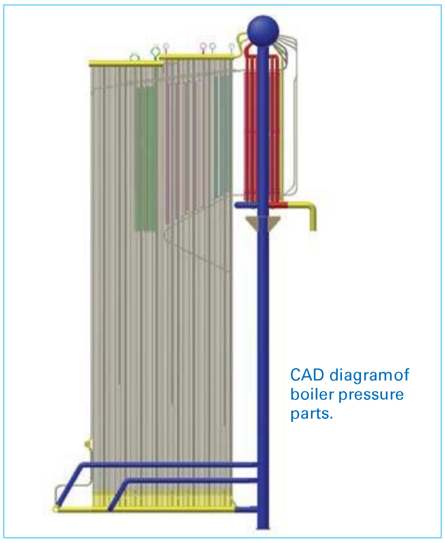
A Case for Higher Steam Pressures

Early sugar industry steam pressures varied between 19 bar and 31 bar. In order to improve the steam cycle efficiency for generating power at sugar mills, a logical step was to drive the steam conditions up, leading to a global trend.

At the time, Brazil was highly dependent on power from hydro-electric power stations and found that during their dry season, they could not sustain the growing demand for electricity. These periods of high demand coincide with the Brazilian sugar cane crushing season. The potential for electricity from co-generation at sugar mills became evident and incentivised the expansion of the sugar industry. In order to optimise generation efficiency, the Brazilian industry initially standardised on 63–68 bar boilers and more recently, boilers of 85 bar, 100 bar, and even 120 bar have been erected and commissioned.

Although the higher steam conditions increase overall cycle efficiency, the cost of the boilers and turbines increases sharply above 45 bar, as only exotic alloys can handle elevated temperatures and pressures.

Hence, the 85–120 bar stations were mainly constructed in areas where local power demand, or renewable power incentives, drove the price for electrical export to levels justifying capital outlay for expensive equipment.


CAD diagramof boiler pressure parts.

Until now, John Thompson has supplied bi-drum boilers to the sugar industry.

These efficient boilers are configured at steam pressures varying from 19 bar up to 45 bar. At these pressures, the expanded evaporation bank tubes, between the two drums, provides a very cost-effective boiler construction.

However, due to industry trends, John Thompson increasingly receives enquiries for boilers to operate at pressures of 65–120bar.

Bi-drum versus Mono-drum

In bi-drum boilers, the top of the mud drum and the bottom of the steam drum are always exposed to the hot flue gas. Furthermore, the steam drum level control range is limited by the roof and evaporation bank tube positions.

At high operating pressures, the use of bi-drum boilers has certain disadvantages/limitations:

1)Beyond 45 bar, the bi-drum design becomes very limiting due to drum ligaments, which necessitates impractically thick (and costly) drum shells.

2)The effectiveness of the evaporation bank decreases as the log mean temperature difference between the flue gas and the saturated water temperature drops, and the natural circulation of water and steam in the bank diminishes.

3) Expanded tubes are no longer viable.

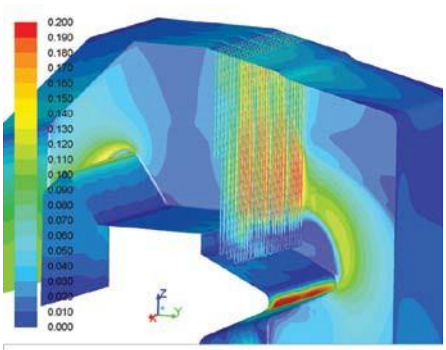
At pressures of 85 bar onwards, a mono-drum boiler configuration, similar to most large power utility boilers, needs to be considered.

Designing Mono-drum Boilers

John Thompson Watertube business unit has developed a mono-drum boiler suitable for burning bagasse, other biomass, and coal, to meet the requirements of the sugar, pulp and paper industries.

In designing new mono-drum boilers, the John Thompson philosophy was to retain the simplicity and proven reliability of the bi-drum as far as possible, while gaining the advantages of a mono-drum design.

The most noticeably change was replacing the conventional bi-drum mainbank with a flag-type evaporator and single drum.



CFD heat fluxdiagram.

The John Thompson Watertube engineering team has developed a range of boilers that can be bottom or top supported depending on application and evaporative rating, with nominal steam pressures and temperatures from 65 bar at 480°C up to 110 bar at 540°C.

The boiler design is based on proven John Thompson methodology combined with in-house CFD expertise to optimise the combustion, heat transfer and circulation while minimising the risk of erosion in the gas passes.

The pressure envelope is configured so that the unit can be bottom supported, using the furnace walls and down comers as support members, without any differential thermal expansions between any adjacent pressure parts. This configuration reduces the structural steel requirements significantly only serving to provide access on and around the boiler.

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