BAGASSE GASIFICATION RESEARCH LITERATURE SURVEY

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CONTENT PAGE

Title **Page**

CONTENT PAGE

FIGURES

TABLES

1. INTRODUCTION

This part of the research entails the subject or literature survey of the bagasse gasification systems in question. The following sections will highlight the different types of bagasse gasification systems including but not limited to their design, advantages and disadvantages. The intent of the literature survey is to assist the reader into understanding the reason(s) for the author to choose a particular type of the bagasse gasification system to base the research on.

The choice of the system is based on the author's confidence that it will give him the required conclusions both from a scientific perspective and a feasibility perspective.

2. LITERATURE SURVEY

The gasification system has been studied throughout the energy environment for a long time. This system has been implemented in countries that utilize carbonaceous compounds as their source of energy. Taking into consideration the main objective in researching new ways or systems in the energy environment, the main objective is to find cheaper and more efficient methods of energy (electrical) generation. Most of the work on the gasification systems has been done successfully with coal (Ahlawait, 2014).

Since the principle of gasification relies on the carbon content of the mother compound, this has resulted in the idea of developing a system that uses bagasse. As in any sugar cane sugar producing factories, bagasse is an abundant commodity and an almost free fuel source. Countries such as Brazil, Australia, India and China have undertaken experimental projects in this bagasse gasification field. It is believed that the success of the bagasse gasification system in the cane sugar industry would result in the energy efficiency of at least 45% more than the current system (direct combustion) (Granatstein, 2003). There are, however, some obstacles that needs to be overcome before the system can be adopted. One of the problems in countries such as South Africa is the inaccessibility of the experimental equipment to prove the theoretical benefits of the system.

Intense research, none the less, has been undertaken and the results prove that the system would result in higher steam/power plant efficiencies. Although the main focus would be an improved system, a study undertaken by Electrowatt-Ekono, Yaakko Poyry Group in the assessment of alternative and supplementary sources to bagasse for biomass energy generation has showed that a chemical content and the resulting by-products of the system needs to be considered in a thorough manner. This includes the disposal facilities or alternative usage of the by-products of the bagasse gasification process.

There have been a number of papers presented on this topic. Most of these papers in South Africa have concentrated on the evaluation of tests/experiments undertaken in other countries and relied on the accuracy of the data collected to conclude that this system can improve the efficiency of a steam/power generation plant. According to a paper presented by KTKF Kong Win Chang, *et al,* on Bagasse Gasification Technologies for Electricity Production in the Sugar Industry (Kong Win Chang, 1996);

"The conventional steam cycle using condensing turbo-alternator sets has a potential of producing annual exportable electricity of only 115kWh/t cane compared with 275kWh/t cane with the biomass integrated gasification gas turbine technology (BIG-GT) (Kong Win Chang, 1996)"

This statement is based on the assumption that the bagasse used will be the same quantity used on the conventional system. It is further stated that if the trash and tops of the cane were used, the estimated electrical energy that could be exported would rise to approximately 2050 GWh per annum. The exported amount is estimated after the assumption that the electricity requirement of the Mauritian sugar industry would have been fulfilled. The paper further compares the annual electricity production potential between using conventional steam cycle and using BIG-GT technology, Table 1 below tabulates the (*annual electricity production potential in Mauritius)* (Kong Win Chang, 1996).

Table 1: Example of Electricity Production Potential

	Conventional Steam Cycle		**BIG-GT Technology**	
	kWh/t cane	**GWh**	**kWh/t cane**	**GWh**
All bagasse for electricity production	143	825	303	1751
Less electricity for factory	28	162	28	162
Annual exportable electricity	115	663	275	1589
Cane tops and leaves @72% moisture	45	258	88	509
Less electricity for CTL processing	8	47	8	47

Annual exportable electricity	37	211	80	462
Total Exportable Energy	**151**	**874**	**355**	**2051**

The table above shows that using the conventional steam cycle, the electrical power generated would be 874 GWh compared to 2051 GWh if the BIG-T technology was to be used. This data is related to the cane/bagasse quantities of the Mauritian sugar industry taken in 1996.

Other publications such as *Gasification Technology by* P.A Hobson *et al*, also support the theory of improved energy efficiency of the bagasse gasification system (Hodson, 2009).

Some models that have been done have been based on new installations, however, the first step in the South African sugar industry, since possibilities of constructing new plants are diminished by the economic status of the country (and the sugar industry at large), the research should look at the systems that can be easily integrated into the current systems. This is shown on a paper by KTKF Kong Win Chang *et al*, from the Mauritius Sugar Industry Research Institute in Reduit, Mauritius on Bagasse Gasification Technologies for Electricity Production in the Sugar Industry which contain a possible system arrangement for a BIG-GT system that can be easily integrated into the current system (Wong Sak Hoi, 1999).

One of the methods that can be used to compare the conventional system to a bagasse gasification system is that a background on the technical content of these systems should be understood. According to the theory of heat engines developed by William John Macquorn Rankine, (1820 – 1872), an ideal condition of a heat energy converted to work system will only have an efficiency of between 22 – 26% depending on the thermal conditions and assuming a boiler efficiency of 100% (Contributors, Rankine Cycle, 2014). Comparing the standard back-pressure or condensing turbines used in the sugar industry these days to the gas turbines that would be used on the bagasse gasification system, it can be shown that the efficiencies are 45 – 50% and 60 – 85% respectively. The other main limiting factor on the direct combustion system is the entry temperature to the turbines which is typically 565°C (the creep limiting of stainless steel, which most commercially available turbines are designed with) (Contributors, Rankine Cycle, 2014), whereas the gasification plant can be operated at higher temperatures e.g. 900° to 1400°C. (Contributors, Combined Cycle, 2014)

A typical diagram of a Rankine Cycle is shown below;

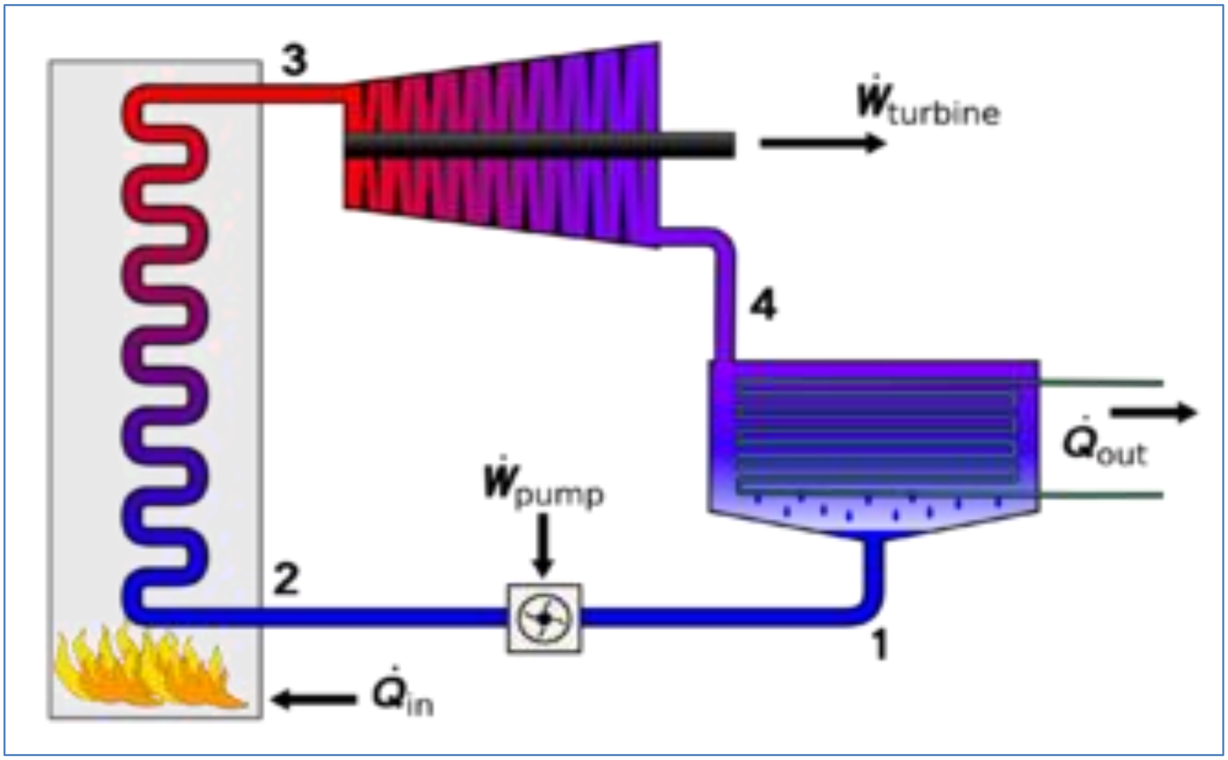

Figure 1: Rankine Cycle

From the data collected and papers referred to, it can be clearly concluded that the bagasse gasification system should have higher efficiencies as compared to the current direct combustion of bagasse in the boilers.

3. DEFINING THE GASIFICATION PROCESS

Gasification is a process whereby carbonaceous materials are converted into carbon monoxide and hydrogen by the reaction process of its raw materials at high temperatures with a controlled amount of oxygen and /or steam. It can be simplified as referring to it as a method for extracting energy from different types of organic materials. The resulting gas mixture is called synthesis gas or syngas. It is said that the efficiency of using the syngas is significantly higher than the efficiency of direct combustion of the original fuel because it can be combusted at higher temperatures so the thermodynamic upper limit to the efficiency, determined by Carnot's Rule which is a principle that specifies limits on the maximum efficiency any heat engine can obtain, is higher. A gasifier is a cylindrical enclosed reactor that is used to convert carbonaceous compounds into synthesis gas.

There are four main types of gasification processes available commercially, these are:

- Counter-Current Fixed Bed (up-draft),
- Co-Current Fixed Bed (down draft),
- Fluidized Bed Reactor and
- Entrained flow gasifier

3.1.1. Counter-Current Fixed Bed (up-draft)

This system has a fixed bed of carbonaceous fuel (e.g. coal or biomass) through which the gasification agent (steam / oxygen) flows in a counter-current configuration. The thermal efficiency of this system is high as the gas exit temperatures are relatively low. The tar and methane production (in coal as a gasification agent) is high at typical operation temperatures. The product gas must be cleaned before use and the Tar can be recycled to the reactor.

3.1.2. Co-Current Fixed Bed (down-draft)

In this type of gasification system, the gasification agent (gas) flows in a co-current configuration with the fuel entering downwards. The heat is added to the upper part of the bed, by combusting small amounts of the fuel or external heat sources. The energy efficiency of this system is the same as the up-draft gasifiers and the tar levels are lower than that of the up-draft gasifier.

3.1.3. Fluidized Bed Reactor

In this type, the fuel is fluidized in oxygen and steam or air. The ash is removed dry or as heavy agglomerates that de-fluidizes. The fuel required for this system must be highly reactive. The fuel throughput is higher than in the fixed bed gasifiers and the system is most useful to fuels with high corrosive ash.

3.1.4. Entrained Flow Gasifier

In this system, dry pulverized solid, an atomized liquid or fuel slurry is gasified with oxygen in a co-current flow. The tar and methane are not present in the product gas. The oxygen requirement is higher than in the other gasifiers meaning that most energy consumption is used for oxygen production that is required for the process rather than the gasification process itself.

3.2. Gasification of other fuel sources (tested systems)

There has been a number of projects undertaken to test the effectiveness of the gasification processes. Most of the processes used coal as the carbonaceous material to be gasified. A brief process and plant layout of an IGCC plant as presented by *Wikipedia Interaction Forum* (Contributors, Integrated Gasification Combined Cycle, 2014) is shown below:

Integrated Gasification Combined Cycle

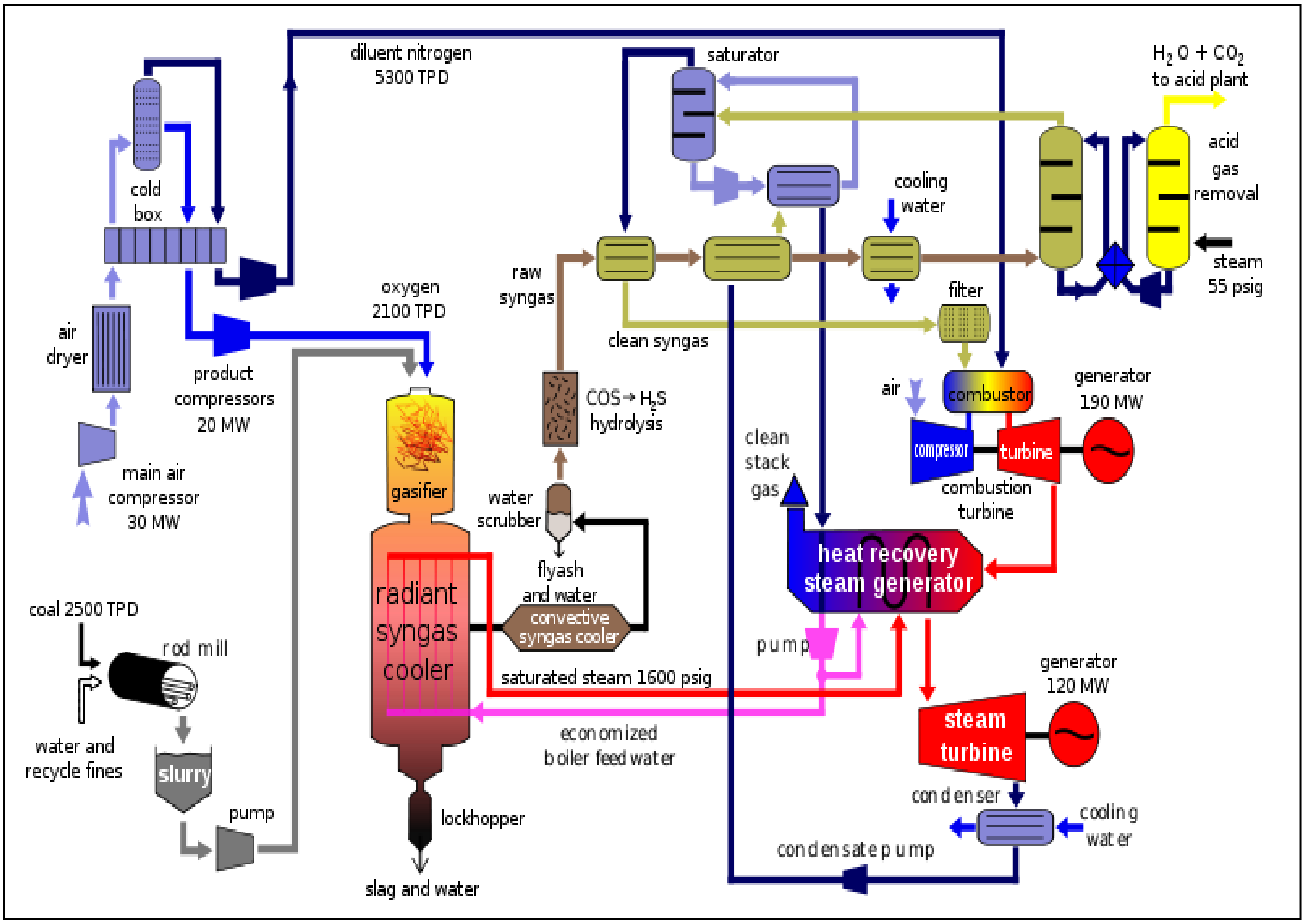

Figure 2: Block Diagram of IGCC Plant which Utilizes HRSG

The above plant is called integrated because its syngas is produced in a gasification unit in the plant which has been optimized for the plant's combined cycle. In this example, the syngas produced is used as fuel in a gas turbine which produces electrical power. To improve the overall process efficiency, heat is recovered from both the gasification process and the gas turbine exhaust in waste heat boilers that produces steam. This steam is then used in steam turbines to produce additional electrical power. In the case of a sugar industry, this steam would also be used as process steam. Process steam, in the context of a cane sugar factory, is the steam used for the process heating or boiling of the juice extracted from cane.

3.3. Relation to the Cane Sugar Industry

If a new cane sugar mill was to be designed or constructed, a similar set-up could be adopted with the difference in the fuel being bagasse rather than coal. However, due to the current economic crisis, the cane sugar industry would prefer to modify the existing plants as compared to designing new ones.

A paper titled: *Bagasse Gasification Technologies for Electricity Production in the Sugar Industry presented in Proc S. Afri Sug Technol Ass (1999)73 by KTKF Kong Win Chang et al,* (Wong Sak Hoi, 1999)has compiled the different technologies that could easily be integrated into current cane sugar industry steam generation plants. This paper presented the following Biomass Integrated Gasification Gas Turbine systems:

- BIG-OC- Open Cycle,
- BIG-CC-Combined Cycle, and
- BIG-STIG-Steam Injection
- BIG-ISTIG-Steam Injection with Intercoolers and
- BIG-ICR-Cycle with Intercoolers and Regeneration

Whereby BIG-OC, BIG-CC and BIG-STIG are currently available technologies and BIG-ISTIG and BIG-ICR are possible future technologies.

3.4. Chosen gasification system for further study

As far as the research contained in this report, the option of choosing a preferred system is based on the available information. The system chosen is a Co-Current Fixed Bed System. In this system, the energy efficiency is maintained by transferring most of the heat generated during the process to the gasification agent entering in the top of the bed. It should be noted that at this stage of development of these processes, the choice of a particular type of process used is a matter of personal preference as almost all the systems are at an experimental phase for bagasse as a feedstock.

A BIG-CC system would be an ideal as it can allow the gasification plant to be operated in conjunction but independent of the conventional boiler system.

4. CONCLUSION

From the data collected and papers referred to, it can be clearly concluded that the bagasse gasification system should have higher efficiencies as compared to the current direct combustion of bagasse in the boilers.

Looking at the future of the sugar industry, it is vital to undertake any initiative that would see the industry into a more sustainable future. Although a lot of work and experiments still has to be undertaken, it is clear that a bagasse gasification system is more efficient than the direct combustion system.

It can therefore be concluded that a bagasse gasification system should be looked at in detail and be adopted as a standard for the sugar industry. Before the implementation, it should be noted that this system relies more on the chemical reactions and the resulting gases or products should be analyzed thoroughly to understand the effect they would have on the environment. Also, it should be noted that any new system requires a trial period so to determine its reliability in practice. This would be best achieved by the BIG_CC, which does not entirely remove the current system but instead integrates the gasification system into it.

In the subsequent section, the evaluation of efficiencies will concentrate on the CCFB system in a BIG-CC configuration.

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