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Norampac and Georgia-Pacific: An Overview Comparison of Key Differences between the Projects

Introduction

TRI licensed its technology for a black liquor steam reformer to Norampac at about the same time it did so with Georgia-Pacific (GP). The Norampac steam reformer began operation before GP's, and achieved dramatically better results. Ultimately, GP decided not to continue operating their reformers. It is regrettable that GP's experience led to this decision. The comparison below helps explain the key differences between the two projects.

Although the two projects were undertaken in parallel, the execution strategies were very different. On the Norampac project, TRI was responsible for the process engineering, detailed design and the supply of all equipment, including instrumentation, for the reformer island. On the GP project, TRI only supplied the PC Heaters and the performance specifications. The detailed design of the reformer island and supply of all the equipment was undertaken by an Engineering Contractor working for GP. During the project execution, TRI was not afforded the opportunity to review or comment on the system design. The main performance differences between Norampac and GP steam reformers resulted directly from deviations made from the performance design specifications provided by TRI.

Background

Norampac Inc, Trenton, Ontario.

Norampac, a division of Cascades Inc Canada, is the largest manufacturer of containerboard in Canada. Its Trenton mill produces 500 tons per day of corrugating medium from mixed hardwoods semi-chem pulp and old corrugated containers (OCC). The mill is a zero effluent facility and is committed to the highest environmental standards and operating efficiency. Prior to installing the TRI spent liquor gasification system the mill had no chemical and energy recovery process. Spent liquor was stored in ponds and sold to local counties for use as a binder and dust suppressant on gravel and dirt roads. This practice was terminated in 2002. After reviewing all options for the processing of spent liquor, Norampac chose the TRI system because it would provide the capability for both chemical and energy recovery, have minimal environmental impact, have a scale-up and turndown capability to meet current and future mill needs, allow the mill to continue as a zero effluent operation, and be affordable.

The spent liquor gasifier is designed to processes 115 Metric tons per day (127 short tons per day) of black liquor solids (at 40% moisture content) in a single reformer vessel with 4 pulsed combustion heaters. The chemicals are recovered and sent to the mill for pulping and the energy is recovered as steam which offsets the production of steam using purchased natural gas. The process started up in September of 2003. The project completed its performance test in April of 2005 and it completed air emissions testing in October 2006 thereby transitioning from commissioning to full commercial operation. The gasifier has logged more than 18,000 hours of operation.

Georgia-Pacific Corporation, Big Island, Virginia

Georgia-Pacific Corporation is one of the world's largest paper companies. The Big Island mill produces 730 tons per day of linerboard from OCC and 870 tons per day of corrugating medium from mixed hardwoods semi-chem pulp. The Steam Reformer project was environmentally driven, displacing two 50 year-old smelters that provided chemical recovery but no energy recovery. The project was funded 50% by the U.S. Department of Energy as a demonstration project for low temperature spent liquor gasification. The system was designed to process 200 tons per day of black liquor solids (at 40% moisture) and utilized two reformers, each with 4 pulsed combustion heaters.

Performance Highlights

The Norampac system started up in September 2003 and has demonstrated 91.5% availability in 2005 and 87.2% availability in 2006 vs. the mill operating budget. To date, the system has accumulated over 18,000 hours of operation while recovering 97.5% of the sodium in the liquor. With continuous system optimization and implementation of recent design enhancements, the availability is expected to reach 95%. As a result of the stability of the steam reformer process, Norampac was able to reduce staff to only one operator per shift.

The GP steam reformers started up in January 2004, and over a similar time period, only achieved 8,500 hours of operation on both reformers. GP's process commissioning was interrupted on several occasions by flow measurement problems and non-process related mechanical failures such as fan bearings, high temperature pump and damper problems, etc. Once these were resolved, and the system was able to operate for longer periods, the result of the deviations from design specifications became evident. The major design differences are highlighted below.

Reformer Fluidization – Both Norampac and GP used bubble cap style fluidizing steam distributors. The Norampac steam distributor was designed for high pressure drop (to ensure uniform bubbling from each cap) and the bubble caps were uniformly distributed over the reformer cross-section. The GP distributor was designed with much lower pressure drop (limited by air compressor supply pressure) and the bubble caps were concentrated in the quadrants, leaving gaps down both center lines of the reformer. This deviation proved to be a major operational deficiency, and the non-uniform fluidization patterns caused the bed to defluidize inside the heater bundles, leading to bed agglomeration. GP, Norampac and TRI collaborated on a 1/3 scale cold flow model testing program that confirmed the Norampac grid design and verified the deficiency of the GP grid design. GP used the cold flow model results to design and test an alternative steam grid. Once this new grid was installed, GP started to achieve longer operational campaigns.

Fluidizing Steam Temperature – The fluidizing steam is superheated through heat recovery with the PC heater flue gas. At Norampac, the fluidizing steam is superheated to 1100 °F, but at GP the superheater was undersized and the fluidizing steam was only delivered to the reformer at approximately 900 °F. The zone between the steam grid and the liquor injector, where the steam partial pressure is high, represents the char reaction zone. When steam is introduced below its reaction temperature, the efficiency of char conversion is decreased. Any energy extracted from the bed material to heat the fluidizing medium up to bed operating temperature robs energy from the injection zone, which has a very high energy demand. Colder injection zones can lead to higher tar formation during pyrolysis of the liquor. This design deficiency could only be addressed by the installation of a duct heater or secondary superheater system to increase the fluidizing medium temperature, but was never implemented by GP.

Liquor Uniformity – TRI specified uniform liquor injection utilizing the complete cross-section of the reformer to maximize liquor contact with the fluidized bed. This promotes rapid heating of the liquor by the bed solids which maximizes volatile yield and minimizes tar production. In addition, since the liquor at both Norampac and GP contains 40% water, the resulting steam bubbles would be uniformly distributed over the bed cross section for consistent fluidization. For this liquor, the target injection flow is about 1 GPM/injector and Norampac had 28 liquor injectors that penetrated the bottom of the vessel in a uniform pattern. During operation, the introduction of liquor in this uniform manner does not disrupt the uniformity of bed fluidization. In contrast, GP only had 12 liquor injectors that penetrated the side of the vessel forming a circular pattern. In addition, due to layout constraints, the liquor injectors were positioned such that only 3 of the 12 injectors were below the criss-cross heater bundles, with the balance pointing directly into the open quadrants. The high liquor flow per injector and the injector layout encouraged bypassing of the heater bundles, resulting in cooler liquor injection zones, more tars production and reduced carbon conversion. Controlled tests at the pilot scale have demonstrated that well-atomized liquor droplets that are uniformly distributed over the whole bed cross-section increase syngas generation and improve carbon conversion. Similarly, simulating poor liquor atomization and distribution, i.e. large droplet size and/or concentrated flows of liquor into a small volume of the fluidized bed, results in less syngas production. When poor liquor uniformity was simulated, the pilot heater bundles dropped their energy input by 10-20% in response to the lower endothermic heat requirement (reduced carbon conversion), syngas production fell by a corresponding amount and increased tars generation was observed.

PC Heater Heat Transfer Coefficients – The measured Heat transfer in the PC heater tube bundles at Norampac was excellent. The overall heat transfer coefficients were measured at 95% of maximum design coefficients. Heat transfer coefficients at GP were substantially lower, despite identical heater designs. The higher liquor flows per injector (larger steam bubbles at injectors) and the non-uniform injection pattern at GP caused significant disruptions in bed fluidization and encouraged heater bypassing. This resulted in sub-optimal fluidization inside the heater bundles, inhibiting heat transfer performance.

Bed Removal – TRI specified bed removal from the bottom of the vessel to preferentially extract bed solids that had passed through the char conversion zone and any oversize particles that have settled to the bottom. Norampac has had relatively good experience with the TRI-specified removal of the bed through three lock hoppers in the bottom of the vessel. GP's engineer elected to remove the bed material from the side of the vessel via a single lock hopper, near the first pulse heater, and directly above the liquor injection zone. Extracting bed material at this point not only allows short circuiting and reduced residence time, but also disrupts the wall effect and changes material flow patterns in the vessel. The effects of this disruption could be detected in the heater bundle temperature measurements. Over an extended period of operation, larger particles would accumulate at the bottom of the reformer and when they built up to the level above the steam grid, the bed fluidization would be compromised. GP installed a manual intermittent single lock hopper system at the bottom of the reformer to address this but stopped using it for safety concerns.

Pulse Heater Reliability – Full scale operation of the PC heaters in both Norampac and GP revealed that there were several areas that needed design improvement; aerovalve assemblies, temperature measurement, baffles and the decoupler seal. These design improvements were implemented on both projects to improve the PC Heater reliability.

There were two additional areas where performance differed between Norampac and GP. GP experienced stress corrosion cracking of the combustion chamber tube sheets. Third Party forensic testing revealed that the cracking was caused by caustic deposition resulting from excursions in boiler feed water quality. This kind of failure has been thoroughly inspected at Norampac with negative results.

The PC heater refractory at Norampac has continued to perform well over the past three years of operation. However, GP experienced failures after very short duration runs. After testing several different refractory materials, it was eventually determined that the refractory was over heating because of maldistribution of combustion air, resulting from the air intake being much smaller than recommended; the velocity profile entering the heater was too high. By designing and installing a distributor to improve combustion air distribution to the aerovalves, the combustion chamber temperatures cooled and became more uniform resulting in dramatically improved refractory life.

Summary

It is regrettable that GP chose not to continue the project, especially in light of Norampac's success. This outcome reinforces the need for close collaboration between the technology supplier and the owner in the early stages of project development for new technologies. TRI's long term partnership with Norampac will result in continued improvement of the technology.