Batch Displacement Cooking & Retrofit Solution for Existing Indian Pulp Mills

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There is a big need to improve the old cooking system in terms of efficiency & fiber strength. The conventional batch digestors and RDH systems can be upgraded to DDS (Displacement Digestor System). This leap can be taken in 2 steps. The 1st one is called DSS Digestor Steam Saving System & then to complete DDS.

INTRODUCTION

What is Conventional Batch Digesting?

Conventional batch reactors are operated in a batch scenario. That is, the reactants are put into the reactor vessel and allowed to react to produce a product, which is then expelled to complete a cycle. This operation is repeated ad infinitum to produce a product on a continuous basis. With reference to the pulp industry, the reactor is referred to as the digester, the product is the cellulose fiber, the reactants are cellulosic bearing furnish (wood or non-wood) and white liquor, and the reaction by-products is the black liquor. The fiber is removed from the digester along with the black liquor. The black liquor by-product contains residual heat and unused chemicals which are not collected for further reuse.

Basic Concept of Displacement Batch Digesters

Despite the various trade names and different supply companies, the basic concepts of displacement batch technology are standard for all commercial offerings. That is, furnish is fed into the batch reactor, the furnish stays in the digester while various liquors from the tank farm are pumped through the bed of furnish which eventually becomes fiber, after the delignification procedure the spent liquor (black liquor) is displaced with washer filtrate to be stored and reused, and lastly the product fiber is discharged to prepare the reactor for the next batch or 'cook'. The stored liquors in the tank farm, having different characteristics of temperatures and Kraft cooking chemicals, are used to heat the furnish or fiber while exposing them to different concentrations of chemicals during the distinct steps of the cooking cycle.

What is the Tank Farm?

The tank farm is a number of vessels used to store spent cooking liquor with the main function being to service the digesters (feed the digesters liquor) which are making product cellulose fiber. The tank farm has pressurized vessels to maintain the stored liquor at temperatures above their flash point as well as atmospheric tanks. The amount of liquors diverted into each vessel from the digesters is based on temperatures and mass balances. Unused liquors in the tank farm are released from the storage vessels while transferring any excess heat into incoming liquors or to cool water to generate hot water. There are many different tank farm configurations depending on the chemical and heat demand determined from the furnish type and quality, as well as the desired finished product type and quality.

Is the Product Produced Continuously?

The advent of the electronic control system in the 1980's, the DCS, has enabled batch reactors to produce product on a continuous basis inherent in plug flow reactors, commonly referred to as a 'continuous digester' in the pulp and paper industry.

Where did Displacement Batch Digesting Start?

In the 1980's trials at Assi Doman in Sweden with collecting the hot spent cooking liquor (hot black liquor) from the digester before the pulp stock was removed (blown) with the hope of reusing the residual heat contained in the liquors for subsequent use in future cycles. The method that was invoked to accomplish this was to displace the hot liquors in the digester with cool washer filtrate that is otherwise sent to the evaporator before the pulp product was removed. It was reasoned that the displaced hot spent liquors could be stored in a tank farm that was comprised of pressure vessels for reuse.

The primary goal of this additional equipment and complexity was to reduce energy costs. The energy savings have been reported to be 50 to 70% by the various suppliers.

The concept eventually was obtained by Radar in Stockholm, Sweden who further developed the technology and marketed this system as RDH, an acronym for Radar Displacement Heating to accompany their RDC digester circulation product.

Serendipitously, while the technology was owned by Beloit of the USA it was discovered that there were other benefits to reuse the hot spent liquor due to residual chemicals in the recycled liquors. These chemicals increased the selectivity of the cooking reactions which subsequently increased

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the pulp fiber strength while allowing the removal of more lignin from the furnish in the digester (i.e. cooking to a lower kappa number). This decreased the lignin removal requirement downstream in the bleach plant equating to lower effluent COD which has pollution implications.

What are the Commercial Systems Offered ?

The owner of Radar at the development time, Rauma Repola of Finland, sold Radar to the Beloit Corporation in the USA with an agreement to retain the use of Radar's RDH technology that was developed to that point in time. Simultaneously with the sale of Radar, Sunds Defibrator of Sweden joined with Rauma Repola. Sunds' Defibrator then developed and marketed a displacement technology under the name of Cold Blow with mixed results. Sunds Defibrator paid royalties to Beloit to use the Radar technology. The two groups at Radar and Sunds Defibrator continued to develop the concept and Sund's marketed joint developed system under the name of Super Batch, while Beloit eventually marketed it under RDH Stage II. The Beloit system was still marketed under the acronym RDH, but Beloit changed the reference to Rapid Displacement Heating. Further RDH developments by Beloit yielded modifications to their systems which were referred to by various titles such as: RDH Stage III, RDH IIIM, RDH 2000 and recently as RDH DD. The majority of the sales for Beloit where with the RDH IIIM in the early 1990's. GLV of Canada purchased Beloit's fiber systems, including the RDH after Beloit's demise in 1998.

Sunds, today absorbed into the Metso Company, maintained the name SuperBatch for all their batch cooking systems with variations such as Super batch K. Recently, GLV of Canada has obtained the Superbatch system from Metso and now owns both the RDH and the Superbatch concepts and is expected to consolidate them. Another company from Austria also attempted this blend of batch cooking with recycle liquor management under different trade names such as EnerBatch and CBC.A new company, CabTec International has studied and refined all the concepts of Superbatch, RDH Enerbatch and CBC to create an advanced displacement batch cooking system simply referred to as DDS for Displacement Digester System. The DDS can be installed immediately or in two phases by first installing a partial DDS system refered to as DSS for Digester Steam Saver. All of CabTec's systems are marketed by Chemical and Pulping Limited (CPL).

Chemical and Pulping Ltd Cooking Systems

The Digester Steam Saver system, DSS is designed for steam savings only and does not offer the reaction benefits of reuseing the residual chemical energy in the spent liquors for hardwood, tropical hardwood, softwood and bamboo. The DSS Type D system has an energy recovery phase in the cooking cycle which is equivalent to one vacuum washer stage of solids removal. The DSS is designed to save energy at a low cost, but this system does not offer the beneficial chemical effects of a true. **DISPLACEMENT DIGESTER SYSTEM - THE DDS.**

DDS in Two Phases with DSS

The DDS system can be installed in two phases in order to minimize capital investment by installing the DSS system in phase one and the remaining required equipment needed for a full displacement DDS in phase two.

The DDS Displacement Digester cooking systems for hardwood, tropical hardwood, softwood and bamboo. These systems reuse the spent cooking liquor to impart chemical benefits to the pulp which allows for low kappa cooking while maintaining high pulp strength. The energy recovery phase of the cooking cycle is equivalent to one vacuum washer stage of solids removal. The Displacement Digester System is designed for a higher steam saving than the DSS as well as adding chemical benefits for low kappa high strength fiber (extended delignification).

In summary, the DSS does not require a tank farm the size of DDS. The DSS Type R and Type D both require only one pressure vessel. The Type D allows for energy recovery similar to a displacement digester system (ie. one washing stage equivalent), however the spent liquor is not reused as in the displacement digester system (DDS) which precludes the chemical benefits similar to the other DDS. All of the DSS configurations are a very economical first option versus the DDS since all the equipment can be used to progress to the DSS, a true displacement digester system, at a future time.

The following table is a summary of the systems offered and is organized according to the following:

- From the top to the bottom in increasing capital investment
- From the top to the bottom in decreasing operational costs
- From the top to the bottom in additional equipment indicating that any systems can be upgraded at a future date. That is, all equipment is utilized from one system to the next advanced system.

RESULTS BASED ON THE EXPERIMENTS DONE

DDS Offers Higher Cooking Performance

Heating Efficiency

The DDS system pumps liquor through the bed of chips in the digester. The digester and it's contents start at ambient temperatures. Liquor is pumped through the digester to increase the temperature of the contents until it reaches close to the cooking temperature. The two phases of liquor pumping are referred to as the warm fill and the hot fill. If needed, steam is added to the digester after the hot fill phase. The digester then continues to cook until the target kappa number is reached.

Increased Strength

The liquors used in the warm and hot fill have reaction chemicals and enough heat energy to delignify the wood or bamboo furnish, despite not being at the final cooking temperature. This activity removes up to 50% of the lignin in the furnish before the digester enters

Table of Cooking Systems Comparisons

Product	Steam Consumption	Washing in Digester	Cooking Chemistry
DSS Family			
DSS Type E	Minimum	none	conventional kraft
DSS Type T	Moderate	none	conventional kraft
DSS Type D	Good	one vacuum washer	conventional kraft
DDS Family			
DDS Model P	Better	one vacuum washer	kraft extended delignification
DDS Model G	Best	one vacuum washer	kraft extended delignification

the time-at-temperature cooking phase. Therefore, the final removal of lignin at the higher cooking temperature can occur with a lower alkali concentration. The lower alkali concentration at the high cooking temperature does significantly less damage to the fiber compared to conventional cooking. This is one of the reasons that the DDS system will produce higher strength fiber at the same kappa number or similar strength fiber at much lower kappa numbers compared to conventional cooking.

DDS versus RDH

The DDS cooking system is an enhanced design of the RDH cooking system. The modifications create more stable temperatures and residue chemicals in the tank farm, less channeling in the digester, and more efficient pulp discharge to ensure lower kappa variation, more consistent production rates, and highly automated cooking operations with minimum operator intervention. This superior design has addressed these performance concerns by better piping configurations, better heat exchanger design and most importantly, through the use of modern process control techniques (Advanced Process Control).

Tank Farm Temperatures

The DDS tank farm produces a higher temperature accumulators with better temperature segregation. The higher temperatures at the beginning of the cooking cycle remove and strip out of the digester substantial amounts of byproducts to allow for a lower alkali charge later in the cooking cycle which thereby producing less fiber damage. This is also the reason that the DDS is able to cook bamboo with other woods and produce quality fiber.

Proprietary Advanced Process Control

Digester Discharge

Displacement batch digesters are not pressurized after the cooking is completed due to the displacing of the hot spent cooking liquors to the tank farm. Therefore, the pulp in the digester can not be 'blown' or flashed to a blow tank similar to conventional batch digesters because most of the energy has been displaced to the tank farm. The technique used to empty the digester is to pump the contents from the digester. However, as the level of the digester decreases the $NPSH_{available}$ decreases, the pulp consistency varies and the tendency for high consistency pulp clumps creates a constantly varying suction environment to the discharge pump. The DDS control system has minimized these challenges with 'fuzzy logic control (FLC)'.

Tank Farm Management

The tank farm is used to store chemical and thermal energy contained in the hot spent cooking liquors for reuse. The tank farm serves the digesters, which need to produce pulp without disruption. The DDS cooking system uses 'model predictive control (MPC)' to predict the levels in the tank farm which are used to make adjustments to the flows between the tankage as well as to the digester scheduler.

Digester Channeling

The flow of liquid in the digester must remain in a 'plug flow' profile with an interface zone between the different fluids as thin as possible. The DDS™ cooking system uses 'multi-variable control (MVC)' to maintain plug flow inside the digester.

Piping Techniques

Digester Discharge

The DDS cooking system has minimiz--ed suction head variations to the discharge pump by using new piping configurations.

Temperature Variations

The DDS cooking system uses various piping connections for liquor segregation to minimize temperature variations in the accumulators.

Digester Connections

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Case Study: RDH to DDS upgrade at DingFung Pulp in Guangdong, China

DingFung pulp (bleached 30% bamboo 70% mixed hardwood) upgraded their RDH system to DDS in 2004 (the first DDS installation) with the following results:

REFERENCES

www.chempulp.com

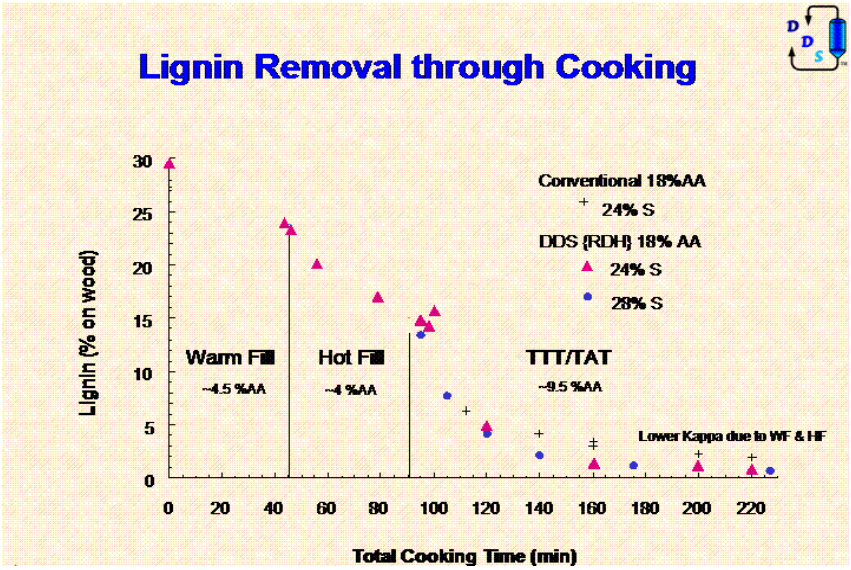
Handbook for Pulp & Paper Technolog--ists; Smook, G.A.
Environmental Engineering Reference Manual; Lindeburg, Michael R.

Chemical Engineering Reference Manual; Robinson, Randall N.

Appendix

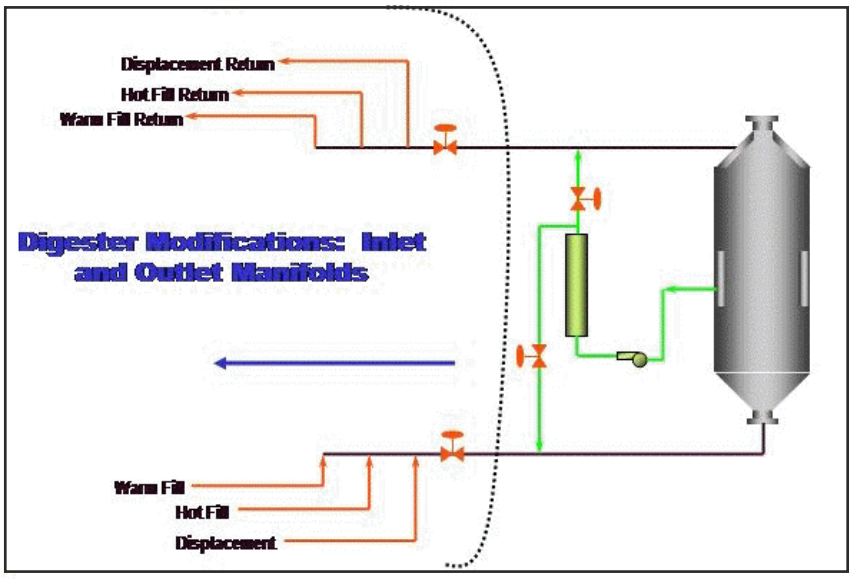
Who Owns the Technology?

The basic patent for displacement technology was owned by Beloit until their disbandment in 1998, at which



(Source NC State University; Raleigh, NC; USA)

Item	Unit	RDH 10/03 - 3/04	DDS 4/04 - 11/04	Difference	Note
Digesters	-	3	4	+1	
Production	t/month	5905	8138	+2233	9000t in Aug 04
Yield/cook	t/cook	10. 6	11. 1	+0. 5	
Bleaching Pulp Yield	%	47. 4	47. 7	+0. 3	
Steam Consumption	t/tp	0. 93	0. 80	-0. 09	
Reject rate	%	4. 2	2. 3	-1.9	
Kappa no.	-	15. 7	14. 6	-0.9	
Defoamer usage	kg/tp	1. 35	0. 93	-0. 42	
Residual alkali	%	0. 50	0. 41	-0. 09	
Chlorine	kg/tp	87. 5	4 - 7 / 04: 85.1 8 - 11 / 04: 69.0	-18. 5	60. 5 in Nov
Brightness	%ISO	87. 9	88. 2	+0. 3	



time it was purchased by GL&V of Canada. This basic patent does not cover countries in Asia Pacific, and will expire worldwide shortly. The other related patents that Beloit owned were also purchased by GL&V of Canada, but they only cover a few countries in the world and almost none in Asia Pacific. CabTec International respects patent protection and does not offer unauthorized technology. The information concerning patents as well as an electronic search function can be accessed at various government websites, including the US Patent Office and the Canadian Patent Office.

Original Basic Batch Digester Displacement Patent; Designee: Radar Beloit - GL&V (Expired)

Fagerlund, #4,578,149; Process for Digesting Cellulosic Material with Heat Recovery. This is the basic concept for DDS, RDH, SuperBatch, EnerBatch and CBC. Expired in March 2003.

Related Patents and Filings (Partial Listing)

Designee: CabTec International llc

Bianchini, #6,752,903; Method and Apparatus to Mitigate the Interference Caused by High Molecular Weight By-Products in Pulping Processes. Expiration in August 2021.

Bianchini, Patent Pending; Method and Apparatus to Distribute the Inflow of Liquors in a Batch Digester. This is marketed with the DDS and DSS systems. Filed on 19 Jan 05.

Bianchini, Patent Pending; Method and Apparatus to Decrease Steam Con--sumption in Conventional Batch Digesters. This is marketed as the DSS system. Filed on 19 Apr 05.

Bianchini, Patent Pending; Method and Apparatus to Optimize Displacement Batch Cooking Using Advanced Control. This is marketed with the DDS system. Filed on 8 Mar 05.

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