Some notes on developments in high grade continuous evaporating crystallization

Einige Bemerkungen zur Entwicklung der kontinuierlichen Verdampfungskristallisatoren

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Improving operational efficiencies, when crystallizing high grade massecuite in continuous evaporating crystallizers (continuous vacuum pans), has been the focus of considerable effort within the Fives Cail Group. This has resulted in the implementation of several innovations to both the operation and design of continuous evaporating crystallizers. Operational developments include methods for controlling encrustation build-up as well as means for improving the efficiencies of cleaning the evaporating crystallizers to remove encrustation using water, steam and juice as alternatives. Design innovations include the development of the Fives Cail double and Fletcher Smith split evaporating crystallizers. The advantages of these alternatives compared with standard units are described and details of practical results from actual installations are also provided. Approaches for achieving efficient operation are also described.

Key words: massecuite, continuous evaporating crystallizers, encrustation, crystallization

Für die Verbesserung der Effizienz bei der Kristallisation von Magmen hoher Reinheit in kontinuierlichen Verdampfungskristallisatoren werden innerhalb der Fives-Cail Group große Anstrengungen unternommen. Daraus resultierte die Einführung verschiedener Neuerungen sowohl bei den Arbeitsabläufen als auch in der Konstruktionsweise dieser Kristallisatoren. Es wurden Verfahren zur Kontrolle der Belagbildung ebenso entwickelt wie Methoden zur Verbesserung der Wirksamkeit bei der Belagentfernung, bei denen alternativ Wasser, Dampf oder Saft genutzt wird. Zu den innovativen Konstruktionen zählen der Doppel-Kristallisator von Fives-Cail sowie der geteilte Kristallisator von Fletcher Smith. Die Vorteile dieser Anlagen werden mit herkömmlichen verglichen und es werden praktische Resultate aktueller Installationen aufgeführt.

Stichwörter: Magma, kontinuierlicher Verdampfungskristallisator, Belagbildung, Kristallisation

1 Introduction

The advantages of using continuous evaporating crystallizers (or continuous vacuum pans – CVPs) mean their use is increasing with the Fives Cail group (FCG) now having a total of 390 units installed or under construction worldwide (Fig. 1).

With high grade (HG) massecuites, for present purposes considered as those used for producing a product sugar from a massecuite with a purity greater than 75%, the benefits are especially significant and should make their use particularly attractive. Yet concerns over perceived problems, mainly to do with encrustation, mean only just over 30% of the presently installed FCG units are used for this duty. The FCG, Tongaat-Hulett Sugar (THS) and others have, as a consequence, spent some considerable effort developing operational techniques and plant and equipment design improvements for eliminating or minimizing the effect of these problems.

Fig. 1: A 200 m³ split CVP of the Fletcher Smith/Tongaat-Hulett design in Guatemala

2 Appraisal of high-grade massecuite continuous evaporating crystallization operations

The high quantity of HG massecuite produced, more than 60% of the total, has an important impact and, for example, means larger CVPs are needed which leads to greater capital cost savings. The increasing size of CVPs being sold indicates this benefit is recognized with the FCG having now sold 66 CVPs with massecuite holding capacities of 150 m³ or greater, of which 32 are in the range 200–250 m³.

Greater steam savings are a major factor favoring the application of CVPs for HG duty. FCG studies show steam savings amounting to ±5% on cane can be obtained by using a CVP rather than batch

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evaporating crystallizers for HG crystallization. This has also been confirmed from the practical results reported by the San Antonio factory in Nicaragua (*Wright* et al., 2004). Another aspect favoring CVP HG use is the improved sugar quality and exhaustion that can be achieved, as THS (*Rein* et al., 1985; *Rein*, 1986; *Rein* and *Msimanga*, 1999) and other (*Broadfoot* et al., 2004; *Broadfoot*, 2005) studies have clearly demonstrated. Good control of HG CVPs has been successfully achieved by means of a variety of methods comprising, the direct control philosophy using radio frequency or microwave sensors preferred by THS, the mass-balance or 'predictive' control method of Fives-Cail, or the 'forced-feed' system favored by the SRI (*Getaz*, 2000; *Broadfoot*, 2005). The 160 m^3 CVP at Raceland in Louisiana gives one of the best examples of what can be achieved. During the 2005 season, this CVP produced product sugar at 99.0% purity while achieving a 66% exhaustion of a 75.6% purity massecuite (51.6% molasses purity). This is an especially good result when considering the quality of the sugar produced and purity of the massecuite.

Improvements in both design and operating practices of CVPs can be supported by fundamental studies, particularly for specifying the operating conditions which maximize performance. The technique of dynamic programming has been used by *Love* (1991 and 2002) to determine optimum operating profiles for HG CVPs. This indicates that optimum operation requires relatively low crystal contents for most of the evaporating crystallizer and only needs to be increased in the last few compartments to maximize the exhaustion.

3 Encrustation management and control

Two categories of encrustation problems are encountered with continuous evaporating crystallizers (CVPs). The first results from accumulations on exposed surfaces above the massecuite crystallization level, which cause problems when pieces break off. The second results from a build-up on heating surfaces which gives a consequent reduction in heat transfer rates. Both problems are strongly purity dependent and hence of greater concern for HG massecuites.

Techniques for controlling encrustation above the massecuite crystallization level include the use of fine water sprays, which is an effective commonly used method consuming only small quantities of water (*Rein*, 1990). However, the efficiency is often affected by inadequate spray coverage. Another effective control measure, originally used at Illovo in South Africa (*Vermeulen* and *Pillay*, 2002), involves 'steaming-out'. This procedure is easily automated and similar to batch evaporating crystallizer steaming-out except for being carried out 'on-the-run'. If performed correctly it has been found to be completely effective and to cause no ill effects except for a small loss of around 15–20 minutes of production time. The frequency of application of the steam-outs is typically once a day for HG massecuites but, for the highest purity products, application each shift may be needed.

4 CVP cleaning and equipment design developments

All CVPs need to be periodically taken off-line for cleaning off heating surface encrustation, but the required intervals between cleaning for HG massecuite is much shorter. This ranges from as little as 10 days for some very high purity applications to over 1 month in others. The effects that factors besides purity have on the rate of encrustation are not clearly understood, but practical experience indicates that 'how hard a CVP is being pushed' (i.e. the rate of crystal deposition) is significant. Therefore, generous or 'over' sizing of CVPs is one way to extend the interval between cleaning for installations where this is a critical factor. Similar observations, with respect to the benefits that operating with the minimum steam/production levels have on reducing the rate of encrustation build up, have been reported by *Broadfoot* (2005).

General design aspects needing to be considered for this operation are type and size of the temporary massecuite holding facilities and how the CVP is emptied and refilled both with massecuite and cleaning fluid (water/juice/steam).

5 CVP cleaning methods

Three different methods for cleaning CVPs to remove encrustation are being employed with FCG installations. The most common method involves vigorously crystallization water in the CVP until all the encrustation is dissolved or washed off. Whilst effective, this method is the most wasteful and time consuming, since it generates quite large quantities of sweet-water and, owing to the amount needed, cold water usually has to be used.

The use of clarified juice instead of water is practiced in a number of installations with good success. Since the clarified juice is already very hot, the rate of encrustation dissolution is much faster and a quick soak and short crystallization period of 20–30 minutes is generally sufficient. At the Enterprise factory in Louisiana, where this technique is practiced, the total CVP downtime for cleaning has been reduced to between 3–3.5 hours. Using clarified juice also eliminates having to handle the additional water load, but does require provision of adequate storage facilities in order to ensure the withdrawal and return of the substantial quantities of juice can take place quickly and without causing any disruption to the process.

The third method, consisting of simply steaming out the CVP, has successfully been used at Felixton, in South Africa, to shorten the cleaning time from around 6.25 hours down to 3.5 hours (*Rein*, 1990). This technique is also being successfully used in a few other installations but it is not always able to fully remove encrustation in all compartments. In these situations using a water spray system located above the calandria to provide a short duration drenching of the calandria with hot water (or clarified juice) provides a means to effectively dislodge the last remaining encrustation. This cleaning method is potentially the quickest, provides the least disruption to the operations, and requires the least equipment.

6 CVP design developments

Although some factories schedule the cleaning of their CVPs to coincide with scheduled stops, many don't have these and cannot afford to have a whole high-grade station shutdown while the CVP is off-line. The most obvious solution is to then provide multiple units, but this is expensive. For this reason the FCG has designed special CVPs that enable one half to be shut-down while the other remains in operation.

The Fives-Cail design (CCTWD model) called a 'double' evaporating crystallizer (*Journet* and *Pelletan*, 1999) is created by the installation of a longitudinal partition in the CVP to create two parallel units (Fig. 2). Each side of this evaporating crystallizer comprises 11 compartments and is operated independently of the other.

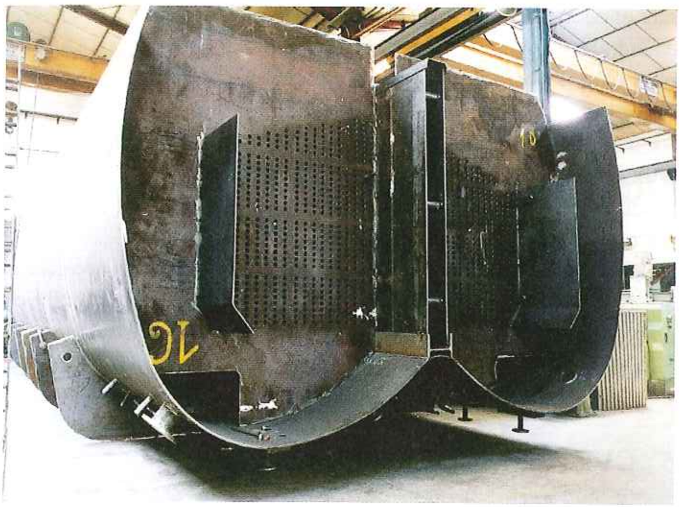

Fig. 2: A Fives-Cail double CVP under construction

The Fletcher Smith design called a 'split' evaporating crystallizer uses a transverse partition plate and a so called hammer-head arrangement of compartments where the last and 1st cell are adjacent to each other in the center of the evaporating crystallizer.

These double and split designs of CVP provide, for small additional cost, the means to maintain continuous operation during CVP cleaning. By boosting the crystallization rate on the operating side of the CVP during the time the other is being cleaned, it is possible to maintain the production at about 70% of the nominal design. Then by manipulating stock levels, a double or split evaporating crystallizer will allow CVP cleaning to be carried out with hardly any disruption to the factory production. These designs also provide another significant benefit, of particular importance for the larger evaporating crystallizers, which is a halving of the size of the holding tank facilities needed.

7 Conclusions

The use of CVPs for HG massecuite production provides particularly attractive benefits. Operational development work has resulted in on-the-run control and cleaning technique improvements and to more efficient plant designs. Equipment design development work conducted by the FCG includes the construction of progressively larger units, together with special double and split evaporating crystallizer designs.

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Développements en cristallisation de masse cuite de pureté élevée dans des cristalliseurs continus par évaporation (Résumé)

L'amélioration de l'efficacité du travail en cristallisation de masse cuite de pureté élevée dans des cristalliseurs continus par évaporation (cuites continus) a été l'objet d'efforts importants au sein du Groupe Fives Cail. Il en a résulté l'introduction de plusieurs innovations tant en méthode d'exploitation qu'en conception des cristalliseurs continus par évaporation. Les développements relatifs à l'exploitation incluent des méthodes pour contrôler/limiter l'incrustation aussi bien que des moyens d'améliorer l'efficacité du nettoyage des cristalliseurs par évaporation pour éliminer les incrustations en utilisant l'eau, la vapeur et/ou le jus. Les innovations de conception incluent le développement de la cuite double Fives Cail et de la «split pan» Fives Fletcher. Les avantages de ces différentes solutions comparées aux cuites standard sont décrits et des détails des résultats pratiques des installations actuelles sont également fournis. Des approches pour aboutir à une exploitation plus efficiente sont également décrites.

Apuntes sobre desarrollos en cocimientos en tachos continuos de alto grado (Resumen)

El mejoramiento de las eficiencias operacionales con masa cocidas de alto grado en tachos continuos ha sido objeto de considerable esfuerzo al interior de Fives Cail Group. Esto ha resultado en la implementación de varias innovaciones tanto en la operación como el diseño de los tachos continuos. Desarrollos operacionales incluyen métodos para controlar el crecimiento de la incrustación y medios para mejorar las eficiencias de limpieza para remover incrustación usando agua, vapor y jugo como alternativas. Innovaciones de diseño incluyen el desarrollo del tacho doble de Fives Cail y el tacho split de Fives Fletcher. Se describen las ventajas de estas alternativas comparadas con unidades estándar y también se suministran detalles de resultados prácticos de instalaciones reales. Se describen también aproximaciones para lograr operación eficiente.

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