The configuration and control principles of an automatic pan boiling system are described. Measurements of viscosity and consistency by means of a V/C meter and electric properties in radio frequency (R/F) were tested at Peikang Factory for the control of crystallization in high purity massecuites. A personal computer with special software and key was installed to acquire the data for analysis and to compare the output signals of the R/F probe and the V/C meter. The V/C signal showed an obvious undulation at the seeding point and appeared to be superior to the R/F probe.

Key words: Viscosity/consistency, radio frequency, series resistance, series capacitance, distributed control system.

INTRODUCTION

Due to the increasing demand of white sugar in the Taiwan sugar market, a sugar refinery with a capacity of 500 tons per day was constructed at Peikang in 1988/89. To improve sugar quality and sugar recovery, and also to save energy and labor costs, the automation of pan boiling was undertaken using the Siemens distributed control system.

In sugar boiling, the supersaturation of the mother liquor and the crystal content are the most important factors controlling crystal deposition rate. At present, no measuring instruments are available for direct on-line measurement. Some substitutions are therefore used to estimate these values. The conductivity of massecuite is a usable process variable for the control of low grade strikes, but fails in high purity (above 96) strikes. Thus, several attempts have been made to satisfy the control of crystallization in massecuites of high purity. One method is the measurement of viscosity and consistency by means of the V/C meter (Hashimoto and Kawamura, Moller et al) and the other method is the measurement of electrical properties in radio-frequency (Moller, Radford et al, Reichard et al). The former method was used for the automation of white pan boiling in Peikang Sugar Refinery, but the instrument is very difficult to repair. Another instrument for efficient control of sugar boiling is still needed.
The efficiency of the V/C meter and the radio frequency (R/F) instrument for automatic pan boiling control was investigated at Peikang Factory. A personal computer with special control software was installed to record the V/C and R/F values simultaneously.

MATERIALS AND METHODS

A sketch of the sugar boiling pan is shown in Figure 1. Each pan is equipped with level, temperature, steam pressure, vacuum, R/F and V/C transmitters as well as all necessary control valves and pneumatic solenoid valves. The A/D
converters, under computer control, perform the basic function of data acquisition of input signals. The output signals after model calculation are transmitted to D/A converters to control the valves of the manipulated variables.

According to the technology of the sugar boiling process, a high purity strike is undertaken by following sequential steps:

1. **Drawing in**

A pre-condition for drawing in the footing material is that the pan is under vacuum, i.e. the vacuum of the pan is raised to a preset value before the syrup is drawn in. When a preset level of syrup is reached, the steam valve is opened and the agitator is switched on. When the defined final level has been reached, the syrup control valve is closed and the concentration step starts.

2. **Concentrating**

During this process the syrup is concentrated until the seeding point is reached. The only variable in this process is the "prepared for seeding" point. A typical control curve around the seeding point is shown in Figure 2, the abscissa is time and the ordinate is V/C value.

3. **Seeding**

At this stage the seeding valve is opened for a definite time. This time is preset and seeding starts as soon as the seeding point is reached (Figure 2).

4. **Graining**

The graining phase is the most critical phase in the overall boiling process, and commences with the seeding point. Various graining patterns can be preset by means of a standard program. Suitable values are entered for the following parameters: prepare for seeding point, seeding point, minimum juice density, maximum juice density, juice density when growing commences and the graining time (Figure 2). With the exception of time, all parameters are quoted relative to the seeding point. This ensures that if the seeding point is altered, the boiling curve shifts accordingly and is still coupled to the seeding point.

After the seeding point concentration is continued until the strike contains sufficient crystals, i.e. till the maximum syrup is reached. The syrup valve is then opened fully until the minimum syrup density is obtained, and only the crystal present should grow from this point. During the graining time period, the syrup valve is controlled from \( W_{\text{min}} \) to WHK. As soon as WHK is reached, the next step commences.
FIGURE 2. Control/curve of viscosity/consistency around the seeding point:
WSV = prepare for seeding, WSP = seeding point, \( W_{max} \) = maximum syrup density, WHK = syrup density at the beginning of growing, \( T \) = graining time.

5. Growing

The reference value of viscosity/consistency in the growing phase is calculated from the value of massecuite level and five different slopes which are related to the levels X1 to X6. The polygonal control curve is shown in Figure 3.

6. Tightening

In this step, the syrup control valve is closed and the mother liquor is thickened further. When the massecuite density reaches a desired maximum the strike is completed. The V/C value is used to determine the end point.
7. Discharge

In this step the vacuum of the pan is released. As soon as atmospheric pressure is obtained the massecuite is discharged into a receiver.

8. Steaming out

The pan is rinsed with steam to remove residual crystals as these could lead to the premature production of fine grains during the next cycle. The duration of steaming out is controlled by a timer.

9. Pan free

In this step all signals are reset. The controls then revert to the start up parameters. The instrumentation checks if all requirements for a new strike are fulfilled and signals pan free, ready to accept the next strike.

A typical control curve for the whole automatic pan boiling system used in high purity granule sugar massecuite is shown in Figure 3.
The V/C meter was used for our pan boiling of high purity massecuite, but was very difficult to repair when a breakdown occurred. A R/F probe was chosen as the substitute. It has two separate 4-20 milliamp output signals, one is a series resistance (RS) and the other is a series capacitance (XS). The data obtained from RF-RS, RF-XS and V/C probes from the automatic pan boiling process, were compared. The system used for data acquisition is shown in Figure 4.

![Figure 4. System for data acquisition.](image)

Several 4-20 milliamp analog input signals (level, V/C, RF-RS, RF-XS, etc) were transferred from the local panel to the automation sub-system. The signals were taken through a PCLD-780 (screw terminal board) to a personal computer with PCL-812 card which changes these signals from 4-20 milliamp to 1-5 VDC. The Genesis control series software (ICONICS, Inc) with copy protection key was installed in the personal computer to provide a complete system for industrial process control, supervisory control and data acquisition. The desired data and historical trends were logged (by this system) and saved for comparison and analysis.

RESULTS AND DISCUSSION

A typical historical trend during the automatic pan boiling of high purity granule sugar massecuite is shown in Figure 5. This strike was controlled by V/C meter signals and a preset curve. Simultaneously the computer recorded the output signals of the R/F probe (XS and RS) The data were analyzed. When the syrup was concentrated and the Brix was increased to the seeding point, the V/C signal showed an obvious undulation, increased from zero to about 30% then decreased to about 27% within 20 min. All parameters relating to the seeding point were easy to set (Figure 2). The RF-XS signal decreased from about 91% to about 85%, and then increased to about 87%. The undulation was not as steep as the V/C value, but can
A typical historical trend of automatic pan boiling runs. The other signal of the R/F probe, the XF-RS, did not show sufficient variation in the vicinity of the seeding point, and so it was not suitable for the automation of pan boiling. During the growing, tightening, and discharge stages, the V/C signal tended to increase as the crystal content or syrup density increased. The RF-XS signal was a mirror image, i.e., the measured value decreased as the crystal content increased. Both signals showed sufficient variation for the setting of parameters during growing, tightening and discharge. Table 1 shows the typical experimental data.

Due to electrical interference, some abnormal dips were observed in the boiling curves of the XF-XS signals which were recorded by the personal computer. Unless the noise is suppressed, the R/F probe is not a suitable replacement for the V/C meter in automatic pan boiling control. The measurements of viscosity and consistency by means of the V/C meter showed an obvious and steep undulation at the seeding point, and appeared to be superior to the R/F probe.
TABLE 1. Typical experimental data.

<table>
<thead>
<tr>
<th>State</th>
<th>Level (%)</th>
<th>V/C (%)</th>
<th>RF-XS (%)</th>
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</thead>
<tbody>
<tr>
<td>Growing</td>
<td>45</td>
<td>28</td>
<td>87</td>
</tr>
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<td></td>
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<td>29</td>
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<td></td>
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</tr>
<tr>
<td>Tightening</td>
<td>95</td>
<td>55</td>
<td>48</td>
</tr>
<tr>
<td>Discharge</td>
<td>93</td>
<td>64</td>
<td>39</td>
</tr>
</tbody>
</table>

REFERENCE

AUTOMATISATION DES CUITES EN HAUTEPURETE

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RESUME

On décrit le système et les principes d'automatisation pour les cuites. On a mesuré la viscosité, la consistance et les propriétés électriques de la massecuite, en radio fréquence, à la sucrerie de Peikang, pour le contrôle de la cristallisation en haute pureté. Un micro ordinateur est utilisé pour l'acquisition des mesures faites par le capteur radio fréquence. L'appareil mesure aussi la viscosité. Le signal émanant de l'appareil de viscosité montre une ondulation au moment du drainage et semble être supérieure à celui du capteur radio fréquence.

COCIMIENTO AUTOMÁTICO EN TACHOS PARA MASAS COCIDAS DE ALTA PUREZA

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RESUMEN

La configuración y principios de control de un sistema automático para tachos de cocimiento es descrito. Medidas de viscosidad y consistencia por medio de un metro V/C y de propiedades eléctricas en radio frecuencia (R/F) para el control de cristalización de masa cocidas de alta pureza fueron probadas en la fabrica Peikang. Una computadora personal con programas y claves especiales fue instalada para adquirir la data para los análisis y comparaciones de las señales de el sensor de (R/F) y el metro de (V/C). La señal de V/C demostró una ondulación obvia durante el punto de semillamiento y parece ser superior que el sensor de R/F.