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Dynamic Imaging as a Tool to Increase Yield, Conserve Resources and Reduce Production Costs

Abstract

Dynamic imaging technology provides an ideal way to measure and control the sugar crystal growth process with the end goal of optimizing yields, minimizing natural resources and minimizing operating utilities. Starting with improvements to the technology, this paper will detail how this can be done by studying actual batch productions starting with the clarifier, the pan and finally the centrifuge, and explaining how the software output can provide the information to the operator to make good decisions to efficiently control the process at each point in order to reach a successful end point. Resource and utility savings projections will be offered to demonstrate the return on investment that can be realized.

Introduction

Dynamic imaging operates on the basic principle of capturing real time images of a process, having software analyze the images for particular features and conditions and providing outputs upon which the operator can make decisions based on the data output and the visual output from the camera. This paper outlines the relevant applications of dynamic imaging within a sugar production facility, and compares it to other industry methods used. Sugar production processes where this technology can be employed include clarifying, crystallisation, centrifuging, and product quality control.

Fundamentals

A quality imaging system depends on the quality of the three building blocks of the system; the process lens, the camera and viewing lens combination and the illumination to view the process fluid and particulate. The process lens should use the fused glass to metal technology to create the transparent pressure boundary required for the light and camera to see through. The glass is fused directly to the metal creating a high pressure seal that requires no gasket and creates no recessed cavity where eddy currents can develop allowing crystals to stagnate (see Fig. 1). This technology also permits the use of insertion lens tubes for the camera and light which create a measurement zone in the middle of the flow and not along the pipe wall.

The imaging sensor, or camera, is the simulation of the human eyes in the dynamic imaging system. Gigabit Ethernet technology, incorporating high colour sensitivity, and designed specifically for process vision applications along with lenses designed to conduct a well focused

image to the sensor are required for optimal resolution of process images. Current technology enables capturing and processing of 15 to 20 images per second which means process information is gathered and converted to analytics at a near real time rate.

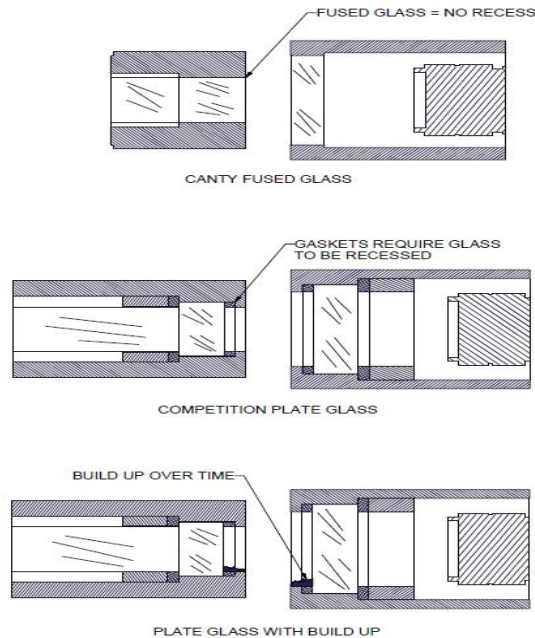


Figure 1. Fused Glass To Metal Lenses.

Perhaps the most critical component of these building blocks is the illumination system. Without the proper consistency, or style of light, the imaging sensor cannot perform to it's highest specification. Good results hinge directly on the screen wide consistency of the illumination as well as the intensity. LED technology is used to provide pixel to pixel consistency within 1% which enables the imaging sensor and software to detect process particles the same way everywhere in the field of view and throughout the duration of the analysis.

The technology is represented in the schematic in Figure 2 and is available in fully rated explosion proof or weatherproof configuration.

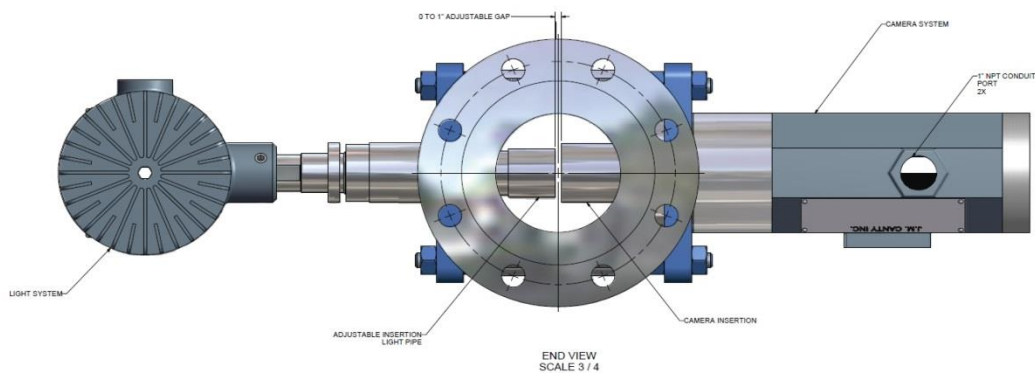


Figure 2. In-Line Imaging System

Process Applications

Clarifier

How and where can the use of this technology benefit the quality and overall cost profile of the product? We start at the clarifier. Installing an imaging system into the liquor discharge line provides advantages over current turbidity or light obscuration technologies. A common fault of non visual instrumentation is the inability to discern between solids and gas bubbles. The bubbles get counted into the data producing error in the result. Vision technology has the ability to classify gas bubbles apart from solids thereby preventing them from disturbing the solids analysis. The graphical output in Figure 3 shows the effect bubbles have on a turbidity reading.

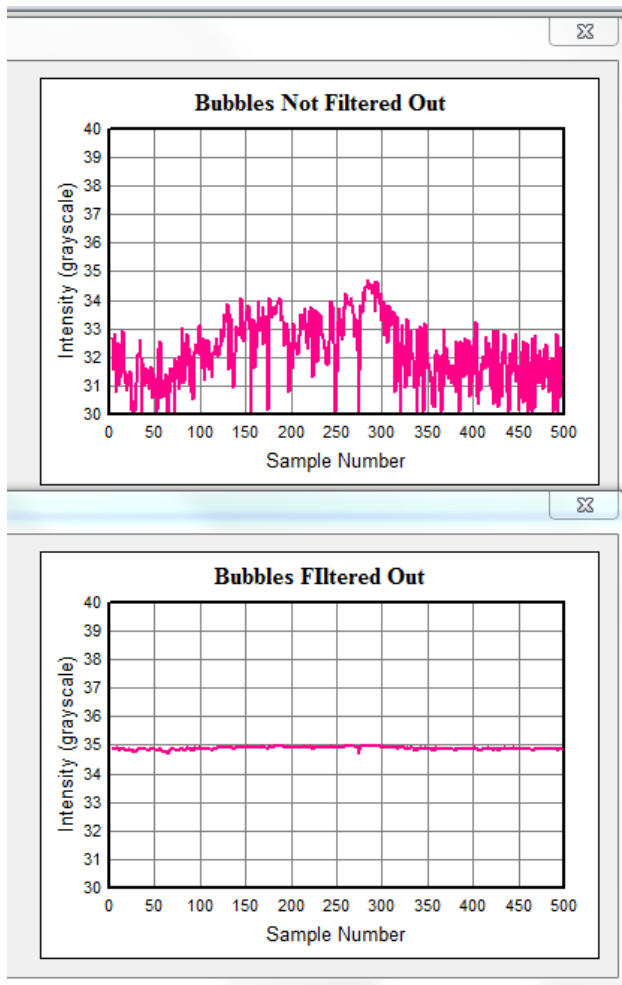


Figure 3. Intensity (turbidity) Result

The data is a measure of 180 degree light transmittance through the process fluid. As solids/bubbles increase the intensity read drops. It is apparent from the filtered and non filtered result that the bubbles have a significant effect in skewing the turbidity reading. One of the key benefits of clarification is the reduction of turbidity² and therefore it is important to know the actual turbidity in the clarified liquor so the process can be maintained at an optimal level. When the true turbidity is masked it is difficult to make process judgments from batch to batch.

Vacuum Pan

A second point of application is the vacuum pan (Fig. 4) where crystallization takes place¹. There are several sightglasses mounted in a vertical arrangement to assist the operator in determining the liquor level during boiling. This is a significant opportunity to acquire cost savings. Fused



Figure 4. Typical Sugar Pan³.

glass technology provides a sure way to seal the sight glass which is critical in maintaining the vacuum at the least cost. Traditional sight glasses are usually a plate of glass retained by a metal flange. Bolting a piece of glass into a flanged port creates large, uneven residual stresses on the glass. Over torqueing can fracture the glass, now or later, and not enough torque will allow the vacuum to leak. The fused glass to metal sight glass consists of an inner glass portion which is fused to a surrounding ring. This places the glass under several thousand pounds of compression making it stable and not subject to tensile stresses. The retaining flange sits on the metal ring and so there are no residual stresses applied to the glass. In addition, the retaining flange can be tightened down sufficiently to create a leak proof seal.

The difference in energy consumption per liter is demonstrated in the following analysis. The energy to heat a mass of water to its boiling point can easily be calculated using this formula:

$$Q = m C_p (T_2 - T_1) \quad \text{Eq. 1}$$

Where m = mass, C_p = specific heat, T_2 = final temp, T_1 = starting temp. A sample calculation is provided below for ambient pressure, 14.7 psia, and 2.9 psia vacuum conditions:

To heat 1 litre of water from 20°C to a boiling point of 100°C (ambient; 14.7 psi)

$$Q = 1(4.186)(100 - 20)$$

$$Q = 334.88 \text{ kJ} / 0.093 \text{ kWh per litre}$$

To heat 1 litre of water from 20°C to a boiling point of 60°C (vacuum; 2.9 psi)

$$Q = m C_p (T_2 - T_1)$$

$$Q = 1(4.186)(60 - 20)$$

$$Q = 167.44 \text{ kJ} / 0.047 \text{ kWh per litre}$$

In charted form:

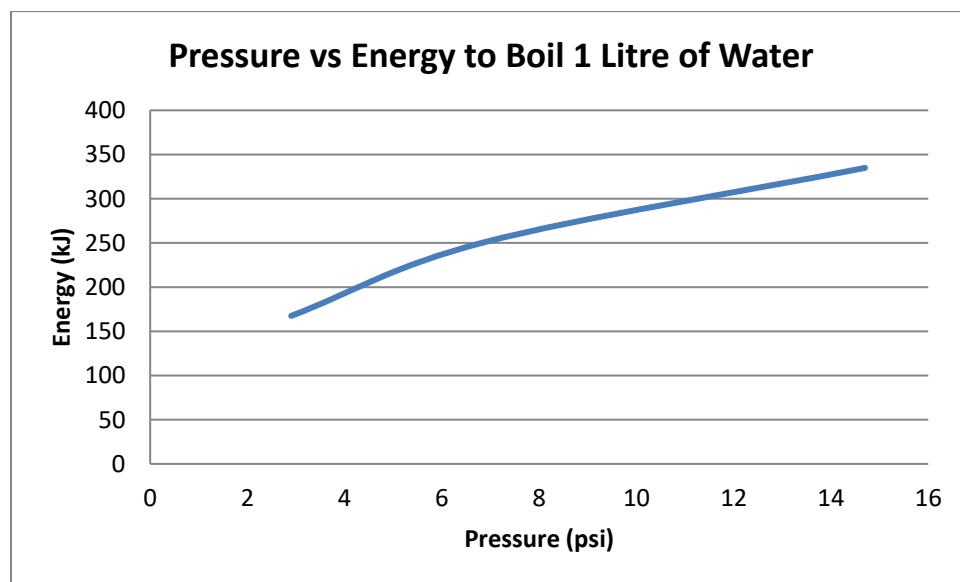


Figure 5. Boiling Energy of Water at Various Pressures (Absolute)

From the chart it is apparent that the energy required for boiling is proportional to the integrity of the pan's pressure boundary. If there are leaks, costs go up.

Vacuum Pan – Crystallization Analysis

A third point of application is in monitoring the crystallization process through the various growth stages. Traditionally a small sample would be removed and visually analyzed by the operator. This method is quite subjective and does not provide a quantifiable analysis of the sugar crystals. Vision technology can provide the on screen visual for the operator and can also provide an objective analysis of the size and concentration inside the pan at any time from initial seeding through to full growth. A proper instrument will insert through a single vessel port and

provide illumination and camera sensor in one package. It is important that the instrument not be a flush mounted type instrument, rather it must insert into the process to be away from the wall and any eddy effects or low temperature areas where growth may lag the remainder of the strike.

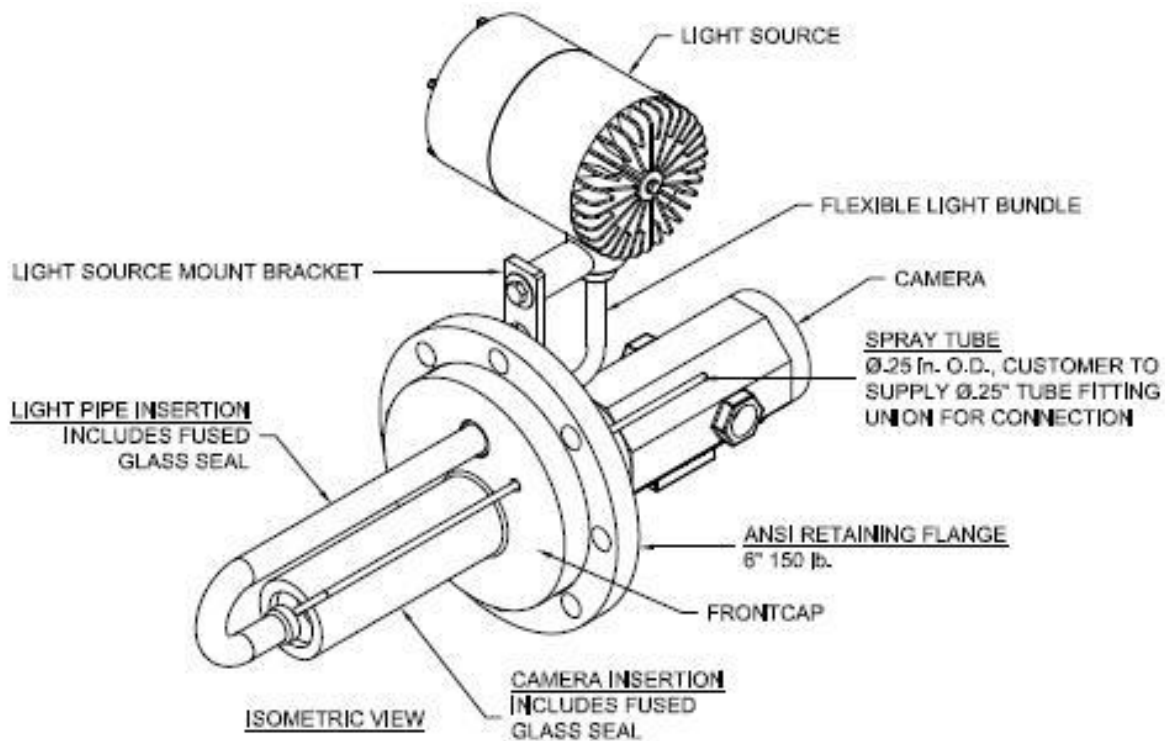


Figure 6. Typical Insertion Style SugarScope

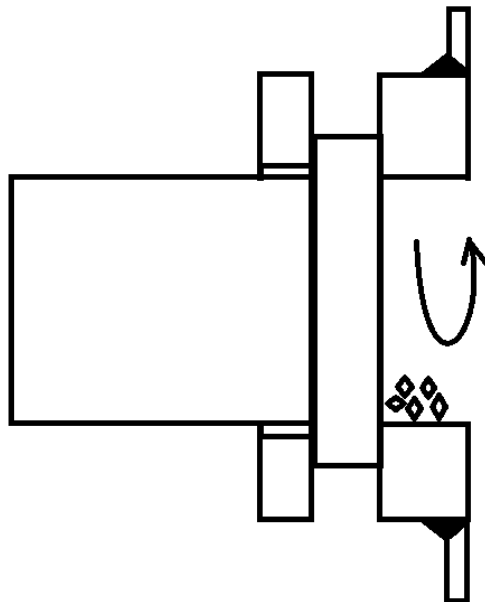


Figure 7. Poor Installation

The following images show the crystallization process at various time points beginning with the detection of initial seeding.

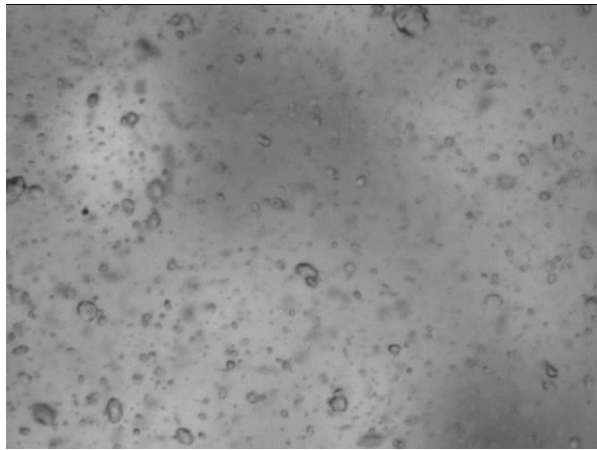


Figure 8. Initial Seeding

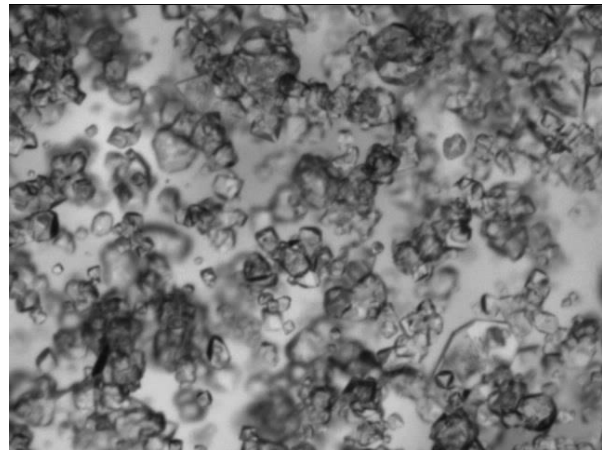


Figure 9. Seeding + 30 Minutes

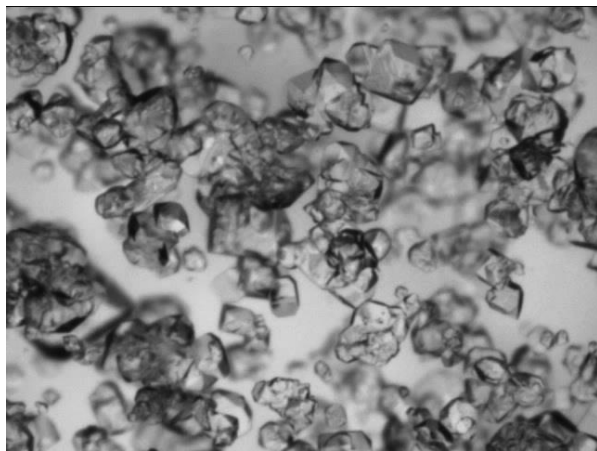


Figure 10. Seeding + 60 Minutes

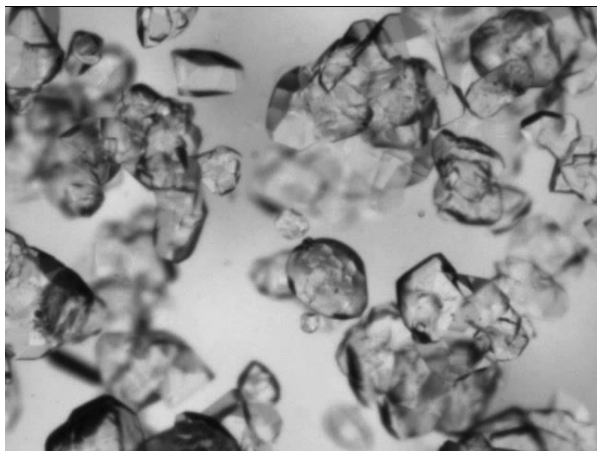


Figure 11. Seeding + 150 minutes

The images are digitized and then sized by minor diameter. There are multiple particle characteristics captured and computed for each particle which can be used to filter for specific features. Data reported includes intensity, major/minor diameter, aspect ratio, perimeter, area, volume and circularity. Figure 12 shows a typical digitization of the image. The analysis occurs in near real time as the process is ongoing. Outputs are available on a minute to minute basis. The software can be set to show trending, such as D10, D50, D90, and/or a complete distribution of size by minor diameter or any other characteristic desired.

A major advantage of vision technology is that the software can learn to better discern the process based on the operators observations and inputs.

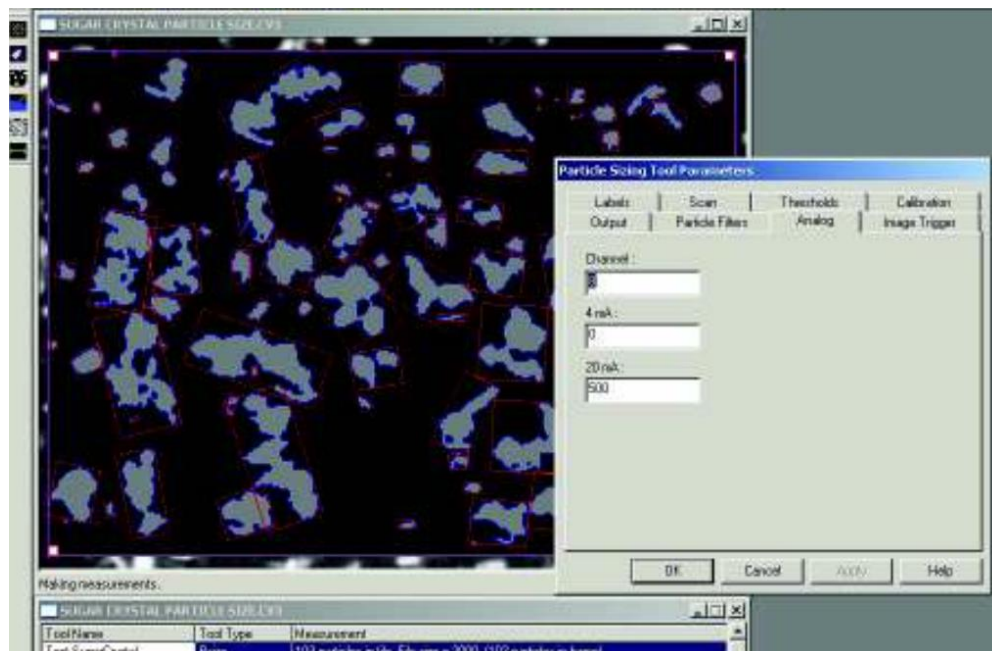


Figure 12. Digitized Image of Sugar Crystals.

Cost Analysis

Assessing the benefits of monitoring and analysis of the process through the use of vision technology can now be quantified in a meaningful way. An estimated calculation is provided to illustrate savings that may be achieved with the installation of the technology on the vacuum pans.

- Reduction of boiling times / increase of throughput (up to 33%)
- Increase yield by 10%
- Reduction in annual water/steam usage (up to 33%)

Total cost savings depend upon current operating efficiencies, however a conservative estimate of labor, energy and resource savings, plus yield increase, would amount to approximately \$50,000 per pan per year.

References:

1. Southern Minnesota Beet Sugar Cooperative, 'Crystallization', Retrieved from <http://www.smbcsc.com/OurSugar/SugarProcess/Crystallization.aspx> January 7, 2016.
2. Mkhize, S. C., Davis, S. B. 2004. Raw Sugar Filterability Improvements With Syrup Clarification. Proceedings of the South African Sugar Technology Association.
3. Southern Minnesota ..., 'Crystallization'.