IMAGE BASED ON-LINE PARTICLE SIZING USING ETHERNET CONTROLS

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KEYWORDS

Particle Size, Particle Shape, Particle Color, Vision System, Visual Verification, Digital Ethernet Control, Crystal Growth,

ABSTRACT

Imaging based particle size analysis of liquids and solids provides significant advantages over other methods since 2-dimensional size, shape and color information is provided along with a visual verification. Systems can be used on-line under demanding operating conditions or in the lab. This paper will discuss newly developed technology that expands the range for image based particle analysis systems by integrating an optical zoom lens with digital Ethernet control. Until now every time the size range was changed on an imaging system the lens needed to be manually adjusted. This adjustment then required the user to recalibrate the entire system. This manual adjustment and recalibration limited the usefulness for image based particle size analysis. The optical zoom lens overcomes this limitation and provides for particle ranges in the order of 1-7000 microns out of a single system. This 1-7000 dynamic range can be applied to a maximum size of 100mm.Results can be outputted in a simple display or as output signals such as 4-20mA or digital files on Ethernet for process control. All data can be archived for a historical record.

INTRODUCTION

The traditional Vision Processing measurement for particle sizing provides 2-dimensional (2-D) information consisting of Particle Area, Particle Perimeter, Particle Major Axis, Particle Minor Axis for each particle detected. When a variety of materials of differing size ranges is to be

measured with the traditional Vision Processing equipment, the camera lens magnification needs to be manually re-adjusted and a new pixel scale factor determined. This manual effort is time consuming and because it is done by a human, it is error prone. By adding motor control with position feed back to each of several of the equipment adjustments, the process of re-configuring the Vision Sensor for different products requires only selecting the desired product from a list on the controlling computer. The computer has a pre-stored list of pixel scale factors for all lens zoom positions. A new material or product being added to the user's list on the controller computer requires the initial selection of each setup parameter, but this is done only one time for each product. The dynamic range of the resulting Vision Measuring System is the product of the lens zoom ratio, and the number of pixels across the camera image. For a 1024 pixel wide image and a 7 to 1 zoom lens, the dynamic range from smallest to largest particle that can be measured is more than 1 to 7000. For a given product, this dynamic range is limited by the 1024 pixels that make up one image.

LAB TEST CONFIGURATION

Figure 1 shows the lab version of the LAB PLUS SOLIDSIZER™ used for the particle size data measurement of dry fine granular materials. This equipment has digital Ethernet control of camera zoom and focus as well as feed rate and camera position.

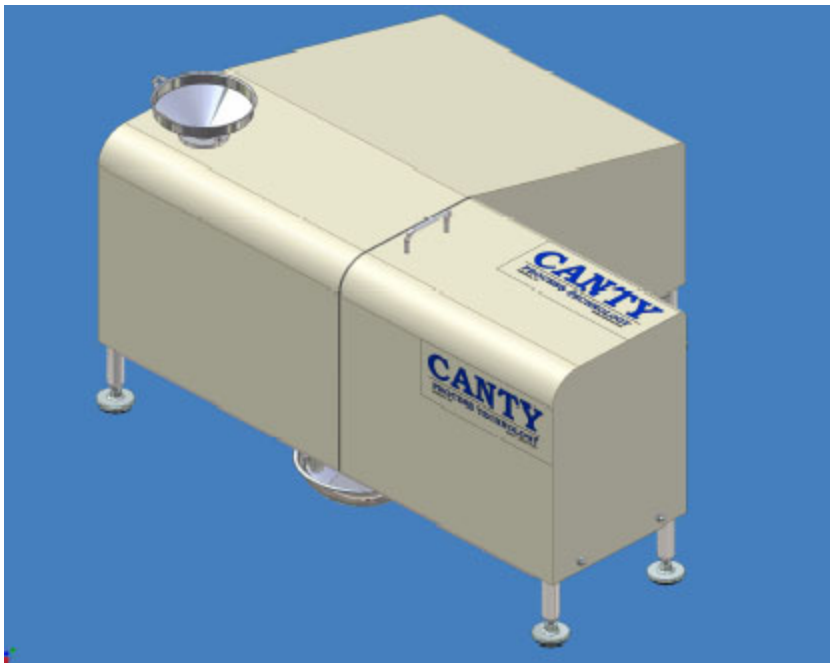


Figure 1, LAB PLUS SOLIDSIZER™ measures dry fine granular materials under computer control

The LAB PLUS SOLIDSIZER™ integrates computer control with the key elements of the Vision based particle sizing approach. It includes a CCD camera and lens, functioning as the sensor, and the computer based vision processor that extracts measurement data from the process images provided by the camera and provides output data to the operator. A lighting system is essential for obtaining accurate results and is integrated into the equipment configuration along with the camera. The light is oriented to form a consistent silhouette of each granule falling in front of the camera lens. While the camera, material feeder, and lighting can be exposed to the production area environment, the computer needs to be located in a general-purpose or control room away from the harsher environment. The camera is a black and white process camera with 1/100,000 s-1 shutter speed and all auto gain control functions disabled. A zoom lens system with motor drive and position feedback is used to obtain images of the granular particles suitable for image processing. The computer measures each particle in terms of pixels. A pixel scale factor in Microns is available for the full zoom range of the lens.

Product images shown in Figures 2 and 3 present a back lighted 3700 x 2800 micron field of view of the particles as they fall in front of the uniform illumination screen. A key benefit of the vision-based measurements detailed here is the ability to visually verify the proper operation of the camera/light as well as the vision processing computer.

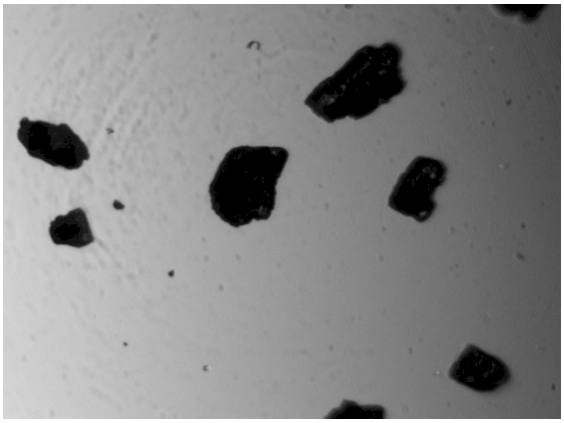


Figure 2: Raw Image

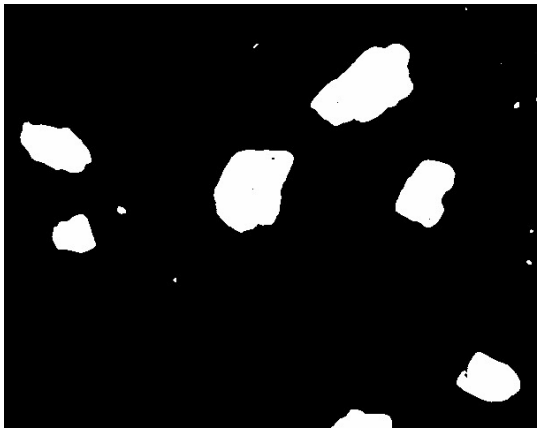
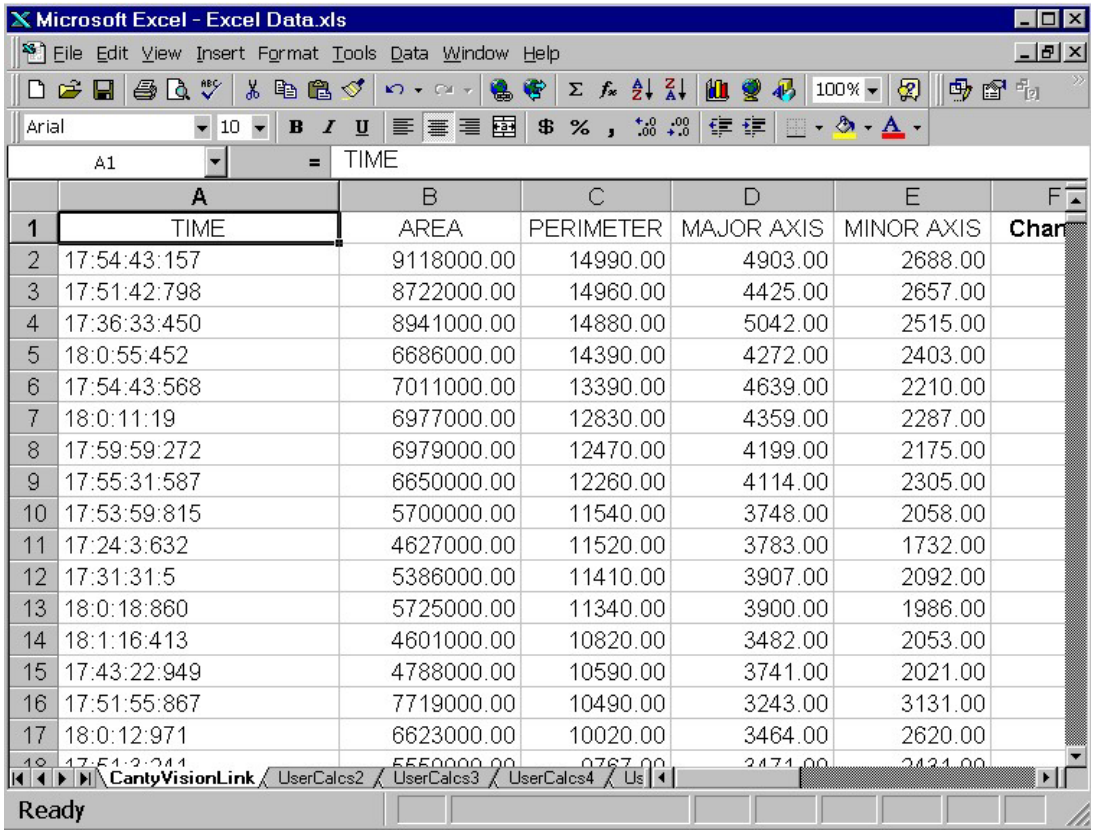


Figure 3: Processed Image

RESULTS

Figure 5 shows a portion of the measurement data in spreadsheet form and Figure 6 presents the particle size distribution for the sample with an average size of 1800 microns The plots give a continuous particle size distribution in terms of the volume percentage of particles with a minor axis dimension less than the size specified on the x-axis of the plot. This distribution was plotted for over 3,000 particles.



	A	B	C	D	E	F
1	TIME	AREA	PERIMETER	MAJOR AXIS	MINOR AXIS	Char
2	17:54:43:157	9118000.00	14990.00	4903.00	2688.00	
3	17:51:42:798	8722000.00	14960.00	4425.00	2657.00	
4	17:36:33:450	8941000.00	14880.00	5042.00	2515.00	
5	18:0:55:452	6686000.00	14390.00	4272.00	2403.00	
6	17:54:43:568	7011000.00	13390.00	4639.00	2210.00	
7	18:0:11:19	6977000.00	12830.00	4359.00	2287.00	
8	17:59:59:272	6979000.00	12470.00	4199.00	2175.00	
9	17:55:31:587	6650000.00	12260.00	4114.00	2305.00	
10	17:53:59:815	5700000.00	11540.00	3748.00	2058.00	
11	17:24:3:632	4627000.00	11520.00	3783.00	1732.00	
12	17:31:31:5	5386000.00	11410.00	3907.00	2092.00	
13	18:0:18:860	5725000.00	11340.00	3900.00	1986.00	
14	18:1:16:413	4601000.00	10820.00	3482.00	2053.00	
15	17:43:22:949	4788000.00	10590.00	3741.00	2021.00	
16	17:51:55:867	7719000.00	10490.00	3243.00	3131.00	
17	18:0:12:971	6623000.00	10020.00	3464.00	2620.00	

Figure 5: LAB PLUS SOLIDSIZER™ Measured Results Imported into a Spreadsheet

The particle measurement data as shown in Figure 5 is used to estimate the volume of each particle and enable the display of a volume percent passing curve shown in Figure 6. This is a widely used presentation used to report particle size distribution. An alternate format is the Bin Distribution showing the particle count in each size bin shown in Figure 7. These measurements and plots can be quickly made for the sample material with largest particles of 3000 Microns and then a sample with the largest particle at 300 Micron by using the digital Ethernet control features of a LAB PLUS SOLIDSIZER™.

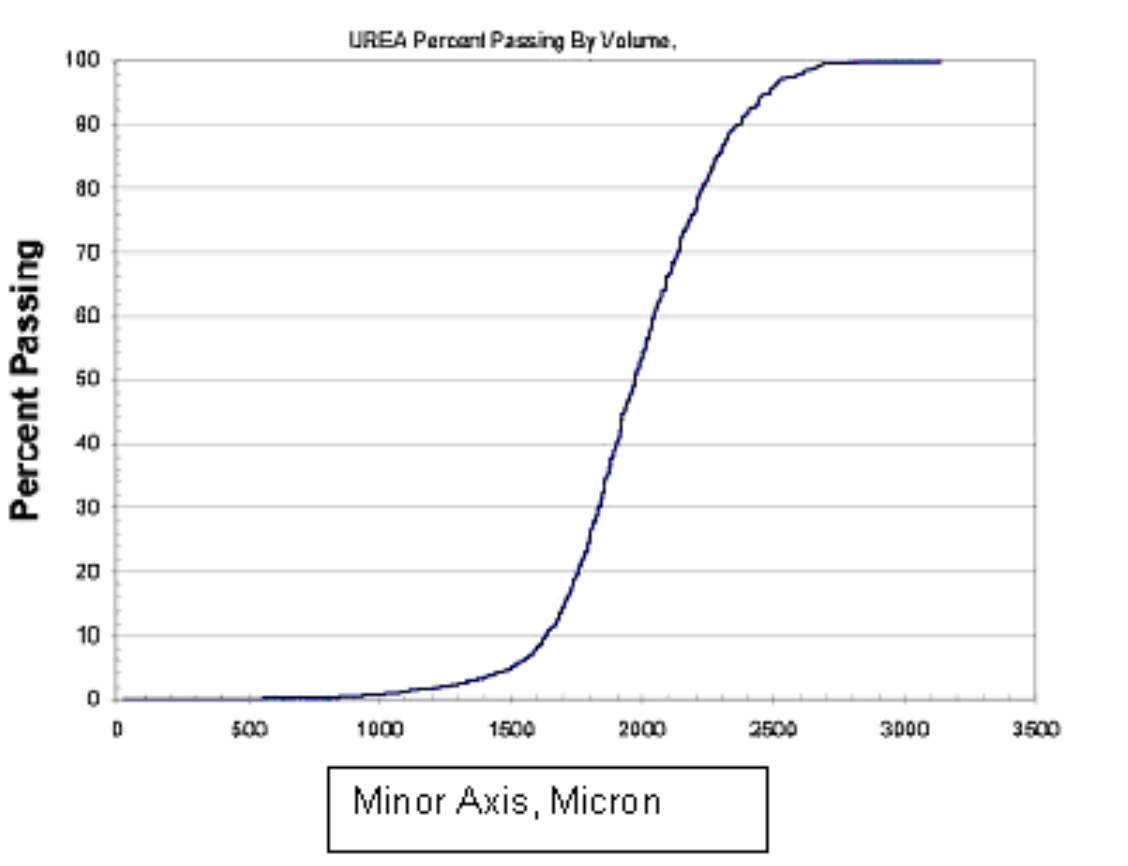


Figure 6: Volume Percent Passing verses Particle Minor Axis

DISCUSSION OF DRY GRANULAR PARTICLE SIZING

For lab applications, the measurement output is stored as a data file and printed as a chart in one of the above formats. For on-line process measurements, the output is a 4-20 mA analog control signal output from the vision processor to the process controller. This is a well-established industry standard interface. This output mechanism allows for automated online process control of the granular material production by the vision system. When the characteristics of the granules being produced begin to shift such that the vision system detects a significant number of particles that are out of the desired size range, a feedback signal sent via a 4-20 mA to the process controller initiates a change in the production process. This closed loop control effectively keeps the output granules at the desired size.

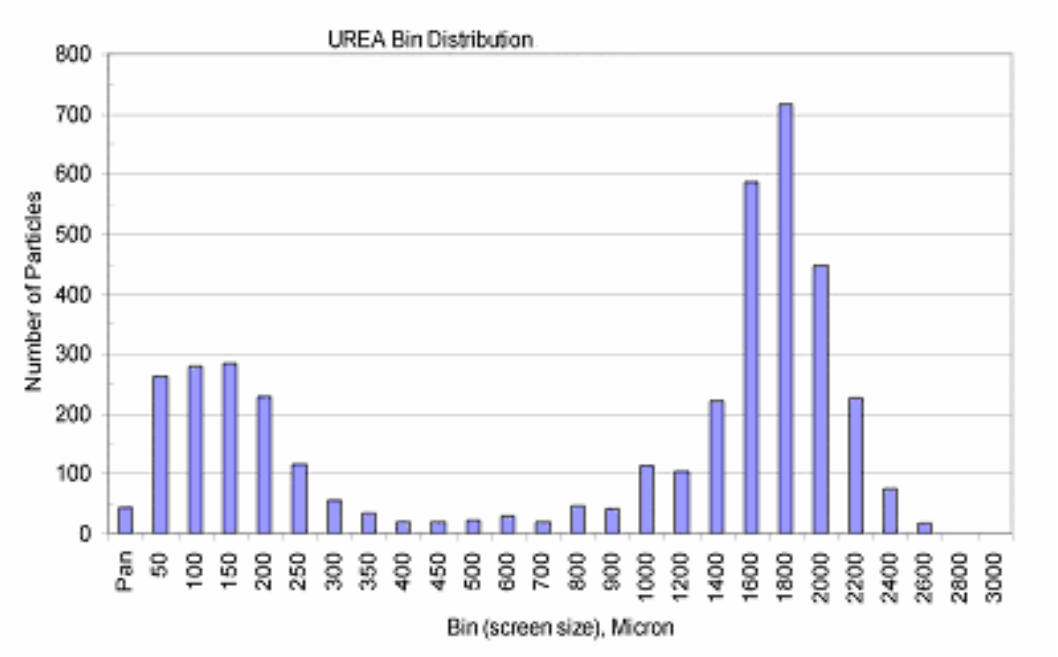


Figure 7: Particle Size Analysis, Count verses Size Bin

OTHER CAMERA SYSTEMS BENEFIT FROM DIGITAL ETHERNET CONTROL

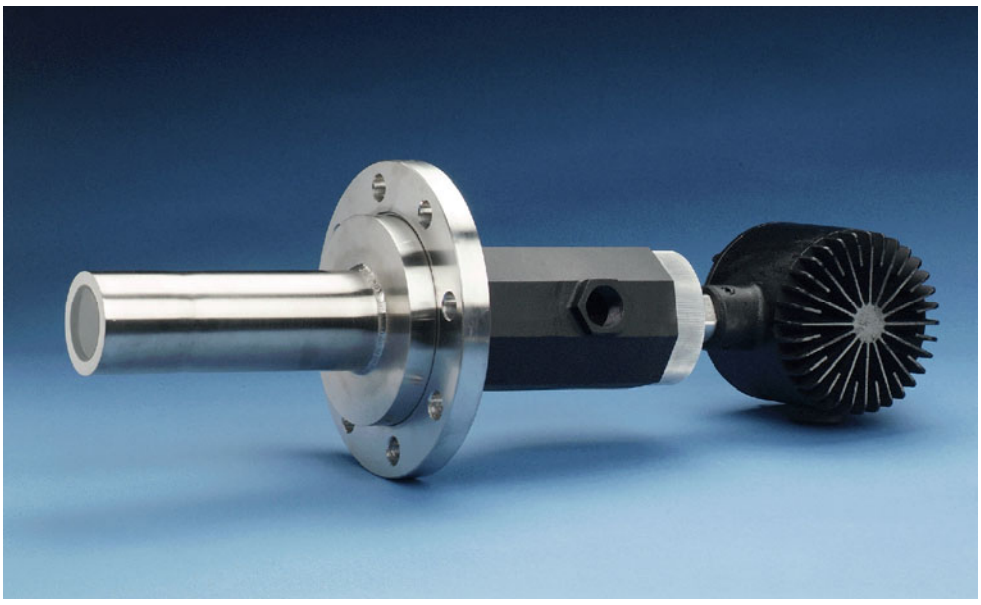


Figure 8, Crystal Microscope Process Camera

In-Line Crystallization – A Crystal Microscope system provides unique inline images of crystal growth. These images are captured from the point of nucleation through full growth and are processed to extract valuable crystal size and shape data. Where the crystal size growth is too wide for a single lens magnification, the computer controlled motor driven zoom lens allows full crystal growth to be tracked by the computer. The Crystal Microscope captures the crystal image for sizing and shape analysis and also provides a live, full video picture of the process under pressure and temperature. The Microscope camera can connect to the process vessel with either a tri-clamp sanitary fitting or a flanged connection in a range connection sizes. The in-process view by the Crystal Microscope Process Camera requires no sampling lines to extract process material and crystals are analyzed under actual process conditions.

CRYSTALLIZATION PROCESS MONITORING

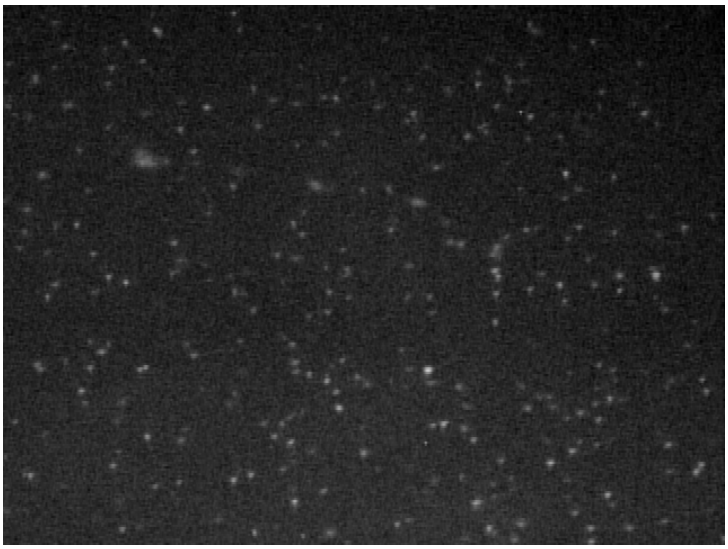


Figure 9, Primary Nucleation seen by Crystal Microscope Process Camera

The first event in the crystallization batch process needed for controlling crystal growth is the point of nucleation where seed crystals are added to saturated liquor. When the size of the crystal reaches one micron the Crystal Microscope can begin to see and analyze crystal size. Figure 9 shows crystals shortly after seeding and Figure 10 shows crystals after some growth. Figure 11 shows the crystals near the full size condition at the end of the batch.

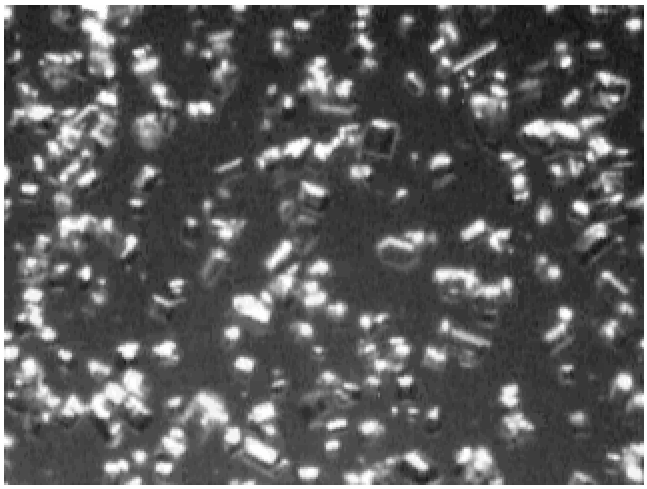


Figure 10, Crystal Growth after seeding seen by Crystal Microscope Process Camera

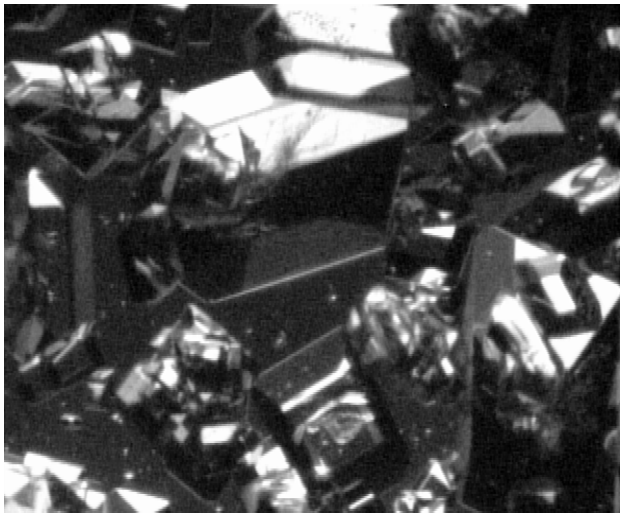


Figure 11, Crystal Growth near full size seen by Crystal Microscope Process Camera

As the crystals grow, their shapes become more defined to the eye and crystal size and shape can be analyzed by the computer software. The shape information is sometimes critical to the process and this is something only available with a vision based system. Nucleation and crystal growth together determine the final yield of product and the particle size distribution. The Crystal Microscope Process Camera and Vision System characterize each of the batch process stages to supply valuable information about the product growth and control the process parameters.

CONCLUSION

The vision based 2-D Particle analysis with an integrated optical zoom lens controlled by the Vision Processor Computer offers a data acquisition technique that permits real time process control of a wide range of products. For both dry granules and crystal growth in a temperature controlled batch process, the vision based system has the ability to continuously measure the size and shape of the production. This measurement enables efficient process control so that optimal product streams are produced. Better process control leads to cost savings as less oversized or undersized product is made.