Closed Loop Defoamer Control Stabilizes Paper Machine Operations and Reduces Costs

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Abstract

For many years papermakers have invested in on-line sensors and analyzers to measure specific parameters and properties in the papermaking process. In order to fully realize the economic benefits associated with on-line instrumentation and measurements, closed loop control is a critical step required for a successful control program.

Introduction

Closed loop control has a long history in industry and in paper making. The earliest controls were mechanical devices such as the governors used on water wheels and steam engines and controlled only a single device. The paper industry recognized their value as it led to better control of the process and increased production.

The early 1900s saw the development of control devices based on electricity such as the compression rheostat and induced current sensors. These too were applied to the control of equipment again; these were typically single application feed-back loops. The superior control and broader applications allowed papermakers to improve the process and control it more effectively. Starting in the 1920s and 30s and continuing through the present electrical devices were continually improved and new sensors became available. During the 1940s and 1950s multiple control strategies based on analog controllers were developed and provided the next step forward.

The advent and growth of solid state science however has probably had the greatest impact on closed loop control through three contributions. The first was the ability to develop more sensitive, more complex and more robust sensors. The second, low-cost digital computers allowed non-hardware logic which could be easily modified as well as hierarchical control and complex mathematical processing of the process sensor signal. The third was the ability to move signals long distances digitally over both wire and fiber optics without degradation which allowed large scale control throughout the paper mill site. These developments were critical to the wide scale DCS control systems now present in most new and retrofitted into many older mills.

One specific example is the ability of papermakers to successfully measure entrained air and dissolved gas in the wet end of a paper machine. Entrained air and dissolved gas can lead to a reduction in paper machine drainage, excessive steam usage and reduced sheet strength. On-line entrained air and dissolved gas measurements can be utilized to close loop control wet end defoamer addition rates. In doing this the papermaker is able to realize significant cost reductions associated with both machine issues and excessive chemical addition.

History of Controlling Entrained Air in Papermaking Systems

Like feedback control the problem of entrained air in the papermaking system has an equally long history. As long as paper has been made the goal has been to produce a single uniform surface. The release of entrained air or dissolved gases from the stock during sheet formation have always been associated with defects such as holes or surface defects, even in handmade papers. As papermaking was mechanized and machine speeds increased entrained air was found to slow drainage and cause pump cavitation to the point that machine builders responded with mechanical de-aerators. The high customer demands, along with the high production rates of modern machines have made the need for entrained air control nearly universal.

In addition to mechanical air control via deculators and similar devices papermakers have also relied on a variety of chemical defoamers. These products provide the papermaker with flexibility in that the amount or even type of defoamer may be changed as process conditions and product needs dictate. Like control science, defoamer science has progressed through many stages. Early on it was not uncommon to find a 55 gallon drum of kerosene at the edge of the wire pit with a small nail hole which allowed kerosene to slowly drip out (the earliest metering system?)

In the 1930s the hydrophobic silica- in-oil defoamers were patented by the Hercules Powder Company and became widely used over the next 30 years. Defoamers substituting EBS for the silica and extended with water were developed to provide better cost effectiveness. Water based defoamers were developed during the same period to meet the desire for low cost products which when over-used did not break the mill's defoamer budget. While the historical defoamers are still available, new blended products which not only provide effective defoaming, but minimize impact on sheet properties and functionality such as sizing have been added to most product lines.

Present Methods & Strategies for Controlling Entrained Air

Today, state of the art defoamers can be classified in two general types based on use. First are products which act on surface foam, the second are those aimed at stock de-aeration. Application however remains troublesome.

Traditionally defoamer is added based on operator observation of the wire pit foam or the visual color or texture of the sheet as it travels down the table. These techniques provide little sensitivity to and are actually biased to overuse. Overuse in turn can impact sheet sizing, lead to deposits, contribute to felt filling or cause increased dirt counts. Hence there remains a need for improved defoamer control.

Paper mills have traditionally struggled to automate wet end defoamer addition rates. The excessive use of defoamer can lead to issues with sizing and deposition, however traditional control based on visual observation of foam levels did not allow for maximizing performance of the paper machine without significant over-addition. By combining sound on-line measurement technology with closed loop control, mills can now quickly and accurately measure entrained air at the head box and control and optimize defoamer addition rates.

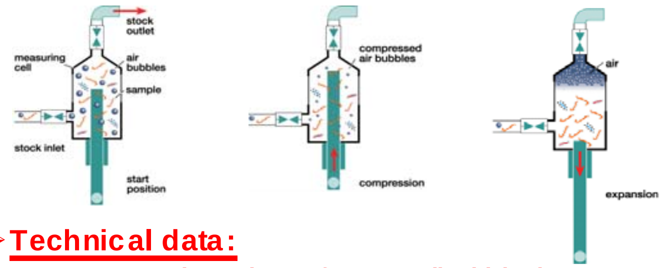
Online Gas Analyzer – Description and Principle of Operation

Providing a sound entrained air measurement in real time can in and of itself lead to a significant change in operator perception of defoamer need. Coupling the entrained air measurement with closed loop control either via the process DCS or a stand-alone controller provides the ability to optimize defoamer use based on head box entrained air rather than observation of the wire pit and table thus lessening the over-use bias of visual control.

The analyzer used in this work measures both free and releasable dissolved gases in paper stock suspensions at up to 3% consistency. These measurements are accomplished by both compressing and expanding the gases during the measurement cycle 1 to 2 minutes in duration. The units are capable of continuously monitoring two process streams per unit.

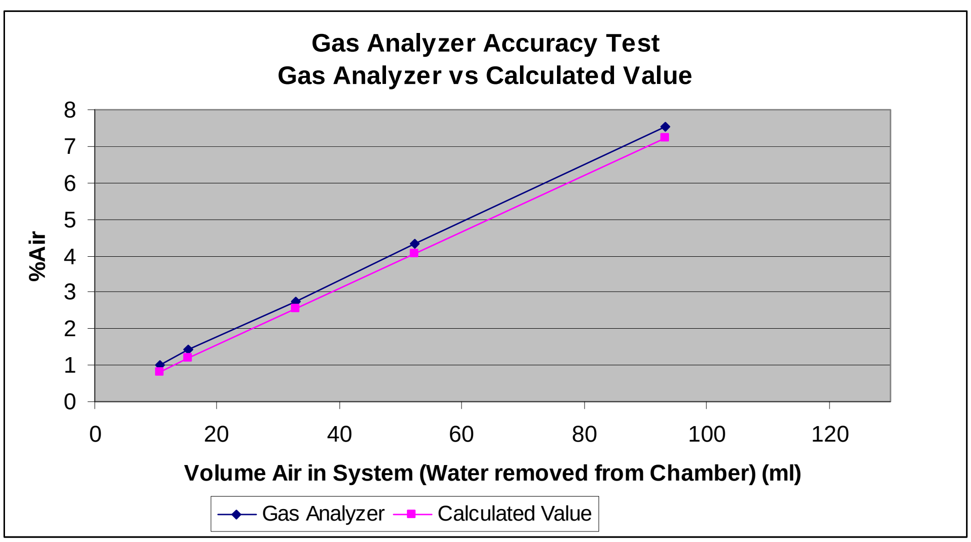
The entrained gas (%free air) in the form of gas bubbles is measured by compressing a sample in the measuring cell in step one of the measurement. The volumetric share of the entrained gas is calculated by Boyle's law ($p \times V$ = const.). In step two dissolved gas that may be released is measured by expanding the sample. The expansion cycle simulates the process on the paper machine wire where the stock suspension is subject to a sharp drop in pressure. As the pressure in the measuring cell is reduced, soluble gases in the stock suspension are released. Again, Boyle's law is used to calculate the amount of released dissolved gases. Upon completion of the testing, an integrated rinse cycle begins to thoroughly clean and prepares the instrument for the next set of measurements.

$$p_1 V_1 = p_2 V_2 = p_3 V_3$$



- **Technical data:**
  - 0.00 – 8.00 % by volume free gas (bubbles)
  - 0.00 – 8.00 % by volume dissolved gas
  - Accuracy +/- 0.02 % by volume
  - Automatic cleaning cycle

The figure below shows the instrument's accuracy conforms well to theoretical calculations.



This paper outlines the application of an online entrained air/dissolved air measurement and the steps needed to implement a successful wet end defoamer paper machine control strategy. The sources of entrained and dissolved air will be reviewed as well as how to utilize these distinctive measurements in a control strategy. Case studies will be shared showing the implementation of defoamer control programs and the benefits achieved. All results are based on commercial applications at a number of mills throughout North America.

Case Studies – Online Systems and Closed Loop Control of Defoamers

Case 1: Affect of Entrained Air and Defoamer Dosages on Paper Machine Conditions

A trial run to confirm the entrained air measurement followed changes in entrained air produced by changing defoamer dose. Figure 1a shows entrained air increased as defoamer feed decreased while dissolved air remained essentially unchanged as expected. Figures 1b & 1c show how defoamer application is related to wet process conditions, in this case couch and flat box vacuums which can affect consistency and drainage.

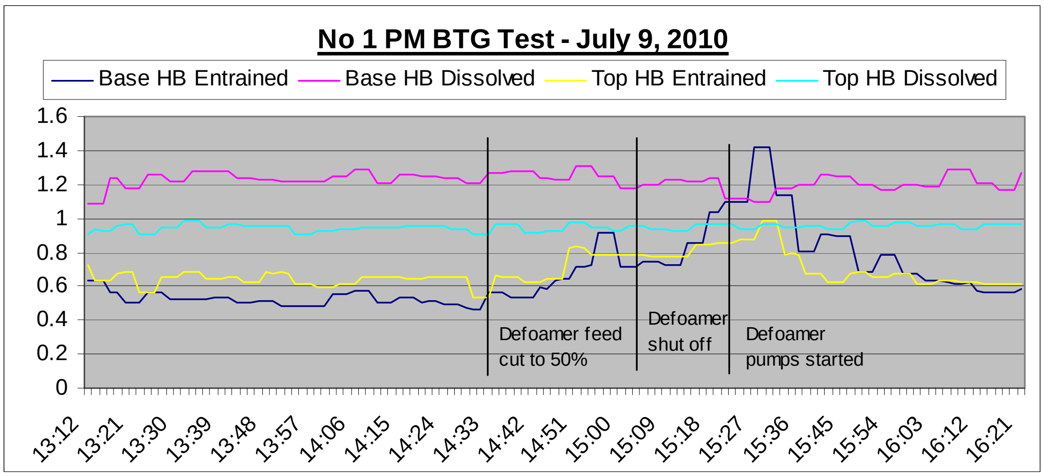
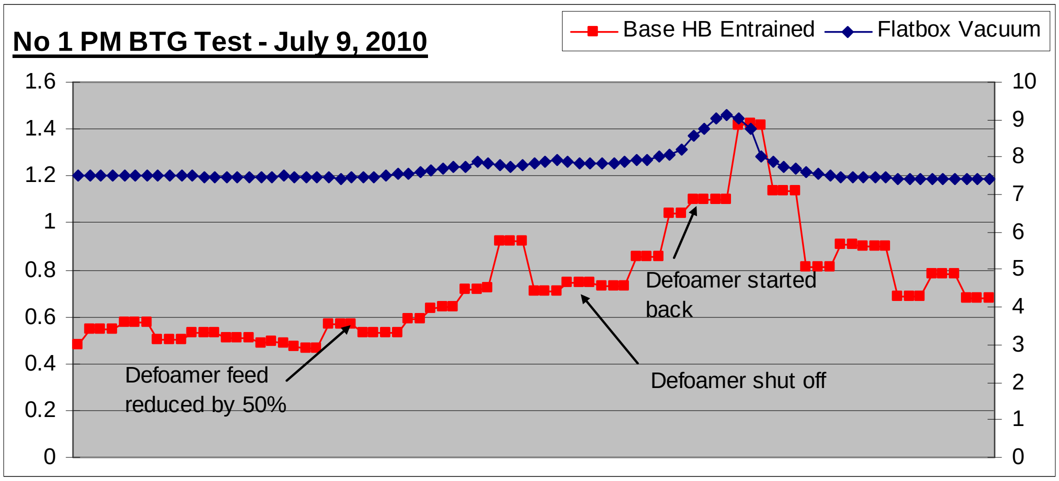
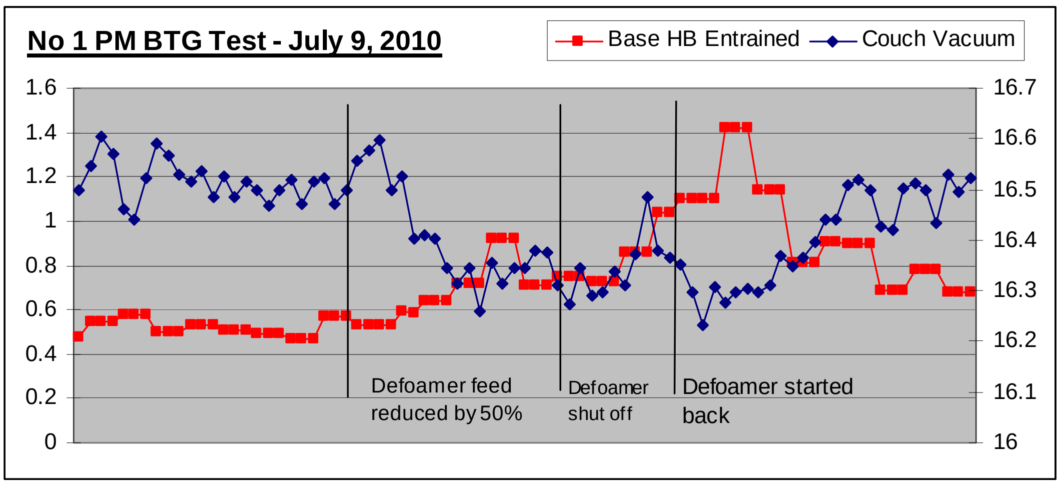


Figure 1a: Impact of defoamer on measured entrained air.





Figures 1b & c: Relationship of defoamer applications to wet-end process conditions.

Case Study 2 – Defoamer Optimization Using Continuous Closed Loop Control

Case two is an example of defoamer optimization using entrained air measurement in continuous closed loop control of the defoamer application. It is also a good example of the steps involved in implementing closed loop control of the defoamer program. The data comes from a southern Kraft Mill making both linerboard and medium on high speed fourdrinier machines.

The root problem was poor sheet quality caused when the table turned 'foamy'. Manual EGT testing showed the problem was related to high levels of entrained air at the head box. Over the years operators had learned that excessive wire pit foam was a leading indicator that the table would begin to get foamy and sheet breaks and defects would soon follow. Hence they used this observation as the basis for adding defoamer but since there was no way to know when the period of high entrained air ended, subsequent defoamer reductions were only slowly implemented, if at all. This led to the second issue; excessive defoamer use based on prior year history and annual budget.

A manual Entrained Air Tester (EGT) was used to profile the machine and showed high levels of entrained air. Especially problematic was a significant increase in entrained air at the refined stock chest. Additional manual EGT testing showed that the entrained air content of the head box varied by up to 3% due to process variations while wire pit entrained air was essentially zero.

On line entrained air testing was proposed as a potential solution. Working with mill management, electricians and process control group a suitable location was found to site an instrument, utilities were connected, sampling lines were installed and the unit was connected to the mill DCS. Sample points consisted of 1 inch taps off the stock line to the head box or off of the head box bypass lines. Connection to the DCS (PI system) consisted of connecting the 4-20 ma signal cables; however this could not be completed until a week after the unit was installed. In this case the defoamer pumps were already tied into and controlled through the DCS.

The unit was commissioned and the operators were trained on its use. Although the unit was not yet connected to the DCS, after a short introductory period the operators were began using it to adjust defoamer. The use of the manual ‘closed loop’ control resulted in a gradual decrease in defoamer use as operators gained confidence and began using it to adjust defoamer. (First 11 controlled data points in Figure 2) Following tie in to the DCS the control strategy resulted in continued optimization of defoamer use.

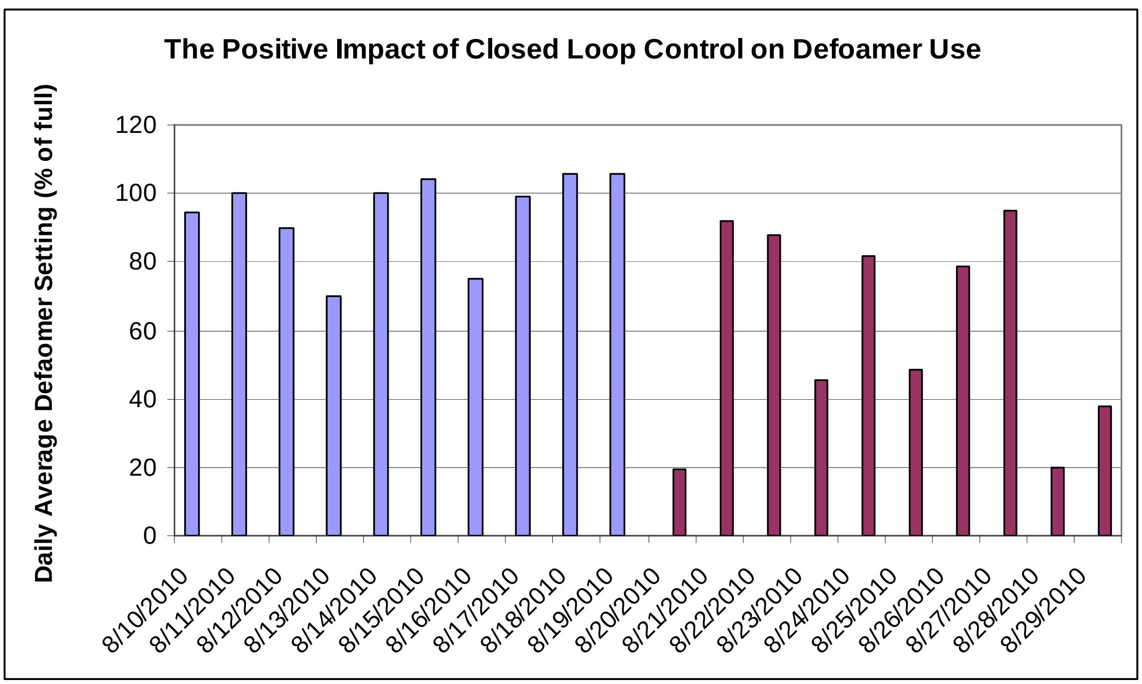


Figure 2: Defoamer use vs. time

Figure three shows that the key issue, defoamer over-use versus budget was moved to a new lower level by implementing continuous entrained air measurement and closed loop control of defoamer addition.

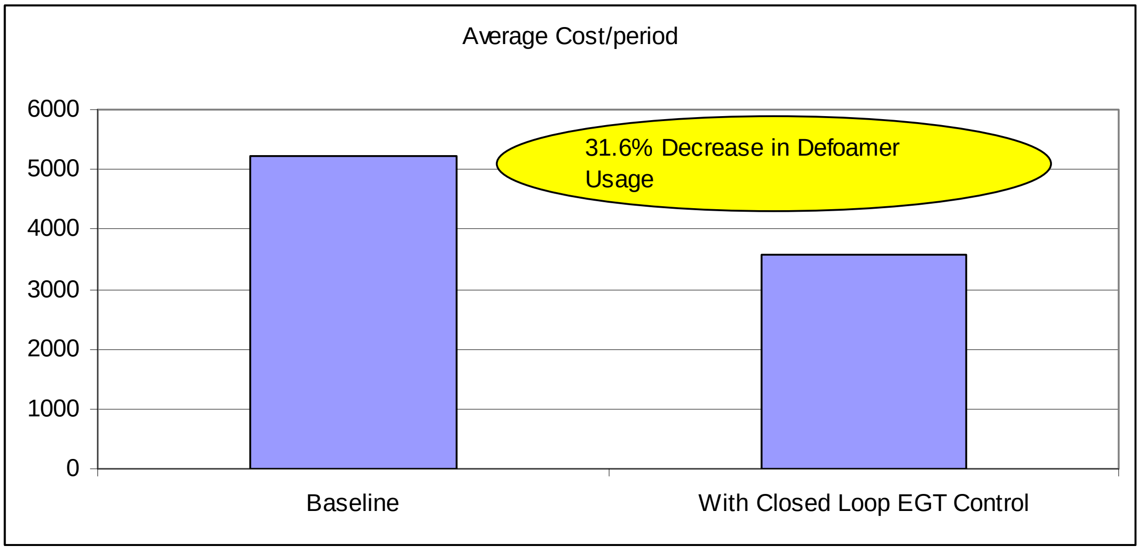
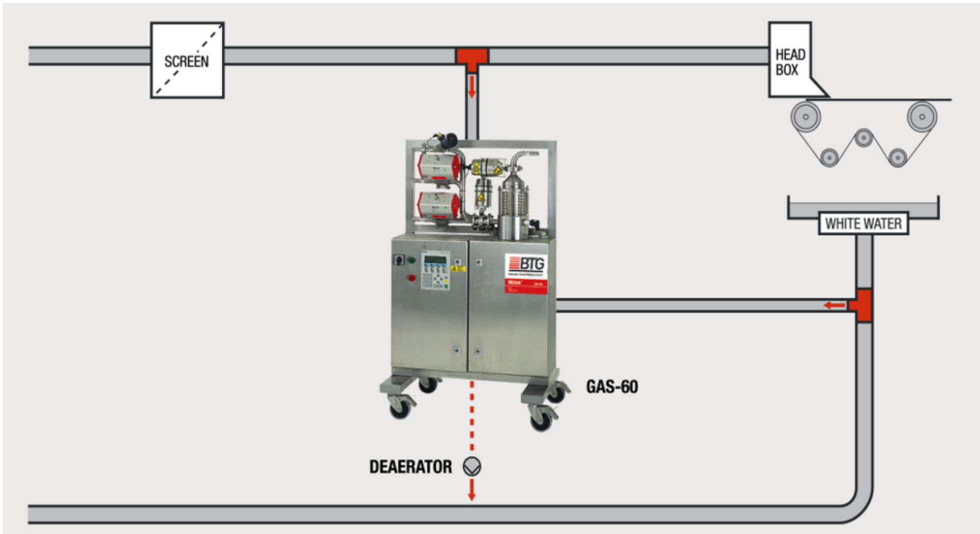


Figure 3: Comparison of average defoamer use before and after unit installation controlled through the DCS.

In summary, entrained air measurement based closed loop control is a powerful means to manage defoamer use and program cost.

Case Study 3 – Closed Loop Defoamer Control Reduces Defoamer and Sheet Defects

Case Study three shows how closed loop based on entrained air measurement reduced sheet defects (pinholes). This European machine was equipped with an undersized mechanical deaerator and had a history of pinholes in the sheet. Testing showed both free and dissolved gases were present in the headbox stock. It was suspected that this air was carried with the wire where it released and formed pinholes as it escaped through the sheet. A possible contributor of the air at this mill was the use of recycled stock which contained calcium carbonate. Calcium carbonate can be a source of dissolved and entrained gas when it is carried into the acidic paper making system where it generates carbon dioxide gas. Based on best practices a target 1% air maximum was chosen to control the system and the simple control sequence shown below was implemented.



Once the control loop was put into operation the average defoamer consumption decreased by 40%, accompanied by a reduction in the dissolved gas content. In the end an additional benefit of using only the defoamer needed not only reduced chemical costs, but also enhanced efficiency of the retention aid.

The paper company collaborated with the German Paper Research Foundation (PTS) to determine the affect of gas content control on pinhole number and size distribution. Paper samples of high and low dissolved gas content were taken before and after closed loop control of defoamer (deaerator) chemical dose. Results (figures 4a and 4b) confirmed that gas content control significantly reduced pinhole number resulting in improved quality.

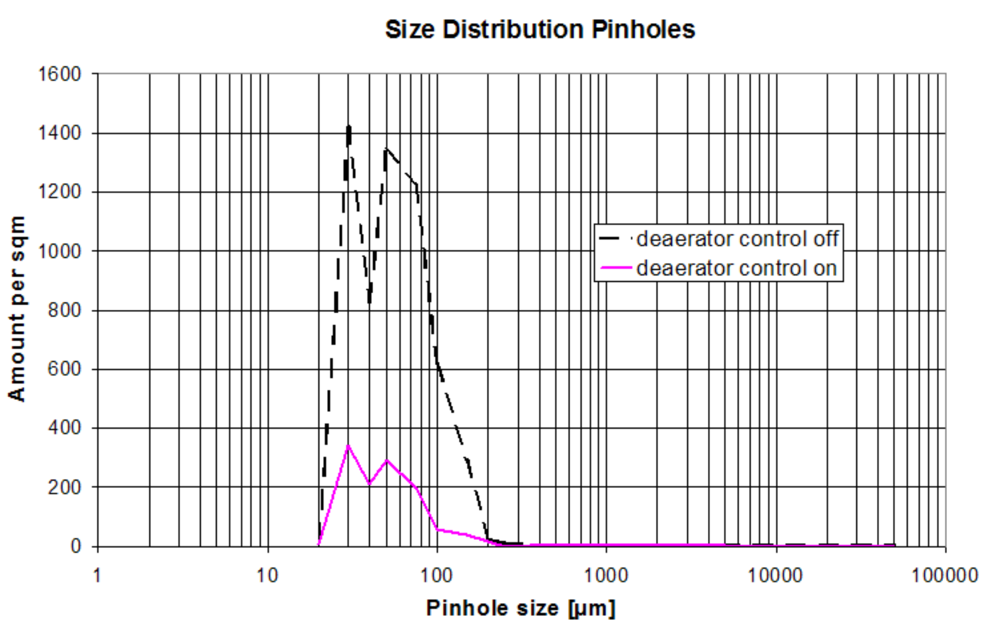


Figure 4a: Lower gas content resulted in a six-fold decrease in pinholes.

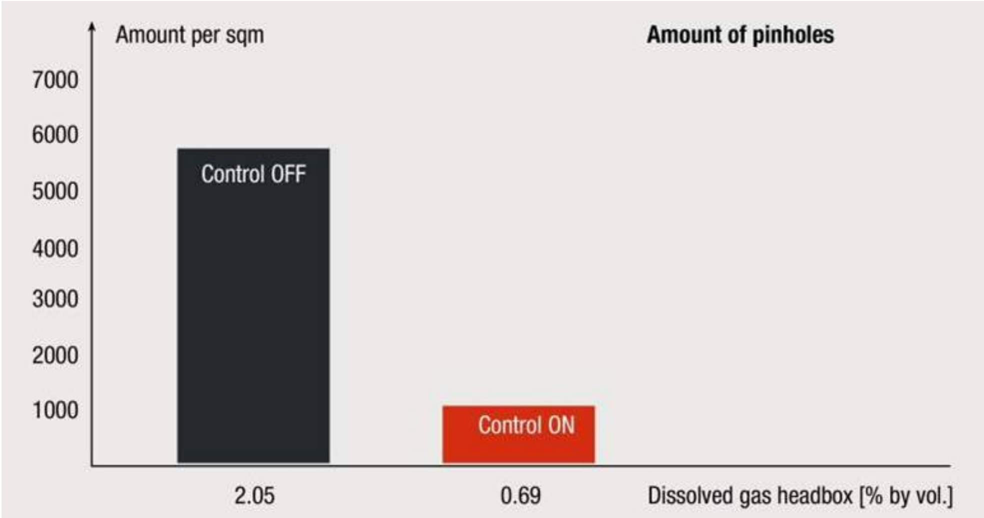


Figure 4b: The Affect of Gas content control on the amount of pinholes

Conclusion

The use of entrained air monitoring to provide closed loop control of the paper machine wet end can provide advantages of reduced cost, reduced defoamer use, as well as the advantage of improved product quality.