Application Case Study: Pressure Control in Adiabatic Cooling

Introduction

A prospective client requested Whitman's review of a new application they were working on involving industrial adiabatic cooling technology, seeking an analysis and recommendation on control sensor solutions that could fit into a new product lineup they were developing. "Sure, we'll help," we said, "that sounds pretty cool." Pun completely intended!

About Us

As a veteran-owned small business, Whitman Controls is dedicated to supplying premium quality, reliable, technologically advanced instrumentation for use in nearly any application. Our Bristol, CT manufacturing facility embodies over 40 years of engineering, fabrication, and customer service expertise, serving both end-user and manufacturing customers nationwide through direct and distribution channels.

Application Summary

One of nature's most interesting climate phenomena is adiabatic cooling. As air rises in altitude such as when blowing over a mountain range, this air encounters decreasing air pressure as it gains elevation. When air pressure decreases, it causes the air mass to expand, and this expansion cools the air's temperature as the kinetic energy in the air molecules drops.

This relationship between decreasing vapor pressure and decreasing vapor temperatures is known as adiabatic cooling, and humans have ingeniously adapted this natural process to a great many of our own uses. In particular, adiabatic cooling is used for commercial and industrial thermal control applications ranging from livestock comfort cooling to data center refrigeration and more.

Most often, industrial adiabatic cooling is performed in an air-assisted cooling tower, where closed-loop cooling water is recirculated through heat exchanger coils with forced outside air pulled across these coils to dissipate the water's heat into the air. The adiabatic cooling component is achieved by spraying service water into the flowing air stream before it hits the coils.

As this service water is jetted out of high-pressure supply nozzles into the much lower-pressure air stream, it rapidly expands and cools the air. This cooled air now has higher heat removal capacity, achieving greater overall cooling of the recirculated water than dry air alone. Because this cooling effect is a function of pressure change and mass flow (proportionally adding water into a given airflow), adiabatic cooling systems are best operated using advanced PID controls to manage cooling water, service water, and induced air streams.

Challenge

Pumping water out of spray nozzles is not itself a complicated process, but when trying to achieve a very precise physics reaction with these spray nozzles, the required automation does get more complex. Our client's objective was to implement online process controls that would modulate the service water spray coming out of nozzle headers on their adiabatic coolers such that the spraying pressure and flow resulted in a predictable air temperature, and ultimately in a target cooling water exit temperature. Accomplishing this required automated controls to compare process variables to our client's proprietary adiabatic cooling data tables, and make real-time adjustments to pump speeds and control valve states.

Not only was our client looking to design and select an instrumented solution to this process control challenge, but they were doing so as part of their overall product design phase in launching a new platform of adiabatic coolers. Our client was at the 'design development' part of their launch process, engaging suppliers such as Whitman for a market-ready solution that they could take to their next phase of pilot testing.

This made the challenge a little bit more interesting, in that we're more involved on the engineering end supporting the development of a solution via calculated hydraulic and thermal modeling (being performed by advanced process modeling software). More data, more theoretical predictions, and more calculated functional parameters were needed before making a launch decision, and Whitman was happy to support this effort.

The specific engineering challenge at hand included these control elements:

- Recirculated cooling water flow needs to stay within a consistent flow rate range, adjusting recirc water pump speeds via their variable speed drives.

- When outside air is cool enough to achieve the desired cooling water exit temperature, spray nozzles remain off and the air fans would spin at a minimum RPM via their variable speed drives.

- As the outside air temperature rises, the air fans increase in RPM linearly as needed to maintain the desired cooling water exit temp.

- Once outside air is too warm to achieve the desired cooling water exit temp, the spray nozzle service water engages, controlled to a set starting header pressure and flow rate. Pressure is maintained by controlling pump RPMs via their variable speed drives, and flow rate trimmed via flow control valves on each bank of spray headers.

- The relationship between spray nozzle header pressure and flow is algorithmically weighed against outside air temperature, cooling water in and out temperatures, and overall system load. Without giving away our client's proprietary cooling functions, we can say that this relationship is what our control solution would need to provide to achieve their novel, highly energy-efficient adiabatic cooling profile.

"The reason we looked at Whitman's sensors was because of their high accuracy and repeatability at good prices. Our control algorithms need really solid input readings, and they depend on sensors being consistent for as long as possible between calibrations." - **Senior Process Engineer, Confidential Adiabatic Cooling System OEM**

Solution

Whitman's application engineering team performed the requested application review across a few weeks, including plenty of healthy discussions with our client's team in order to fully understand and prioritize data, expectations, and findings. Specifications and data points were shared with our client to feed into their hydraulic modeling system, allowing their engineers to validate our suggestions. Ultimately between Whitman and our client, we landed on two recommended sensors for their upcoming cooling platform:

- Whitman P802 Series High Pressure Stainless Steel Pressure Transducer - this option was recommended on the spray nozzle header service water supply, specifically because of the high pressures involved.

- The P802 pressure transmitter is rated up to 20,000 PSIg with extremely tight accuracy of +/- 0.25% of span.

- Since our client's goal was to pump at high pressures in order to get a large pressure drop when leaving the nozzles (to maximize the adiabatic cooling effect and drive up relative humidity in the air stream), this sensor checked all the boxes between technical capabilities and cost.

- **Whitman P805 Series Stainless Steel Industrial Pressure Transducer** - this option was recommended for the recirculating cooling water loop, fitting well with the wide range of expected process cooling loads as the P805's calibration is temperature compensated.

- This pressure transmitter uses an oil-buffered diaphragm which also works with moderate process pressure spikes, hammer, and other hydraulic upsets without drift.

Adiabatic cooling systems tend to experience vibration and mechanical shock given the nature of the high-speed fans and large pumps installed on these skids. Both the P802 and P805 are rated for vibration, shock, high temperatures, and high cycle counts, altogether assuring long lives in our client's applications.

Results

At the conclusion of our application review, our client returned to their engineering team with options in hand, ready for their final process analysis and review. For capital project decisions that will have long-running impacts for years to come, detailed engineering modeling is always necessary and highly recommended. Whitman continues to support the endeavor by keeping lines open between our client and our application engineers, and we look forward to the deployment phase to come.

Data Bullets

- **15%** increase in service water efficiency
- **8%** decrease in service water pump energy consumption
- **<1** week lead time on stocked OEM instrumentation
- **20%** of Whitman staff pronouncing it “adabiatic” instead of “adiabatic”, both groups being correct of course

Here at Whitman Controls, our values drive us to provide the highest level of servant partnership that you can find. To discuss your applications or to learn more about our capabilities, please contact us at (866) 868-8883, via email at info@whitmancontrols.com, or online at www.whitmancontrols.com.