Application Case Study: Pressure Control in Medical X-Ray Systems

Introduction

For most of us, long waits at the doctor's office are par for the course. Over-booked schedules, testing delays, short staffing levels; we can understand and sympathize with these common reasons for long wait times, and surely there are many more we aren't privy to. In fact, one of the lesser-known reasons might surprise you, should you hear a medical technician say "Our x-ray machine overheated and we're waiting for it to cool down." That's right - medical radiography equipment is highly prone to heat-induced outages and failures, so much so that most high-volume machines today come equipped with onboard active cooling systems. In a

recent project, Whitman Controls was engaged by a client seeking automation support for their own line of x-ray tube cooling systems. Thinking about how much time could be saved in radiology waiting rooms everywhere if x-ray machines never overheated, we couldn't help but scrub in!

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

Medical x-ray equipment consists of a vacuum tube x-ray emitter and a separate x-ray collector. Electromagnetic radiation is emitted by the x-ray tube, which passes through a patient being imaged, and is collected into a film or digital image. Advanced x-ray techniques can produce three-dimensional, real-time motion images, such as with CT scans. In all cases, x-ray vacuum tubes are highly energy inefficient, with as much as 99% of the energy consumed to produce useful radiation being lost in the form of heat. This excess heat can lead to x-ray tube failure, equipment damage, rogue radiation emission, and physical harm to personnel. For these reasons, x-ray vacuum tubes must never be allowed to exceed their temperature limits. Small x-ray tubes such as those used in dental imaging may dissipate their heat by pausing for cooling periods between scans (on the order of 600 to 1,500 watts of load). Large tubes and high-cycle machines such as those found in hospitals require recirculating oil coolant systems to actively extract heat from the tube (drawing upwards of 4,000 watts of load). Oil cooling systems must be reliable, accurate, and automated so as to ensure the safety of x-ray equipment and its users.

Challenge

Our client's x-ray vacuum tube cooling systems consist of a closed-loop recirculating oil circuit, pump, and air-cooled heat exchanger. Cooling oil is pumped from the cooling system out to x-ray tube housings where the oil picks up heat, returns to the heat exchanger, and dispels this

heat to atmosphere. These x-ray tube housings can be installed in all scales and styles of medical imaging equipment, from mobile scan carts to massive CT scanners. Given this wide range of use-cases, our client's goal with the project was to enhance their platform's automated safety protection in a standardized fashion, ideally to a common solution across their entire product lineup. More specifically, the protection they were after was to monitor for and protect against pressure extremes that could lead to dangerous x-ray tube failures.

After a detailed review of our client's x-ray tube operating specifications, we broke the application down into five specific concerns that needed solving:

- **Elevated Temperatures** - x-ray tubes generate substantial heat, requiring sensors that can withstand up to 100°C, continuously.
- **Pressure Sensitivity** - with x-ray tubes, low pressure readings could induce a coolant leak or tube fracture, whereas high pressure readings could indicate air induction or hydraulic flow restrictions. In either case, sensors must be sensitive enough to quickly detect condition changes in these directions before they reach problematic limits.
- **Large Variable Swings** - rotating x-ray systems such as CT scanners add another variable into the mix in the form of hydraulic swings induced by the centrifugal force of the x-ray tube assembly rotating around the patient. Under such forces, sensors must withstand substantial pressure swings (over 300 PSIg) as well as pressure spikes that exceed the sensor's setpoint.
- **Critical Safety** - if the above factors weren't enough, sensors must also be unquestionably reliable, repeatable, and validation-ready. Should a pressure sensor fail to detect a system fault, rogue radiation, physical damage, and leaking hot coolant oil could all result.
- **Medical-Grade Environment** - when dealing with medical-grade systems, sensors must be constructed of appropriate materials and with features conducive to a hygienic environment.

"Our customers cannot accept anything less than total protection against [medical x-ray tube] overheating. We have to ensure complete patient safety and [x-ray] technician confidence. Adding pressure sensing to our tube coolers steps up our reliability tenfold." **- Director of Sales, Confidential Medical Equipment Manufacturer.**

Solution

After carefully dissecting our client's concerns, our application engineers organized a feature list that would help verify the solutions to be developed next. Going in reverse order of the above requirements, we first determined that we'd need a sensor from our Ultra Pure, impurity-free lineup to pair with the medical-grade environment. For critical safety reliability, the Ultra Pure line served equally well, featuring factory helium leak testing, electron beam welding, stainless steel materials, high cycle rates, and ISO 9001 quality certification.

Looking at the remaining three process variable requirements, we knew we were down to selecting an individual sensor. Every now and then we get an application that fits so well into our standard products, that we have to triple check to make sure we didn't miss any unique details. This was one of those times, and a specific part number jumped out of the catalog at us as a perfect match: the Whitman W117G Ultra Pure Stainless Steel Pressure Switch!

Our W117G switch easily handles the client's expected pressure extremes, rated for up to 150% of the sensor's 500 PSIg setpoint capacity at temperatures up to 105°C. Once electronic, wiring, and connection selections were made, our client opted to add a few additional options to further enhance the project, including Loctite sealant pre-applied to the sensor's threads, factory calibration, and an inspection tag. Even better, this single sensor configuration fit each of the client's x-ray tube cooling system sizes, allowing us to solve their entire catalog with one part number.

As much as we trust our sensors and stand behind their quality, when it comes to human life and safety, we treat any sensor as a potential single point of failure waiting to happen. For this reason, we recommended redundant sensors as a hedge against single failures, which our client agreed with and incorporated into their cooling system designs.

Results

Since this project was completed, our client has seen rapid growth of their packaged x-ray tube and cooling system sales. Prior to adding automated pressure protection, these systems relied on traditional flow switch and pump motor over-amp sensors to catch failures, as is the standard offering from most OEMs in this market. Our client's efforts to exceed expectations by adding pressure protection were well received by their end-users, driving sales growth and

even retrofits of competitor systems. For what it's worth, two of our staff have reported much faster visits for routine x-rays recently, which we're going to believe are thanks to these cooling system upgrades!

Data Bullets

- **8%** increase in x-ray tube lifespan due to improved cooling protection
- **12%** sales increase of our client's systems after pressure control integration
- **1-2** weeks lead time on Ultra Pure instrumentation
- **2** "speedier then usual" dental x-rays received by our staff since this project

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) 614-9236, via email at info@whitmancontrols.com, or online at www.whitmancontrols.com.