Testing Brief

Geothermal Cooling of Hydraulic Power Units at Axel Products

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Figure 1, Geothermal Drilling

Introduction

At Axel Products, we don't write much about our facilities, our expansions our instruments or ourselves. We try to describe what we do and how it may help those that we serve. However, in the many workshops, meetings and tours that occur in our building, there always seems to be some that find the geothermal approach to cooling our hydraulic units to be of great interest. This document is a not very technical discussion of that capability.

The Need for Cooling

Many of the materials testing instruments at Axel Products use hydraulic power to generate the dynamic physical movements needed to characterize the dynamic and fatigue behaviors of materials. The hydraulic power is generated by many separate hydraulic power units. Each of the units consists primarily of a motor and hydraulic pump. The hydraulic power units are each attached to between one and four physical testing systems.

Operating hydraulic power units is costly. They need electrical power to operate and they need cooling to eliminate excess heat.

Having many small hydraulic power units operating only when needed by laboratory instruments reduces electrical power used because the demand is intermittent. Hydraulic power units of the size used at Axel are typically cooled with oil-water heat exchangers with the heat being transmitted from the hydraulic oil to cooling water.

At Axel, we originally cooled hydraulic power units with city water. The water from the city was pumped through the heat exchangers and dumped into the city sewer. Needless to say, this was expensive and wasteful. Additionally, the supplied water was colder in the Winter and warmer in the Summer causing sensitive test instruments to behave differently. As the laboratory grew and we brought several additional units into service, our City water use became so costly that we transitioned to a refrigerated water cooling system. A piping loop was installed throughout the facility and heated water was returned from units to a large refrigerated water cooling system, cooled and returned to a tank to be used again based on demand. This system was much less costly to operate than buying city water but still expensive to operate. The refrigerated water cooling system also requires a large volume of cool air to operate. This was not an issue most of the year but in Michigan each year, there are a few hot weeks when it was difficult to supply cool air to the cooling system and we needed to provide cooled air from the laboratory. This was additionally costly. In several instances, the cooling system did not keep up with cooling demand and every hydraulic power unit in the laboratory overheated and shut down. This was a terrible outcome.

Figure 2, Hydraulic Power Units

One of the challenges of cooling the water is that the temperature difference between the supplied cooling water and the water warmed by the hydraulic power units is small. It is desirable to keep hydraulic oil between 100F(38C) and 110F(43C). Most hydraulic power units are arranged to use 70F(21C) cooling water. The cooling water returning from all of the hydraulic power units mixed together returns at approximately 80F(27C). The task at hand is get the 80F(27C) water back to 70F(21C).

As our lab continued to expand, additional test instruments could not be added without adding additional hydraulic power units that required additional water cooling capacity. At the same time, the additional capacity needs were driven by fatigue testing that is much more cost sensitive than other kinds of testing that use hydraulic power in our laboratory. We are very motivated to provide reasonably priced fatigue testing options for our customers so reducing costs in this area is critical to that effort.

Figure 3, Refrigerated Water Cooler

One of our environmentally minded employees, Andreas Poli, advanced the idea of geothermal cooling. Could we simply pump our heated water down into the earth where it is colder, cool it, and then bring it back up? The short answer is yes. Does it make economic sense and how might that work? We struggled to find guidance. Typical geothermal applications involve heat pumps and cooling and heating in fairly defined conditions. The typical HVAC contactor or industrial process contractor doesn't often address this particular arrangement.

Furthermore, the ground in Michigan contains many kinds of soil and rock and water and can vary significantly from one spot to the next so we didn't know with great uncertainty how heat would transfer from our heated cooling water. Some contractors offered to drill an instrumented well to measure these things but one can drill many non-instrumented wells for the cost of one instrumented well. And the instrumented well may not predict performance of a well drilled just 50 feet away.

Furthermore, the earth isn't an infinite heat sink. If we pushed enough heat into the earth around some pipes long enough, the region around the pipes would warm and the ability to cool would degrade or nearly stop.

As with many engineering projects, this project needed to progress or fail but we needed to move ahead to meet our customers' needs

Figure 4, Geothermal Pipes Enter the Building

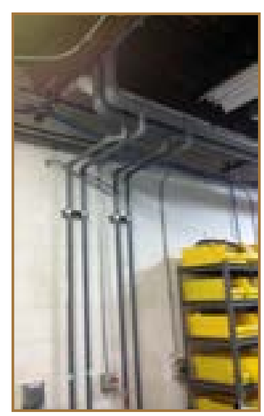

Figure 4, Facility Piping

and we weren't likely to get the detailed performance information desired. However, buying a larger refrigerated water cooling system was distasteful and uninteresting. Certainly one advantage to being a small non-public company is that we can select the most interesting approach over the safest approach; even if it may mean our eventual demise! Despite wanting to drill instrumented wells because the data would be really fun to see, we just picked 10 wells because we had that much space on one site of our parking lot and we drilled 300 feet (100m) down because that was a natural drilling technology point.

Figure 5, Empty Pipe Trench

The Elements of the System

So here is what we built. Our system has 3 water cooling methods, a geothermal field, a fan-fin cooler and a refrigerated water cooling system. All three cooling methods and the hydraulic power units are connected to each other by pipes, valves and pumps. The operation of the valves and pumps is controlled by software running on a Honneywell WEBs-AX controller using live temperature measurements of air and water.

The geothermal field consists of ten wells, each 300 feet (100m) deep. The wells are contained so the water doesn't leave the pipes. The water goes down 300 feet (100m) inside of a pipe and back up to the surface while transferring heat through the pipe wall into the surrounding earth. The water travels through all ten wells and returns cooled.

Figure 10, Pumps and Vavles

The fan-in cooler is simply two big fans blowing air across a radiator six feet off the ground in our parking lot.

The refrigerated water cooling system system is the leftover system from before we started this other project.

How it Works

There are 3 basic operational modes and some emergency conditions.

Outside air temperature is greater than 55F (13 C).
In this case a valve opens and some of the heated water is ported through the geothermal field to keep the cooled water temperature entering the laboratory near 70F (21C).

Outside air is between 10F(-12C) and 55F (13C).
When the outside air is cool, the heated water is directed by valve though the fan-fin cooler that operates by blowing air across the fan-fin radiator. The geothermal field is not used.

Figure 7, Fan Fin Cooler

Outside air is below 10F (-12C).
When it is very cold outside, the heated water is directed by valve though the fan-fin cooler to make the water very, very cold and then

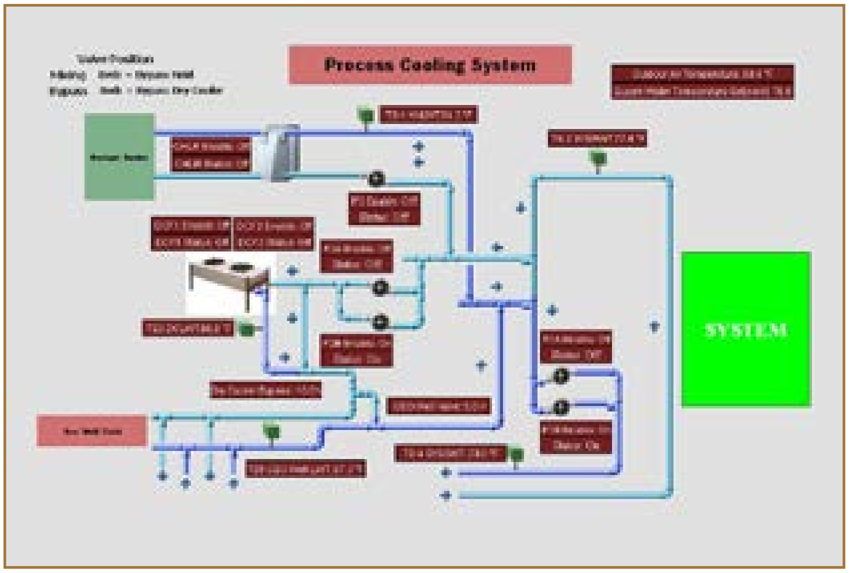

Figure 9, Process Cooling System Diagram

further directed through the geothermal field. This helps the geothermal filed cool down for use when the temperature exceeds 55F(13C) again; likely the following summer.

This methodology is well suited to Michigan's temperatures swings. Sometimes, the fan-fin cooler is used at night and the geothermal field is used in the day. In the short time the system has been in service, we have been able to go through summers using the geothermal field primarily without seeing a decline in performance.

Both the geothermal field and fan-fin cooler operate at a fraction of the cost of the refrigerated water cooling system and so far more reliably. They are just pumps and fans.

If the fan-fin cooler cannot cool the lab entry water to 70F, then the geothermal filed will open to assist. If for any reason, the fan-fin cooler and/or the geothermal field are failing to maintain 70F water to the laboratory, the refrigerated water cooling system will come on also. This hasn't happened yet.

Summary

The cooling of many small hydraulic units using a combination of geothermal cooling and basic fan-fin cooling is working great. For us, this is a good solution for the weather in Michigan where we operate and the particular challenge of cooling many small hydraulic power units. The cost to operate is much less than refrigerated cooling or city water cooling.

For more information, visit www.axelproducts.com.

Axel Products provides physical testing services for engineers and analysts. The focus is on the characterization of nonlinear materials such as elastomers and plastics.

Data from the Axel laboratory is often used to develop material models in finite element analysis codes such as ABAQUS, MSC.Marc, ANSYS, Endurica and LS-Dyna.

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