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Special collaboration

Canada's heat pump pioneer

GeoConneXion magazine pays tribute to the groundbreaking work of Frank Hooper, professor emeritus of mechanical engineering at the University of Toronto

Pumping working fluid through underground piping to extract heat from the earth isn't such a radical idea. Not today, at least. In Canada alone there are more than 80,000 examples of exactly that – homes, hospitals, universities, community centres, hotels, office towers and even the occasional zoo using geoexchange systems to heat buildings.

Wind the clock back sixty years, however, and it was literally a groundbreaking concept. In Canada, the person who first broke that ground was Frank Clement Hooper, a graduate of engineering physics from the University of Toronto who, in hindsight, found himself at the right place at the right time.

Professor Hooper sailing as a young man. He is a member of the Canadian Royal Yacht Club.

World War II had just ended. Thousands of soldiers, most in their 30s, were arriving back in Canada and enrolling in university programs. The University of Toronto was in expansion mode to accommodate the influx of war veterans, and as part of that expansion it established a temporary campus in Ajax, just east of Toronto.

Not only did the university need more teaching space; it desperately needed more teachers. Hooper, just 22 years old at the time, was approached by esteemed Professor E.A. Allcut, head of the mechanical engineering department at the university. Allcut offered the fresh graduate and former student a job as lecturer. Hooper was both surprised and delighted.

"They had one engineer they'd hired to do that job, but he was making such a horrible mess of it that the students didn't want him and they appealed to Allcut to replace him," said Hooper, sitting in his home office in east Toronto recalling those early years. "On short notice, Allcut thought I'd do a fine job, so he asked me to take over."

Hooper obliged, and never looked back. During his first few years he was the youngest lecturer at the university and was often teaching students 10 years his senior. His professional ties with the university remain to this day, 65 years later. "That lecturer position got me started, and it appealed to me greatly – the life, the undertaking, the interaction with the students, and the development of ideas."

It was here where Hooper quickly made his mark, first by laying the early foundation for what is today a flourishing Canadian market for ground-source heat pump systems.

The potential of using heat pumps for heating and ventilation applications fascinated Hooper, who followed research in Europe and the United States but saw little, if any, activity in Canada. He became aware of the enormous amount of energy that was wasted heating buildings directly with fossil fuels, mostly coal at the time. Wood stoves were still used on farms, but most homes had coal furnaces in the basement. Neighbourhood "coal men" delivered bagfuls of the fuel regularly, usually dumping it down a shoot that went directly to the basement.

The thermal efficiency of such heating systems was poor, and this bothered the engineer in Hooper. He wondered whether a better approach lied in heat pump technology, which was well known for mechanical refrigeration applications where cooling was the objective. Using the technology specifically to harvest and repurpose heat for buildings, however, was a largely untested concept in Canada.

In that regard, and under the right soil conditions, Hooper saw the potential of heating homes using ground-source heat pumps. Such systems would extract heat from a working fluid as it travelled through copper coils installed underground. Hooper proposed the idea to Professor Allcut, who backed what would end up being a collaborative research effort with Ontario Hydro that began in 1948. It involved designing and installing a residential system for a newly built five-room home in Port Credit, west of Toronto.

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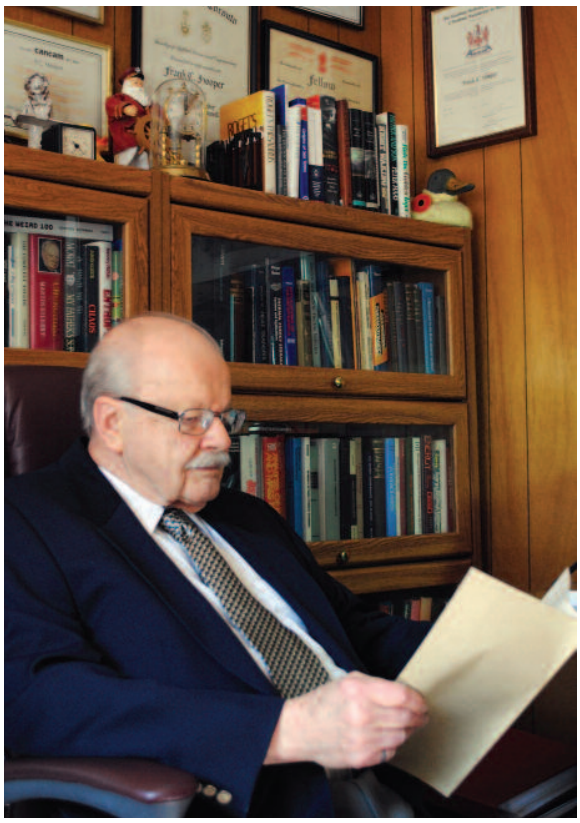

Professor Hooper in his home office reading his only copy of the 1952 study.

"That was certainly the first ground-source heat pump in Canada, and that drew the attention of a lot of people," said Hooper, who reached into a pile of documents on his desk and pulled out a research paper, its cover yellowed by time, dated 1952 and titled "An Experimental Residential Heat Pump." It had been published in the *Canadian Journal of Technology*, a peer-reviewed publication overseen by the National Research Council until 1956, when it was taken over by the Chemical Institute of Canada and renamed.

"It's the only copy I have," Hooper told me as he flipped through its pages, pointing to the many diagrams and charts within. The pages detail the design and performance of his three-coil system. I asked him if the project met his expectations. "Pretty close," he replied, pausing a moment to reflect. "But my hopes for it were higher. We came in at a COP (coefficient of performance) of 2. Unfortunately, the cost of electricity at the time per unit of direct electric heating was about three or four times the cost of gas or coal heating." In other words, it wasn't an economical replacement for heating a home with a coal furnace. For buildings that used direct electric heating, it would have cut their electricity consumption in half. But few buildings were heated this way at the time.

"I was enthusiastic about it. I could see, in my mind, streets full of houses using heat pumps. But I can't say Canadians came rushing to replace their heating systems with this," Hooper said. "Within the engineering community, however, it did get a solid reputation. People knew about it, and I had considerable correspondence with those who were interested. Interest eventually spread, and within about 10 years heat pumps were being installed, though not in great numbers."

Denis Tanguay, president and chief executive officer of the Canadian GeoExchange Coalition, said Hooper's paper was a defining moment for the technology and the industry that would eventually emerge from it. "When I read this paper, 60 years after its first publication, I was stunned by the clarity of the argumentation and the extent of the research and results," said Tanguay, who during a ceremony in May at the University of Toronto's Faculty Club presented Hooper with an award for his pioneering work. "Anyone interested in defining the paternity of GSHP systems in North America should know this article."

Hooper's work, of course, was only beginning. During my interview with the good professor he handed me another document, this one 40 pages thick. "This is my so-called short biography," he said. It was actually his curriculum vitae, the only one I've ever seen with a table of contents, evidence of Hooper's long trail of professional accomplishments.

By the time Hooper had published his residential heat pump study he was already onto his next project, this one focused on reducing energy consumption at Distant Early Warning radar stations – known as the DEW Line – in the far north of Canada. The stations, built in the early years of the Cold War, were established to detect Soviet bombers taking a shortcut to North America across the Arctic.

"These stations were all up in areas that could only be accessed by a dog team or by air," said Hooper, adding that arriving by air was a treacherous affair. "You have to hope there's not a high wind because coming in for landing you'll get blowing ground snow and a whiteout. That condition was quite extensive throughout the Arctic, so bringing in fuel such as heating oil was extremely expensive."

Hooper knew that most DEW Line stations were near frozen lakes, and that below six feet of ice there was water that could be tapped for heat. If a heat pump system, powered by a diesel generator, could be designed to heat the stations it would cut onsite oil consumption in half, he figured. "All I had to do was pump a little of that cold water out, take it to an icing machine that froze the water into ice, and I'd get the latent heat from the water" – kind of like the warm air that blows out the back of a freezer. All Hooper had to do was get rid of the ice he produced, in this case breaking it up with a fan and blowing the pieces into the outside air.

Professor Allcut managed to convince Defence Research and Development Canada, called the Defence Research Board at the time, to sponsor the research. Hooper built the complete system in his lab at U of T, then had it put on a steel skid and shipped by train to Churchill, Manitoba. From there, a tractor moved the skid about two three kilometres outside of town and onto a frozen lake. (An artist's sketch of the setup as seen in the lab hangs prominently on Hooper's office wall, complete with diesel engine, compressor, ice making drum and air blower).

It was a challenge, both to get the system in place and make it operational. Hooper had to drill a hole through the lake ice, but it was so cold it would start freezing instantly. "Everything we did was difficult," he said, with a chuckle. "But when we got it operating I was pleased. I didn't have anything to heat except the hut we were in, but it was a very good demonstration."

Unfortunately, the armed forces up there were a hard sell and didn't necessarily take their queues from the research board. From their perspective, all they saw was a stranger out on the lake in a hut blowing chipped ice into the air. "For them, they had enough ice, so they kind of thought it was a joke. I was making ice for the Eskimos!" Still, Hooper was convinced he could have sold them on the idea, given more time, but the Cold War eventually cooled down and much of the monitoring in the north was replaced by emerging satellite technologies.

As the years passed by Hooper continued his pioneering ways. Throughout the 1950s and 60s he did basic research around heat transfer and his work became increasingly sophisticated. For example, he invented a new device that could accurately measure the thermal conductivity of moist soil with changing thermal properties. The device is still widely used today. In the mid-50s he was hired to do heat-transfer simulation and analysis on the turbine blades of the Orenda Iroquois jet engines used in the Avro Arrow.

"The turbine blades were overheating because of the supersonic flight," explained Hooper. "The temperatures inside the engines were much higher than had been experienced before, so we had to cool the blades. It was very complex business. The shapes were awkward, and the mathematics was awkward." He invented an analog computer capable of simulating the heat supply to the blades, allowing Orenda's engineers to confidently modify how air flowed across and cooled the blades.

"That's how the Arrow ended up flying. That's why we had the world speed record," he said. As Hooper tells this story I look over his shoulder and see a black-and-white picture of the Avro Arrow hanging on the wall. He is particularly proud of his contribution to such a historical Canadian event, even if the outcome – the eventual dismantling of the Arrow program in 1958 – saddened much of the nation.

Hooper's contributions to the field of heat transfer are too many to list here, but his work in the area of seasonal solar storage deserves special mention. Indeed, in the mid-1970s Hooper co-developed Provident House in King City, Ontario, a 2,800-square-foot building that is widely recognized as the first "solar house" in Canada.

"The idea was that the solar collectors on the roof would storage energy in the summer in a large tank of water in the basement, and there would be enough heat in that water to heat the house all winter long," explained Alfred Brunger, a former student of Hooper's and long-time manager of NRCan's national solar test facility in Mississauga.

That early work, said Brunger, has inspired many subsequent projects, most recently the 52-home Drake Landing Solar Community project in Okotoks, Alberta. "Even though Professor Hooper has long since retired, it really is a part of his legacy, and he was honoured at the opening of that project as the pioneer who started it all."

Doug McClenahan, who heads up the solar thermal R&D program at NRCan, was a driving force behind the Drake Landing project. He also worked closely with Hooper between 1977 and 1985 on seasonal solar storage research that the U.S. Department of Energy came to rely on. "They saw Frank and his group as being the only one with the expertise in North America in the area," said McClenahan.

Both Brunger and McClenahan look back on their work with Hooper with fond memories. They recall him as an avid sailor, a gentleman, a well-rounded soul who combined a modern, visionary mind with "old school" character. As I tried to take his picture I could see a bit of that old-school formality. "You don't smile much for pictures," I teased. He just sat quietly and slowly shook his head, posing like a king does for a portrait.

"He does speak formally, and his writing is very formal," said Brunger. "Actually, I learned a lot about how to write English from Professor Hooper. I really owe much to him." But the professor also knows how to have fun. McClenahan recalled attending a conference in California where Hooper decided to duck out early and hit the casino in Reno.

I asked Hooper, now 87, what he most appreciates when he looks back through his 65-year career. "I'm a typical old professor," he replied. "A lot of joys of life were in my students." He then glanced at the picture of the Avro Arrow on his wall and said he wishes some of his contributions could have gone farther. At the same time, he takes great satisfaction for the parts he has played, be it in the areas of heat pumps, heat transfer or solar storage. "I'm content now to accept whatever honours come my way," he said, cracking a smile. "I get a big kick out of it, and I'm still quite interested in what's going on in these areas."

A picture on his desk, given to him by some of his former students, reads: "Hockey Has Gretzky. Baseball Has The Babe. Mech Eng Has Hooper." It's a fitting expression of respect for this professor emeritus, who brought a combination of curiosity, intellect, determination and good character to many fields of growing importance.

"He's had such a long career in so many areas, and he's made such significant pioneering contributions, it's appropriate to reflect on that long career and say thanks," said Brunger. ■

Professor Hooper standing in his home office. On the wall behind him, a sketch showing the lakewater heat pump system he designed for use at DEW Line stations in the Arctic.