Frigid test facility

Unique Winnipeg wind tunnel project challenges refrigeration contractor

By Simon Blake

Some projects are so far away from the everyday that they are difficult to estimate accurately and, as a result, many contractors avoid them like the proverbial plague. But there are always a few companies that step up to the challenge.

Such was the case with a unique refrigerated wind tunnel recently completed by Frontier Refrigeration, Air Conditioning and Heating of Winnipeg at the University of Manitoba. "Specialized projects like this are few and far between. We have a lot of talented people. We search out this type of project to keep them motivated…" reported company president Walter Lehmann.

And if experienced technicians are one key to success in a difficult project, good communication is another. Considerable consultation, both with the customer and between the technical minds at Frontier Refrigeration, was required in preparing a design (from conceptual drawings) for the U of M Icing Wind Tunnel.

This helped ensure that it met the university's needs and minimized problems and changes once fabrication began, reported project manager Larry Kyrzyk. He, along with lead technician Dustin Riddoch, spent three months designing and fabricating the system prior to moving on-site.

A 75-hp motor and 75,000 cfm blower creates wind speeds of up to 160 km-h.

Turning vanes move the airflow around corners.

Project manager Larry Kyrzyk, left, and lead technician Dustin Riddoch display the modular inner wind tunnel inside the outer tunnel. Frontier staff fabricated all panels.

The challenge

The wind tunnel is the centerpiece of the U of M Thermofluids Laboratory in the Department of Mechanical and Manufacturing Engineering. It is designed to test the impact of cold temperatures and ice buildup on power lines, airplane wings, helicopter surfaces, wind turbines and other structures.

Previously, much of this research had been conducted through computer modeling, reported Professor Greg Naterer, P.Eng. "We needed a real-life test facility."

It was a tall order. Existing wind tunnels designed for aircraft wings operate at high wind speeds with small water droplets. However, icing on power lines tends to be the result of large water droplets and relatively low wind speeds. "(Creating a test facility) for both of these is very difficult to achieve," he noted.

The design had to allow continuously variable wind speed (up to 160 km-h) and temperatures down to –37°C.

As well, the wind tunnel had to fit into a lab that was only slightly larger than the icing tunnel itself. This dictated a horizontal design. And because the goal was to test cold weather performance, it had to be a closed loop design rather than a traditional wind tunnel, which takes in outdoor air at one end and exhausts it from the other. "Once you have refrigeration, you have to have a closed loop," reported Naterer.

The design

The design that university and Frontier Refrigeration personnel worked up is fairly simple, in principle anyway (See Fig. 1).

It consists of an outer tunnel or cold chamber, 10 ft. high, made up of insulated steel panels. In the test chamber, this reduces through contracting ductwork into the inner tunnel, which can be removed in sections through end doors when the full outer tunnel is required.

A 75-hp blower with inverted blades pushes the air to wind speeds up to 160 km-h and 75,000 cfm.

Riddoch and two apprentices prefabricated the blower section in one piece, cut it into seven sections and welded assembly flanges. A custom-built hoist was used to re-assemble the sections on-site so that the blower assembly met the specifications of the fan manufacturer.

A combination of rubber blocks and springs quell motor/fan vibration. A variable frequency drive (VFR) brings the motor up to speed in increments to minimize torque reaction during start-up. Smooth quiet running – 73 decibels – is critical to ensure consistent and accurate test results and to avoid disturbing other university activity.

From the fan, the airflow takes two consecutive 90-degree turns and enters the test chamber. Frontier technicians built turning vanes at each corner to turn the airflow with minimal loss of velocity.

The airflow then travels through a series of removable honeycombed plenum screens (air straighteners), again built by Frontier, and contracting ductwork into the smaller tunnel.

Researchers can reconfigure the ducting and screens to simulate different wind patterns and speeds. The airflow then passes the spray bars that, again, can be reconfigured depending on the icing conditions being simulated.

Chilled water is supplied at just above 0°C/32°F from a Frontier custom-built chiller. "It has to be as close to 0°C as possible (without freezing) so that water droplets will freeze instantly on test wings …" explained Naterer.

From there, the air/water mixture flows through a test chamber where readings are taken with a laser-based measurement system.

A large floor-to-ceiling evaporator coil, ordered in three sections and built in place, cools the air. Fin spacing varies from 1/2" to 1/4". The outer, wider spaced fins, provide dehumidification which prevents the evaporator from frosting up.

Frontier technicians built an electric boiler with plate-type heat exchanger, which creates a false load to provide hot gas defrost of the evaporator section. The coils can be defrosted from –30°C in five to ten minutes through a heat injection system that pumps hot gas refrigerant through the DX coils.

Special floor traps were built for drainage. These must withstand two inches of static pressure without back flowing or pressurizing when the wind tunnel is operating.

Considerable effort went into ensuring that the tunnel could withstand these pressures – roughly 1,000 lbs. on each panel – both for implosion and explosion.

All doors are doubled – one opening to the outside and one opening to the inside. High static pressure against the inner doors keeps them closed and prevents the outside doors from snapping open when the wind tunnel is operating. A roller track had to be constructed for each 500 lb. insulated door.

Viewing is through three heated and insulated marine windows that remain clear regardless of temperature – one on top and one on each side. All lighting had to be protected from the 160 km-h wind speeds without affecting the airflow.

Relay-logic controls make the wind tunnel easy to operate and service.

Three 30 hp Copeland Discus compressors with an air-cooled 380,000 Btu/hr condenser and 1,100 lbs. of R404 refrigerant provide cooling. The compressors are staged and running in parallel with a common oil control, noted Kyrzyk. A suction accumulator with heaters comes on with various levels of liquid refrigerant sensors (on the evaporator coil) to boil off the refrigerant and shut down the compressors. The entire refrigeration rack – designed on CAD and pre-assembled at Frontier Refrigeration – had to fit into an elevator and existing mechanical room.

Three 30-hp compressors drop the air temperature to a frigid –37°C.

Controls

Frontier Refrigeration technicians also designed and built the controls. Simplicity for the operator was key, noted Riddoch. The VFD for the blower motor is the only direct digital control component – everything else uses traditional relay logic controls. As well as making service straightforward, this allows graduate students to focus on core experiments rather than learning to program the wind tunnel, he added.

Controls can be locked while an experiment is taking place to prevent any adjustments that could skew results.

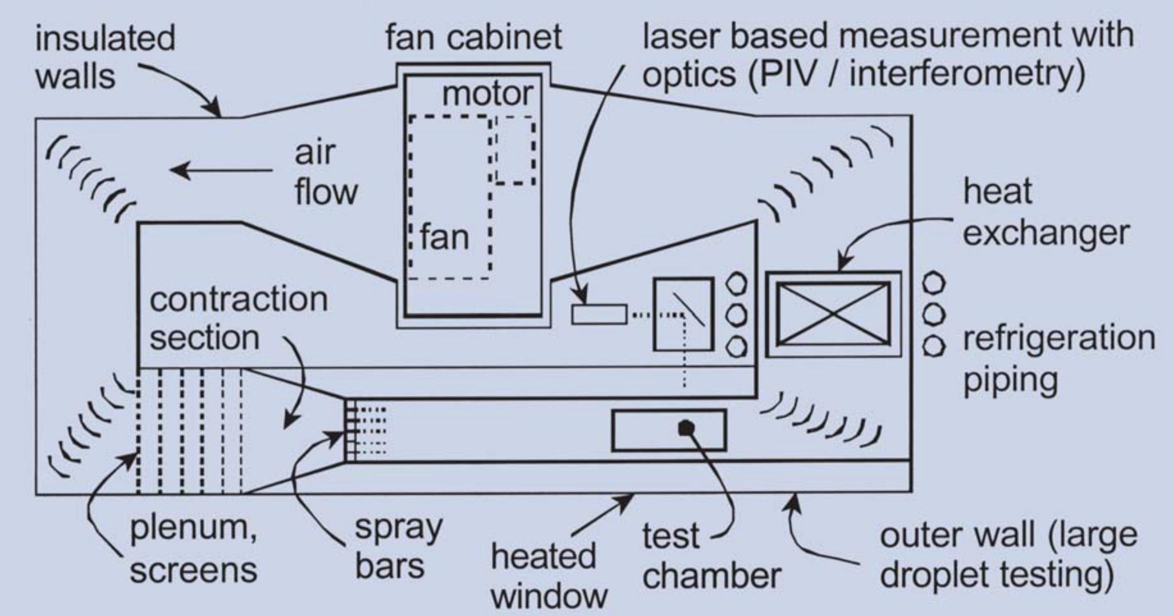

Fig. 1: This top view shows how the wind tunnel was designed as a closed loop to allow precise temperature and wind speed control.

Service access

Not surprisingly, having a contractor heavily involved in the design means that service access is excellent despite the very tight spacing. "We came (to the design) from the service standpoint, not the engineers standpoint," reported Riddoch.

Frontier Refrigeration spent 13 months on the project. "On a daily basis, we had to find solutions to problems that we had never encountered before," reports Lehmann. "Everyone learned an awful lot on this project."

And that perhaps is the message: these types of projects challenge technicians to find new ways to do things. And that keeps them interested and makes the contractor an employer of choice.