Simulation Model Breaks the Ice
on Meeting Efficiency Targets

System simulation models have been widely used for decades to help commercial refrigeration equipment manufacturers test the impacts of various components and design options. By simulating the steady-state operation of the vapor-compression cycle, these models have served as the basis of predictive evaluation in many modern refrigeration applications. Engineers rely on these virtual models to expedite the design process and test prototypes before proceeding with physical equipment development. This has not been the case with ice machine simulation models ... until now.

The transient nature of ice machine operation — continually cycling between ice formation and harvest modes — presents challenges in simulating the effects on the system during these transitions. That's why developing a usable simulation model for the evaluation of ice machines has been historically problematic. It's also why our engineering team at The Helix Innovation Center decided it was time to tackle this challenge head-on.

At the International Refrigeration and Air Conditioning Conference, held in July at Purdue University, a team of Emerson engineers presented a concept for the "Simulation of an Automatic Commercial Ice Maker." This transient simulation model will enable the prediction of component conditions and loads under different operating environments, thus allowing engineers to assess the effects of system design and component changes.

The DOE's new standard of efficiency

The release of this simulation model has timely implications for automatic commercial ice maker (ACIM) manufacturers. In 2015, the Department of Energy (DOE) revised its efficiency standards for machines that produce 50–4,000 pounds of ice per day. The ruling will take effect on Jan. 1, 2018, requiring ACIMs manufactured after that date in the United States to reduce energy consumption by 10–15 percent.

Since ACIMs are produced in a wide range of capacities and used in restaurants, hotels, convenience stores and hospitals, compliance to the new standard has broad industry implications. The ruling affects the two primary classes of ACIMs: batch ice machines (aka "cubers"); and continuous ice machines (aka "flakers" and "nuggets").

With the new DOE standard taking effect in a little more than a year, many ACIM manufacturers have either already begun or are planning to kick off the engineering design cycle. Our new ACIM simulation model is available to help our customers meet this fast-approaching deadline.

ACIM simulation model details

A typical ACIM "cuber" consists of two major subsystems: the vapor compression refrigeration system; and the water supply, circulation and purge system. Refrigeration system components include: compressor, air-cooled condenser, thermostatic expansion device, liquid line/suction line interchanger, and an evaporator that consists of copper tubing attached to a copper or stainless steel grid that serves as the ice-making surface. Once a sufficient amount of ice is formed on this grid, a hot-gas solenoid valve switches to direct the refrigerant from the compressor to the evaporator, thereby releasing the ice into a storage bin.

The water side of the system consists of a water sump, circulation pump, plastic tubing and an evaporator water distributor. A water supply connection control valve and a purge drain control the flow of water in and out of the ice maker. Please see the illustration for a schematic of a batch cuber type of ice machine.

In the ACIM model, the transient ice machine operation incorporates a combination of algebraic and time-based differential equations for the main system components. Its specific operating parameters are the ambient air temperature and the incoming water temperature. The model is designed to simulate the transient operation of an ACIM cuber based on fundamental principles and generalized correlations — calculating time-varying changes in system properties and aggregating performance results as a function of machine capacity and environmental conditions.

Rapid prototyping

The ACIM simulation model will enable engineers to perform rapid "what if" analyses, allowing them to quickly evaluate the impact of a variety of system design options, including:

- The size of the air-cooled condenser and finned surfaces
- Changes in air/water flow rates, as well as ambient air and inlet water temperature
- Compressor capacity and/or efficiency during freeze and harvest cycles
- Evaluation of alternative refrigerants
- Suction/liquid line heat exchanger
- Thermal expansion valve properties

To verify the validity of simulation data, results from the model were compared with the experimental data of a standard 500-pound capacity ice machine, operating under various ambient air and water inlet temperatures. Key measures of the ice machine's performance include: cycle time (duration of freeze and harvest cycles); energy input per 100 pounds of ice; and energy usage during a 24-hour period. Against these measures and in a variety of operating conditions, the model achieved accuracy levels within 5 percent.

Now that it's established, the ACIM simulation model enables the prediction of component performance, evaluation of loads under different operating conditions and assessment of system design changes — all within a virtual environment. We're looking forward to working with our ACIM OEM partners to help them achieve the efficiency levels set forth by the DOE.

Schematic demonstrates the components used in an ACIM that produces batches of cubes.