

Unique Tracking Number Assigned by MORTS 1435
RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM
(2 pages suggested, 3 pages maximum)
TC/TG: 10.9 Refrigeration Applications for Foods and Beverages

Title:

Optimizing Blast Freezer Effectiveness

Applicability to ASHRAE Research Strategic Plan:

This directly meets the needs of:

- A6. Develop integrated, best practice design methods that will allow energy consumption, life cycle cost, and environmental impact to be minimized, and that will allow system life span and IEQ to be maximized.
- A8. Establish benchmark data on energy use in industrial refrigeration
- C6. Establish design tools to improve the installed energy efficiency of heating, ventilating, cooling, and refrigeration systems and their components.
- D1. Establish techniques to improve the energy efficiency and reliability of heating, ventilating, cooling, and refrigeration system components (e.g., heat exchangers, compressors, pumps, fans, distribution systems).

Research Category:

Design Tools; Energy Conservation; Food Processing and Preservation; Refrigeration Systems

Research Classification:

Basic/Applied Research; Technology Transfer

TC/TG Priority:

1

TC Vote:

Reasons for Negative Votes and Abstentions:

For 8; Against 0; Abstentions 0; Absent 2; Total 10

*George Briley was one of the absent members. His is a senior member that has a hard time communicating. Please forgive our single absent vote.

Estimated Cost:

\$50,000

Estimated Duration:

18 months duration

Other Interested TC/TGs:

TC10.1 Custom Engineered Refrigeration Systems

Possible Co-funding Organizations:

Application of Results:

Refrigeration Handbook Chapters 9, 12, 13 and 15 (mainly 13)

State-of-the-Art (Background):

Optimal design and operation of food blast freezers requires the classic economic compromise between capital expenditure and operating costs; however, in practice, rarely are these competing effects considered in specifying equipment.

Optimal design and operation of blast freezers involves consideration of a large number of factors including: product quality, evaporative weight loss, rate of freezing/freezing time, product thermal

properties, surface heat transfer coefficients, air temperature and velocity, insulation thickness and air infiltration, refrigeration system capacity and efficiency, fan and air-cooling coil performance, capital costs, operating costs, and energy use. The optimal freezer will completely freeze the product at the desired production rate with low weight loss and quality deterioration, and for lowest life cycle cost.

The general stages in design of a blast freezer involves the following steps:

- specification of product size, packaging, shape, production rate and final storage temperature;
- selection of freezer type and level of automation based on overall economic strategy, desired rate of freezing for quality maintenance, and consistency with pre- and post-freezing processing operations;
- thermal design of the freezer and the associated refrigeration system; and
- detailed mechanical design.

The thermal design includes:

- (a) defining the size of the freezer and the product residence time;
- (b) specifying the operating conditions, in particular, air velocity and temperature to achieve complete freezing within the available cycle time;
- (c) estimating the heat and moisture load;
- (d) sizing the fans, evaporator coils, compressors and other refrigeration system components to match the freezer capacity; and
- (e) estimating the operating costs such as energy use and weight loss that are affected by the operating conditions.

Possible design tradeoffs include:

- lower air temperature to reduce freezing time and hence the physical size of the freezer versus increased insulation and air infiltration heat loads, increased capacity and cost of the refrigeration system (particularly the compressor); and increased energy use (lower COP due to lower compressor suction conditions);
- increased air velocity to reduce freezing time versus increased fan size and power; increased heat load and refrigeration system capacity and operating costs;
- improved air flow design (freezer layout) to reduce pressure drop and hence fan size, fan power and refrigeration capacity for the same air velocity versus increased capital cost for the freezer structure;
- larger air-cooling coils to improve temperature pull-down, increase hours between coil defrosting and increase evaporation temperature (and hence reduced compressor capacity and energy use) versus the extra capital cost for the coils.

Methods are available to:

- (a) define freezer layout (Refrigeration Handbook Chapters 13 and 15);
- (b) predict freezing times (Refrigeration Handbook Chapters 8 and 9);
- (c) estimate air pressure drop and select fans (Fundamentals Handbook Chapters 2 and 34, HVAC Systems and Equipment Handbook Chapter 18)
- (d) estimate heat and moisture loads (Refrigeration Handbook Chapter 12);
- (e) design refrigeration systems and select components (Refrigeration Handbook Chapters 1 to 3);
- (f) estimate energy use (Fundamentals Chapters 1 and 30); and
- (g) predict the effect of changing conditions on the relative amount of product weight loss (Cleland et al., 2005).

However, easy to use, systematic methods and systems to optimize these potentially conflicting aspects are not currently available.

Advancement to the State-of-the-Art:

The research will enable more accurate life cycle costing of blast freezers to be undertaken. Experience suggests that a well-designed blast freezer will have similar capital cost but can have 10 to 30% lower on-going energy costs than current industry-standard designs.

Justification and Value to ASHRAE:

This research will benefit two main groups:

Manufacturers, engineers and contractors that design and build blast freezers will be able to provide an improved service to their customers the food processing and cold storage industry.

Owners and operators of blast freezers will be able to specify and operate more cost-effective and energy efficient freezers.

Currently the frozen food market represents approximately \$30 billion in annual sales in the United States alone; most frozen foods utilize specially constructed blast freezers. The innovation of today's frozen food manufacturers means the market is growing. The U.S. energy use for the freezing process is estimated to be at least 4 million MWh/year (\$160 million per annum).

Life cycle cost savings of 10 to 20% should be achieved with the new methods. Given that the combined replacement and new freezer installation rates are about 5% of the total number of facilities per year, over 10 years the life cycle savings could be 5 to 10% and the energy savings 5 to 15% (\$8 million to \$24 million per annum) with good penetration rates for the improved design methodology.

Objective:

The objectives of this project are to:

1. Through the process of literature review, manufacturer contact and other research methods, the contractor shall develop a comprehensive set of design, equipment selection, and costing methodologies relevant to blast freezer systems.
2. Use these methods to develop an integrated model of a blast freezer including input of proposed freezer layout/configuration and other input data; estimation of freezing time, air pressure drops and heat loads; specification of key equipment (fans, cooling coils, compressors and condensers); estimation of capital and operating costs (including energy).
3. Implement the integrated model as software including optimization techniques. Preferably the software would be based on commonly available software such as spreadsheets for ease of use by industrial practitioners.
4. Validate the model against a data for a number of existing blast freezer installations.
5. Develop a report that documents the methodologies and software.

Key References:

ASHRAE (2002) *Refrigeration Handbook*

ASHRAE (2001) *Fundamentals Handbook*

ASHRAE (2004) *HVAC Systems and Equipment Handbook*

Cleland, D.J. & Valentas, K.J. (1997) Prediction of freezing time and design of food freezers. In *Handbook of Food Engineering Practice*, eds. E. Rotstein, R.P. Singh & K.J. Valentas, p. 71-124, CRC Press, Boca Raton, Florida.

Cleland, D.J., Love, R.J., Merts, I., Bronlund, J.E. (2005) Minimizing product weight loss. *Proceeding IRHACE Technical Conference*, Nelson, New Zealand, May 2005 (CD-Rom).