Freezing Solutions Ltd

MULTIPASS™ - The Secret of Improving Freezing Efficiencies

Here, we discuss:

- ✓ How to reduce the size of your refrigeration system
- ✓ Identifying the hidden cost in freezing – fan power
- ✓ Understanding the true cost of reducing freezing times
- ✓ How an average size plant can save $300K in refrigeration operating costs
- ✓ Explanation of Freezing Solution's patented approach to freezing

The challenge of improving freezing efficiency is common to all freezing applications; here we set about explaining how improvements in freezing efficiencies can be achieved during the design stage.

There are two main areas of focus for improving efficiencies within freezing applications:

1. The compressor/condenser side where the heat is removed from the refrigeration system; and
2. The evaporator side where the heat is removed from the product.

Efficiency improvements relating to compressor/condenser aspects of freezing are well documented and widely understood; comprising four main focus areas:

- Reduction of suction line pressure drops
- Elimination of air from the system
- Multi-staging the compressors or the use of economisers
- Reducing the condensing temperature

More information on these methods, contact our office.

The Demands on the Evaporator

The area that is often less understood, both by customers and practitioners alike, is the evaporator side of the refrigeration system - it is in this area that the most effective cost reductions can be achieved, due to the reductions available to the refrigeration load overall.

Refrigeration load comprises, amongst other things, the product load, which in short, is the removal of the heat from the product in order to freeze it. Product load is the sum of the sensible heat reduction before and after freezing plus the latent heat component, comprising of the heat removal to change the state of the product.

If we take water (at 20°C) as an example, and wish to produce ice (at -18°C), the sensible heat is the heat removal required to lower the temperature from 20°C to 0°C and then from 0°C to -18°C, while the latent heat would be the energy required to change the liquid to solid (i.e. water to ice).

The values of the specific and latent heats vary from product to product depending on its moisture content and the solid composition, and for a given product, the product load is constant and there is nothing that can be done to change that heat content (heat load).

There are however the other loads we can influence, the most significant of which is the fan power.

Increases in Throughput Place Additional Stress on the Refrigeration System
As the throughput of a plant increases, a focus is often directed towards freezing faster and reducing the capital costs to freeze; in addition, quality issues also lead to the need to freeze faster.

This combined requirement often increases the costs in two ways. The first is that lower operating temperatures call for larger compressors, condensers and the like; the second is higher energy costs per unit of refrigeration produced. It is this, in addition to the demands for improved safety, that initiated more careful attention to multistage NH_3 systems and also the reintroduction of CO_2 as a refrigerant.

Reducing Freezing Time increases Costs
A major contributor in reducing freezing time is the air velocity over the product. With a fixed air temperature the freezing time can reduce substantially proportional with increased air velocity, this in turn increases the air volume and the system pressure drop resulting in increased fan power. This approach, although able to reduce the freezing time, places significant demands on the refrigeration system as the fan power in some instances represents some 30% of the total heat load required to freeze the product hence becoming a very significant factor in the total plant load and the initial capital cost.

A New Approach to Refrigeration Plant Design
It is within this area that Freezing Solutions has undertaken significant work.

The Objective: -	To reduce the volume of air required without reducing the air velocity over the product
The Methodology: -	To take a closer look at the evaporator design with the view to: a) reduce the system pressure drop; and b) lower the evaporator air-off temperature

At this point, it is important to recognise that there is a multiple effect on the refrigeration plant size and energy consumption of the total system.

The "Traditional" Approach to Freezing:
Let's assume that a plant is operating at a -40°C suction and 25°C condensing. It is an ammonia plant with screw compressors and economisers; by deduction, the plants coefficient of performance (COP) will then be in the order of 1.3.

In short, this means that for every unit of power input into the refrigeration system, 1.3 units of cooling is produced. So for every fan power kW put in, the total cost of providing this power = *1 + 1/1.3 = 1.77kW*

In addition to this, with increased total load, the evaporator's capacity needs to be increased. The result is usually an increase in the depth of the evaporator and therefore through the increase in the system air pressure drop, the need for more fan power is created.

This 'traditional approach means the compressors get larger, as do the condenser(s) vessels and the total system. Consequently, the opportunity to reduce the fan load from 30% to 6-8% of the total heat load has very significant effect on both the capital as well as the operating costs of the plant.

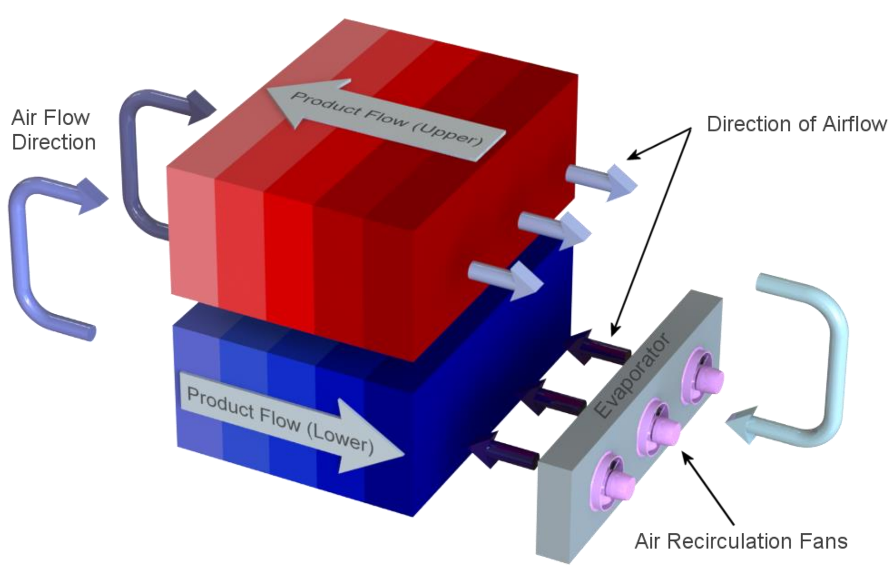
The New Approach to Freezing:
While there is a correlation between reduced air velocity and lower air temperature to achieve a fixed freezing time, the most effective way is to reduce the fan power required; having identified this, Freezing Solutions has patented a new design in freezing to achieve drastic fan power reductions without affecting product retention times.

What Drives the Requirement for Fan Power?
Fan power is determined by the air volume required to be circulated and the system pressure drop, through which the air is being circulated.

Within the system, the air quantity requirement is determined by the nominated air velocity required over the product and the free cross section available for the air to pass through. Expressing this relationship as a formula would be as follows:

$Q = AV$ Where: Q = total air volume
A = free cross section area
V = air velocity over the product

Reduce the System Airflow by adopting a MULTIPASS™ Airflow Configuration:



Q. *But wait…with half the air flow handling the total refrigeration load, won't that mean that the air temperature rise over the product doubles?*

A. At first glance – yes; the net effect could be interpreted as either, lengthening the retention time of the product being frozen, or having to lower the suction temperature to compensate for resulting higher mean air temperature in the tunnel. However, it is the opposite that is true.

The benefits of MULTIPASS™ Airflow Configuration:
MULTIPASS™ airflow configuration reduces the space available for the evaporators; with this reduction in available face area, the evaporator as a consequence needs to be deeper in the direction of the air flow. This means that the air leaving the evaporator can be closer to the actual evaporating temperature than is the case for a single pass airflow configuration.

Q. *But won't a deeper evaporator result in an increased air side pressure drop with increased fan power?*

A. Yes – if it were in a single pass airflow system. However due to MULTIPASS™, the air quantity is halved and the evaporator face velocity drops from 4 -4.5m/s to the order of 2.3 to 3.2 m/s, resulting in reduced air side pressure drop through the evaporator and therefore reduced fan power required.

Examining the Air to Product-flow pattern in a MULTIPASS™ Airflow System

The air to product flow pattern in a MULTIPASS™ Airflow System is counter flow in freezing applications; this results in the coldest air impinging on the coldest product.

There are two drivers for heat transfer from the product to the circulating air:

1. Air velocity over the product; and
2. Temperature difference between the air and the surface of the product.

In a MULTIPASS™ Airflow System, the air exiting the evaporator is colder than in a single pass airflow system at the same air velocity due to the increased evaporator depth. At this point in the air cycle, the temperature differential between the air and the product is the smallest, so a small drop in the air temperature gives rise to a significant relative increase in the total air to product temperature differential.

An increase in available temperature differential improves the ability of the freezer to sub cool the product immediately prior to product discharge.

At the other end of the processing cycle within a MULTIPASS™ Airflow System, the temperature differential between the air at the end of its path immediately prior to entering the evaporator and the entering product is greatest - in the order of 35 to 50 deg. C depending on the application.

Some 3°C higher impinging air temperature on the product represents a small relative reduction in the driving force for heat removal, which is not detrimental to the overall retention time.

The above clearly demonstrates that a MULTIPASS™ Airflow System significantly reduces the energy consumption, while improving the freezing process.

A Working Example:
To illustrate the magnitude of which a MULTIPASS™ automated freezing system delivers savings to processors, the fan power reductions in existing plants were used as a comparison. Recent examples of work undertaken by us have indicated savings of 300-400kW for a plant where 20 x 25kW fans were installed. Using our patented MULTIPASS™ design, we can reduce the fan power to between 120 - 150kW.

In this example, the net energy savings to the client is:

$$400 + \frac{400}{1.3\ (COP)^{i}} = 708kW.$$

Applying this to a typical freezing system, this saving would translate to:

708kW x 320 days x 24 hours = 5,437,440kWHr saved per year

The environmental value of this energy reduction when considering the carbon footprint is:

@0.43kg/kW of electricity[ii] = 2,338,099 kg of CO_2 saved per year

When considering that the average tree absorbs 650kg of CO_2 per year, the savings from an automated freezing system is equivalent to planting 3597 trees per year.

Not only are MULTIPASS™ automated freezing systems better for the environment, with an average unit electricity cost of $0.06/kW, this saving in energy would relate to an annual saving of:

5,437,440kWHr x $0.06/kW = $326,246 per year at this plant

In addition to the available savings, the reduced demands on the refrigeration system results in the opportunity for a considerably smaller and lower capital cost system to be designed to service a highly-efficient, low-fan-power, carbon-emission-reducing freezer.

In short:
While there are several ways to reduce the freezer operating costs, the most dramatic saving is derived from reduced fan input into the system in the first place. The easiest time to achieve this is during the design of a new freezing system.

To find out how MULTIPASS™ can deliver significant savings to your organisation, contact Freezing Solutions today.