

IMPROVING ENERGY EFFICIENCY OF INDUSTRIAL REFRIGERATION PLANT

Introduction:

Minimizing power consumption of industrial and commercial processes is gaining increased focus with rising oil and coal prices, as well as impending emission trading systems in Australia and elsewhere. The power consumed by large industrial refrigeration plant often makes up the major portion of site power use on refrigeration intensive sites, such as food processing plant.

Many such large industrial facilities were constructed even recently with the design focus on functionality and installed cost, often with little regard for the cost of power.

This paper outlines the design and control aspects of industrial refrigeration plants that lead to reduced energy efficiencies, how these aspects are quantified and the measures that are available to improve the system efficiency.

The energy efficiency equation is substantially complicated by issues such as heat recovery and the carbon cost of power. The latter aspect varies widely, depending on the degree of renewable energy available.

Design aspects that lead to reduced efficiencies:

The energy efficiency of any refrigeration plant is fundamentally influenced by two basic parameters:

- a) The system mechanical design, including the selection of refrigeration concept, component selection and pipe design.

- b) The quality of the electronic control system and the control logic utilized.

Design decisions that have a substantial influence on plant power consumption are many and varied, but typical examples include:

1. Plant concept: two-stage, single stage, single stage economised or cascade.
2. Refrigerant: ammonia, carbon dioxide or Freon.
3. Condenser type: Water-cooled, air-cooled or evaporative.
4. Evaporator type: Direct expansion or flooded
5. Compressor model and make
6. Pipe sizing

Under- or over-sizing of components can reduce efficiencies in many ways.

However, even the best designed refrigeration plant can perform poorly if the control system is too basic for the task. In many cases, especially where the plant experiences frequent load changes or load combinations, compressors can run inefficiently or even unnecessarily. Considering the large drive motors used in industrial applications, a 380kW motor, for example, running for no reason is a major operation cost.

Common control issues that lead to excessive plant power use include:

1. Control of the cooling capacity of refrigeration plant using screw compressors exclusively by slide unloading. Screw compressors generally do not unload efficiently with slide control, as shown on the graph below.

IMPROVING ENERGY EFFICIENCY OF INDUSTRIAL REFRIGERATION PLANT

2. The above situation is often exacerbated by finding many compressors in one plant room operating in an unloaded state at the same time.
3. Inadequate head pressure control is another major factor contributing to energy inefficiency. A compressor uses less power at low head pressures and higher power at high head pressures. Most plant run at constant head pressures throughout the year, winter and summer and do not benefit from lower ambient temperatures in winter.
4. Fan control on evaporative condensers or cooling towers is also a major factor contributing to energy inefficiency. Most systems use a simple fan staging strategy, effectively running fewer condensers at low load than during full load. But by doing so, opportunities for fan power savings are lost.
5. Constant suction temperature control under all conditions. Often plants can run at higher suction temperatures during low load periods (eg freezer rooms in winter).
6. Defrost control on fixed timers. Often evaporators can be defrosted less often during low load periods, and defrosts kept shorter.

Screw compressor unloading

As outlined earlier, screw compressors running unloaded for considerable amounts of time lead to substantial and unnecessary energy consumption. This is explained as follows:

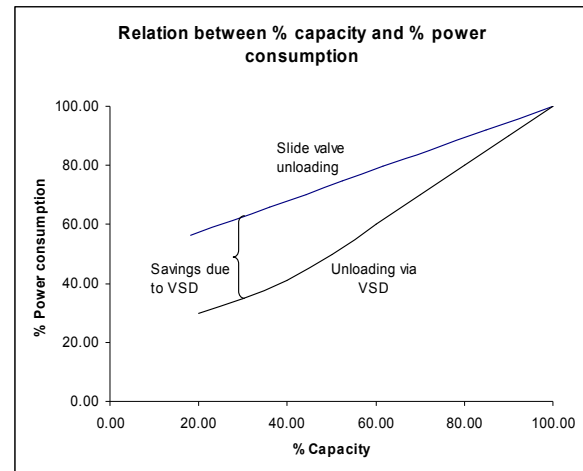
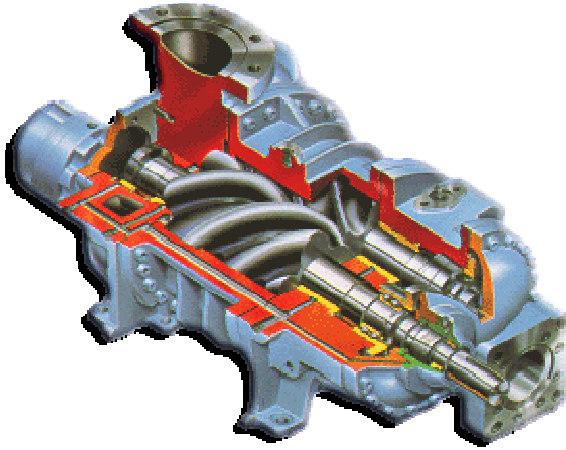


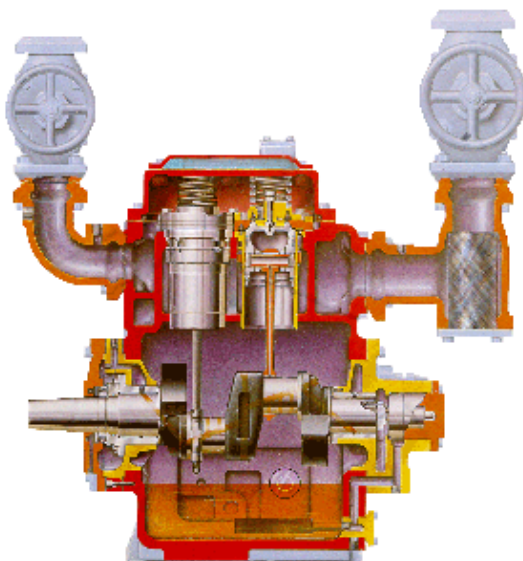
Figure 1: Screw compressor unloading

Most industrial screw compressors are unloaded by means of a capacity control slide and correspondingly their cooling capacity reduces. Some compressor unload continuously (from 10% to 100%), while others unload in steps only (100%, 75%, 50%). With this setup, the relationship between % drop in cooling capacity and % power consumption is non-linear. With reference to the above graph, as an example, at 30% slide position, the cooling capacity of a screw compressor drops to 28% whereas the power consumption is approximately 60%. With the use of a variable speed drive, the relationship between % cooling capacity and % power consumption is more or less linear, especially for cooling capacities between 20 and 80%. This is shown on the graph, and the difference between the power consumed by a compressor unloaded by slide control, and a variable speed driven compressor, is the potential energy saving available.

IMPROVING ENERGY EFFICIENCY OF
INDUSTRIAL REFRIGERATION PLANT



A typical refrigeration screw compressor



A typical refrigeration reciprocating
compressor

It should be noted that reciprocating compressors are more efficient than screw compressors during unloading as they generally employ cylinder unloading. This causes a less significant loss in efficiency.

The higher maintenance costs associated with reciprocating compressors does offset this benefit in many cases, however.

***Analysing plant energy
consumption and savings
potential***

Monitoring of the plant is an excellent starting point to quantify the amount of energy savings possible on an industrial refrigeration plant. Monitoring of compressor power suction pressure, discharge pressure and the slide valve position on the compressors is sufficient to quantify energy savings if the production profile is known. A 2-week monitoring will capture most variations in capacity of the plant. In many instances, weekday operation could be vastly different from weekend operation, with compressors running substantially unloaded on weekends.

Data logging can be done via the plant PLC/SCADA system or specialised logging devices. Once the logged data is collated, a set of calculations are done which will determine any possible annual energy savings on the plant.

***Available measures to achieve an
energy efficient plant***

Based on energy calculations, the next step is to determine what measures need to be taken to achieve these savings. The measures could be any/all of the following:

The savings could be a combination of the following:

1. Implementation of variable speed drives and efficient slide control i.e, slide valve > 75%. The additional advantage is that

**IMPROVING ENERGY EFFICIENCY OF
INDUSTRIAL REFRIGERATION PLANT**

the screw compressors can run at a speed higher than the otherwise maximum speed of 50 Hz. Typical recommended speed range for a screw compressor with a VSD is 1450 – 3600 rpm. Typical recommended speed range for a reciprocating compressor with a VSD is 400 – 900 rpm.

2. Improving the compressor staging logic of the plant, especially on facilities which house multiple operating compressors.
3. Implementation of an variable head pressure control algorithm, general in dependence of ambient and load conditions.
4. Implementation of variable speed drives on the fans of the heat rejection device (evaporative condensers/cooling towers).
5. Where possible, low temperature freezer rooms can be run at lower temperatures at night time, to take advantage of the low ambient conditions and the extra cooling available from the refrigeration plant. In the day time, the freezer can be run at slightly higher temperatures.
6. Use town water supplied to site to increase sub-cooling of liquid refrigerant.

How Minus40 can help

The Minus40 team can assist with the following:

1. Analyse site data to define information requirements for analysis. Generally a site visit is required to familiarize the engineer with site details.
2. Where energy monitoring is required and if plant PLC/SCADA system with logging capabilities is not available, we can setup energy monitoring equipment. Alternatively we conduct manual “snapshot” observations of the plant.
3. Analyse the data, identify potential energy-saving projects and calculate energy savings for each project.
4. Conduct preliminary and detailed return on investment studies on the above identified projects.
5. Assist with preparing government funding applications, e.g. NSW climate change fund.
6. Detailed design, bid support services and project management during project implementation.