How to minimise head pressure in refrigeration

By minimising the head pressure of your existing refrigeration systems, you can increase their efficiency and cooling capacity, and save yourself both energy and money.

Head pressure refers to the pressure in the high pressure side of a refrigeration system – the condenser. Lowering head pressure reduces the temperature at which the condenser operates and increases the efficiency of your refrigeration system. By minimising the head pressure, you can maximise your system's cooling capacity and minimise energy costs.

All refrigeration systems, from small integral standalone equipment such as domestic refrigerators, to those with condensing units or remote condensers, can have the potential to reduce head pressure. This guide is most relevant if you have a system with a condensing unit, or a remote air-cooled or evaporative condenser.

The business case

Through simple actions, you could cut your energy use by 20% or more. Reducing the head pressure of your refrigeration systems will save between 2% and 4% for every 1°C reduction in condensing temperature.

It will also increase the system's cooling capacity. So if your system struggles to maintain the required temperature, reducing head pressure will improve cooling performance and may mean that you do not need to invest in an expensive new refrigeration system.

It doesn't need to cost much. For small refrigeration equipment such as fridges, freezers and integral cabinets, you could reduce the head pressure by simply regularly cleaning the condenser or moving the unit away from sources of heat. If you have a larger commercial or industrial refrigeration system, you might be able to reduce the head pressure by adjusting the control settings.

The technology

Refrigeration systems move heat from somewhere it is not wanted using an evaporator, and lose it somewhere else using a condenser. In the condenser high pressure hot refrigerant gas from the compressor cools and condenses into a liquid. The unwanted heat is lost, normally to the surrounding air.

Figure 1 *Basic refrigeration cycle*

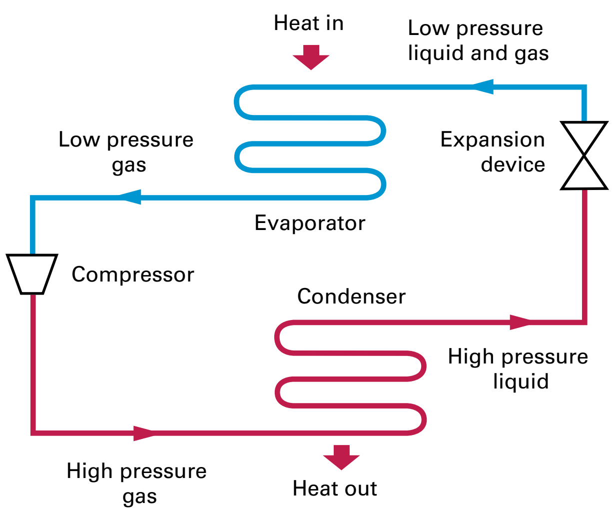

Figure 2 *Factors that affect head pressure*

Factor	Effect
Condenser size (surface area)	The larger the condenser, the lower the head pressure.
Condenser condition	A blocked or corroded condenser transfers heat less efficiently, increasing the head pressure.
Air flow	Air-cooled and evaporative condensers use air to remove the heat. If the air flow is reduced or impeded the condenser transfers heat less efficiently, raising head pressure.
Ambient temperature	The higher the air temperature to which heat is being transferred, the higher the head pressure. It is normal for head pressure to vary with ambient temperature.
Non-condensable gases mixed with the refrigerant	Air and nitrogen can accumulate in the condenser, reducing the available heat transfer surface and increasing head pressure.

The pressure in the high side of a refrigeration system including the condenser is commonly known as the head pressure. It may also be referred to as the discharge or condensing pressure. The temperature at which refrigerant condenses in the condenser is known as the condensing temperature.

When head pressure is higher than necessary, the compressor has to do more work. It will therefore use more power and its efficiency and cooling capacity will decrease. The compressor has to run for longer to provide the required cooling and, in extreme cases, won't be able to provide enough cooling to achieve the required process or storage temperature. So minimising head pressure saves energy, and also maximises the cooling capacity of the refrigeration system, often resulting in better temperature control.

Before looking at how you can minimise head pressure, you'll need to understand the factors that affect it.

Typically, no- and low-cost opportunities to reduce the head pressure of your refrigeration system fall into five general categories.

1. Condenser condition

If a condenser is dirty, you can improve its performance by cleaning it. Cleaning alone can cut your energy use by up to 20%, with an almost immediate payback. If the condenser is corroded or has been damaged you will probably need to replace it.

2. Location

If your condenser is in a position where its air flow is restricted or warmer than necessary, you can relocate it or install baffles to redirect the flow.

At one site, seven condensing units were located on a roof. Their arrangement meant that warm air was flowing from some units onto the condensers of others. As a result, the temperature of the air on to five of the condensers was around 7°C higher than the ambient temperature. Relocating some of the units would have led to a saving of almost 20%.

3. Housings

Most air cooled condensing units are located outside in weatherproof housings. If the housing for your unit is poorly designed, it can mean that warm air re-circulates around the condenser, increasing the air temperature drawn across it. Problems can occur if the air on face is obstructed by the housing; if there are gaps between the condenser and the housing; or if there are insufficient louvers to allow the warm air to escape. You can normally solve any problems by making minor changes to the housing.

In one example, two condensing units each with a 15kW compressor were located in a purpose-built housing which did not fit closely around the units. As shown in *Figure 3* air re-circulated round the gaps between the air on face of the condenser and the housing, rather than being expelled through the louvers in the front.

***Figure 3** Poorly fitting housing on condensing units*

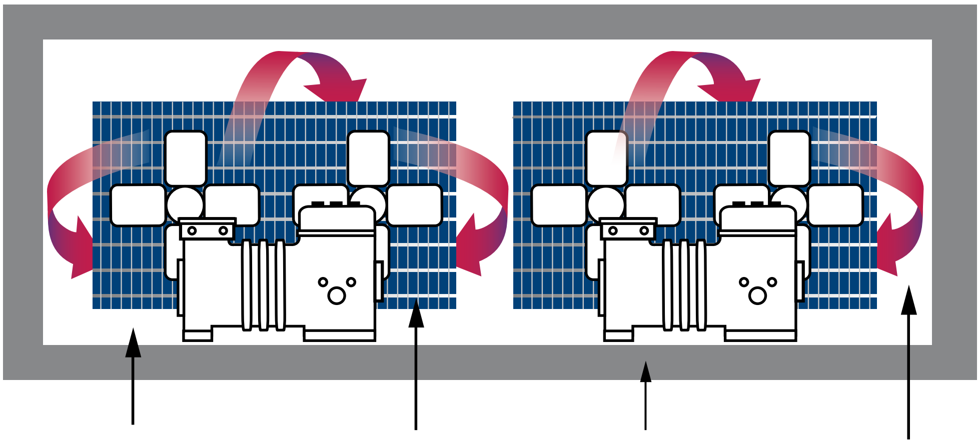

Image provided by Guide 5, Energy Efficiency – Site Guidance, produced by the Food & Drink Industry Refrigeration Efficiency Initiative.

The air re-circulation increased the air temperature onto the condenser by up to 27°C. Savings of 37%, equivalent to £2,700/year, could be achieved by simply blocking the gap between the housing and the air on face with plywood.

4. Head pressure control

If your refrigeration system has head pressure controls, you may be able to lower the head pressure by reducing the set point, especially in cooler weather.

Head pressure, and therefore condensing temperature, should reduce as the ambient temperature reduces. However, in many cases the condensing temperature is controlled so that it does not fall below a pre-set level, regardless of the ambient temperature. *Figure 4* shows this graphically for a time period with falling ambient temperature. The lower (blue) line represents the ambient temperature. If the condensing temperature is allowed to fully float it follows the dotted line. When controlled by head pressure controls it will only reduce to the set point and then remain at this level (the red line). This means that at lower ambient temperatures, the head pressure is higher than it would be if the control setting were reduced or the condensing temperature were allowed to float.

Reducing the head pressure control settings is an easy way to achieve savings on your refrigeration system.

One site's head pressure settings were higher than necessary on all its refrigeration systems. Overall, the potential cost savings were £12,100/year. To achieve these, the site only needed to adjust the electronic system controllers of its two spiral freezers and the high pressure switches of its four condensing units as described in *Figure 5* on the following page.

***Figure 4** Effect of falling ambient temperature on condensing temperature*

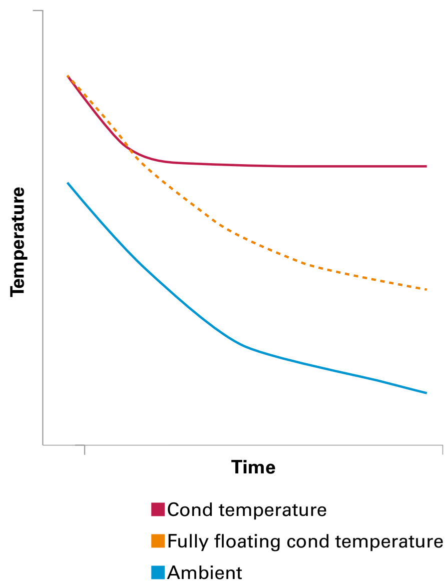

***Figure 5** Head pressure control setting opportunities*

	Spiral 1	Spiral 2	Condensing units
Actual head pressure set point	29 to 36°C	34 to 40°C	34°C
Recommended head pressure set point	25°C	25°C	25°C
Potential saving	10.5%	22%	10%
Cost saving, £/year	£4,800	£4,800	£2,500

In all cases the head pressure was controlled by on/off switching of the condenser fans. The site could have made additional savings by using variable speed fans, which allow closer control of the head pressure. Controlling fan speed also reduces the fans' electricity consumption compared to only switching them on and off.

5. Non-condensable gas in the system

Purging any non-condensable gases from your system's condenser will reduce head pressure. Non-condensable gases such as air and nitrogen can be drawn into your refrigeration system if it operates below atmospheric pressure, or can remain there if they have not been evacuated correctly during installation or servicing.

A qualified refrigeration engineer will need to remove any non-condensable gas that is present. In some cases, it is worth fitting an automatic air purger.

Further information on reducing head pressure can be found in Guide 5, Energy Efficiency – Site Guidance, produced by the Food & Drink Industry Refrigeration Efficiency Initiative which is available from www.ior.org.uk.

How to check if the head pressure of your refrigeration system is too high

You can check whether the head pressure of your refrigeration system is too high by comparing the actual head pressure with the expected head pressure based on your condenser design and the ambient air temperature.

Your system's design information should specify the condensing temperature at a maximum ambient temperature. This allows you to determine the expected condensing temperature at any given ambient temperature. For example, if the design condensing temperature is specified as 45°C at a maximum ambient of 32°C, the difference between the air and condensing temperatures is 13°C. So when the ambient is 15°C, the condensing temperature should be 13°C higher, which is 28°C. If it is higher than 28°C, your system is working less efficiently than it could be. There is rarely a good reason for the condensing temperature to be higher.

If you do not have access to the design information you can use the following guide:

- For remote air-cooled condensers the condensing temperature is typically 10°C to 12°C above the ambient dry bulb temperature.
- For air-cooled condensing units the condensing temperature is typically 15°C to 20°C above the ambient dry bulb temperature.
- For evaporative condensers the condensing temperature is typically 10°C above the ambient wet bulb temperature.

To check whether the head pressure of your refrigeration system is too high, obtain the condensing temperature from the discharge (high) pressure gauge or the system controller and measure the ambient temperature. Advice on reading pressure gauges is given below.

Next, calculate the expected condensing temperature at that ambient temperature, either from the design information or using the guidelines above. If the actual condensing temperature is above the expected value, the head pressure is too high. If the system is not operating at full load, the head pressure might still be higher than necessary even if the actual condensing temperature is below the expected value.

You can read the head pressure of your refrigeration system if it has a pressure gauge or an electronic controller with digital display. Head pressure can be measured anywhere on the high side of a refrigeration system between the compressor discharge and the

***Figure 6** Pressure gauge*

Image provided by Guide 5, Energy Efficiency – Site Guidance, produced by the Food & Drink Industry Refrigeration Efficiency Initiative

expansion device. The saturation temperature equivalent to this pressure is the condensing temperature.

Most pressure gauges show saturation temperature for the refrigerant in use, in addition to pressure. The gauge in *Figure 6* is measuring the head pressure on an ammonia system. The pressure shown on the inner scale is 8.1 barg and the condensing temperature, shown on the outer scale, is 22°C.

Figure 7 provides you with a checklist to help you identify ways of minimising the head pressure of your refrigeration systems.

***Figure 7** A checklist to minimise head pressure*

Considerations	Comments
Is the head pressure controlled by switching condenser fans on/off or controlling their speed?	You can obtain the head pressure control settings either from the system controller, by observing the head pressure at which the fans switch on/off, or from your refrigeration contractor. You might be able to reduce the head pressure simply by reducing the control settings. You need to check first whether there is a recommended minimum head pressure for your refrigeration system (see common problems). If you reduce the head pressure control settings the condenser fans may use more electricity – but this will normally be more than offset by the saving for the compressor.
Is the condenser dirty?	Air-cooled condenser surfaces can become blocked with debris and dust. Condenser cleaning is one of the most important routine maintenance activities. In some locations you'll only need to clean the condenser once a year, but quarterly cleaning may be necessary in others.
Is the condenser corroded? If it's air-cooled, do the fins break off with gentle pressure? Are the condenser fins damaged, for example from an impact?	If a condenser is badly corroded or damaged, you should replace it. This is an opportunity to improve the efficiency of the plant by installing a larger condenser.
Is the air flow to the condenser restricted?	Items placed around the condenser can restrict the air flow, as can its location, for example if it's too close to a wall. Where possible move any obstructions or relocate the condenser.
Is the condenser located where the intake air flow is warmer than necessary?	You can measure the air temperature drawn onto the condenser to check if it is higher than the ambient temperature i.e. if it is being heated. If possible, move the condenser to where the air is cooler, ideally outside away from sources of heat and direct sunlight.

If multiple condensers are sited together, is warm air from one condenser being drawn onto another?	Relocating condensers is usually the only solution, although in some cases you can use baffles to redirect air flow.
Does air re-circulate around the condenser because its housing does not fit closely over the unit?	Housings should be designed to provide good air flow through the condenser, with sufficient louvers to allow the warm air to escape. If there are gaps allowing air to recirculate, you can fit panels around the condenser top, sides and bottom to prevent this. To check if warm air is recirculating, you can measure the air temperature at different points of the condenser air on face and see if it is higher than the ambient temperature.
Are any of the condenser fans faulty?	Often condenser fans switch on/off or their speed varies depending on the load on the condenser. If any of the fans do not run, or do not operate at full speed even on a hot day, then they could be faulty. You should repair or replace them as soon as possible.
Is the evaporating/suction pressure of the system below atmospheric pressure?	Air can be drawn into your system if it operates at below atmospheric pressure. This is common in ammonia frozen food systems. You should regularly check for non-condensable gas in the condenser. On larger systems, you should install an automatic air purger. If non-condensable gas is present, you need to ask a suitably qualified refrigeration engineer to remove it.
Is the head pressure still high after you've checked for all other problems?	Nitrogen or air can remain in systems which have not been evacuated correctly during installation or service. You should check for non-condensable gas in the condenser. If non-condensable gas is present, you need to ask a suitably qualified refrigeration engineer to remove it.

How to check for non-condensable gas in your condenser

- Switch off the refrigeration system or isolate the condenser. Allow the condenser to cool completely.
- Measure the pressure of the refrigerant in the condenser and the equivalent saturation temperature using a refrigeration pressure gauge fitted to the condenser.
- Measure the ambient air temperature around the condenser.
- If the ambient temperature is lower than the indicated refrigerant saturation temperature by more than a few degrees, then there is non-condensable gas in the condenser which needs to be removed by a suitably qualified refrigeration engineer.

You may be able to reduce the head pressure of your refrigeration systems by making changes yourself, or you may need the help of a refrigeration contractor. Information on how to find a contractor is given below.

Common problems

In most cases you can safely reduce the head pressure control setting. Sometimes there may good reasons why a head pressure set point is high, leading to problems if you reduce it too much.

Restrictions on the minimum possible head pressure are summarised below.

- Expansion devices require a minimum pressure drop to work correctly. Electronic expansion valves need a minimum of four bar pressure drop and thermostatic expansion valves need a minimum of six bar. In most cases the head pressure can be reduced significantly without going below these minimum pressure drops. The actual setting will depend on the evaporating pressure – the head pressure can float lower for a frozen food application than for chilled food.

- Some screw compressors require a high head pressure for the oil system to operate reliably. In this case the setting is determined by recommendations from the compressor supplier and it should not be reduced below this.
- Hot, warm or saturated gas defrost requires a higher head pressure when the system is on defrost. However, control strategies can often be adjusted so the head pressure is floated lower when the system is not defrosting (i.e. most of the time).
- Reducing the head pressure too much can cause liquid refrigerant to evaporate in the liquid line if it is routed through an area where the surrounding temperature is significantly higher than the outside ambient. The head pressure set point should not be lower than the temperature of the area through which the liquid line runs. For example, if the liquid line passes through an area maintained at 20°C, the control strategy should not allow the head pressure to drop below the pressure equivalent to this temperature. This would be 7.5 barg for ammonia and 10 barg for R404A.

If you are not sure whether any of the above restrictions apply to your system, you should consult your refrigeration contractor.

Finding a contractor

Work on your refrigeration systems should always be done by a reputable, suitably qualified refrigeration contractor. You may already know someone suitable. If not, you can contact a recognised trade association, such as the British Refrigeration Association or the Institute of Refrigeration, for advice.

Institute of Refrigeration

020 8647 7033
www.ior.org.uk

British Refrigeration Association (BRA)

0118 940 3416
www.feta.co.uk

Some refrigeration equipment is covered by the Government's Enhanced Capital Allowances scheme. Guides on refrigeration equipment eligible for Enhanced Capital Allowances are available from the Carbon Trust website, www.carbontrust.co.uk. You can see a list of ECA approved suppliers at www.eca.gov.uk.

See the Carbon Trust website at www.carbontrust.co.uk/refrigeration for further information to help you make your refrigeration more energy efficient.