AMPC

Refrigeration Energy-Efficiency Opportunities

FOR THE AUSTRALIAN MEAT PROCESSING INDUSTRY

HOW-TO MANUAL

REFRIGERATION ENERGY-EFFICIENCY OPPORTUNITIES

FOR THE AUSTRALIAN MEAT PROCESSING INDUSTRY

HOW-TO MANUAL

PROJECT CODE	2020 - 1017
PREPARED BY	Michael Bellstedt Friedrich Eggers
ILLUSTRATED BY	Tobias Heller
DATE PUBLISHED	30 November 2021
PUBLISHED BY	Minus40 PTY Ltd

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

CONTENTS

BASICS

COMMERCIAL FREON

INDUSTRIAL AMMONIA

ESSENTIALS

HARD YARDS

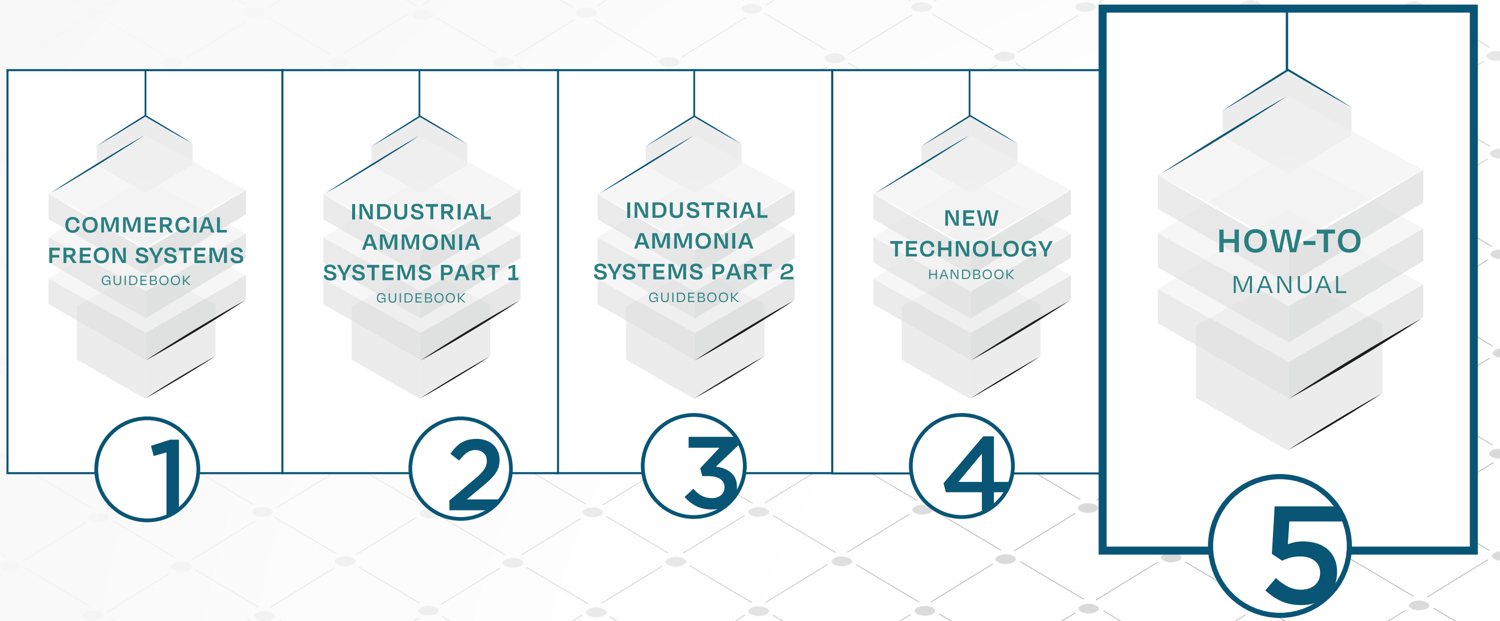
REFINEMENT

INTEGRATION

NEW TECHNOLOGIES

INTRODUCTION

This Guidebook is one of 5 Guidebooks/Manuals which were developed during the **"Refrigeration Plant Energy Improvement"** research project.



Guidebook: Commercial Freon Systems covers **smaller abattoirs** which often use multiple small commercial refrigeration systems with freon refrigerants.

Guidebook: Industrial Ammonia Systems Part 1 & 2 cover **medium to large sized abattoirs** which use large, centralized ammonia systems for refrigeration. These systems are much more complex than small commercial systems and require a stepped, strategic approach to improve energy efficiency.

The New Technology Handbook covers the **most recent developments** in refrigeration as applicable to the red meat industry. Refrigeration is undergoing some decisive changes which will have major impacts on the operational costs of refrigeration systems. **Awareness of these developments** is crucial when it comes to decision-making on major plant upgrades/restorations as investments into outdated technologies could result in a competitive disadvantage.

To further **determine the viability** of opportunities discussed in the books mentioned above, the How-To Manual gives guidance on how to initially assess opportunities and use the AMPC-EEO Calculation Tool where applicable.

AMPC

HOW-TO MANUAL

This How-To Manual is meant to provide guidance on how to assess each Energy Efficiency Opportunity (EEO) and technology presented in the previous guidebooks of the series as seen on the left-hand side.
The following questions are answered in the process: What information is needed? How could this be implemented and what are hardware & control requirements to do so? Where applicable, the AMPC-EEO Calculation Tool is used:

CALCULATION TOOL

To complement this manual in the assessment of EEOs, the AMPC-EEO Calculation Tool can help to quickly estimate savings. The CALCULATION TOOL sections in this manual are there to clarify which inputs are needed to do so. Often savings may not easily be calculated, hence the Calculation Tool does not provide the possibility to do so. This is only due to the fact, that such a calculation cannot be done in line with the simple high-level approach that was used here. This does not mean that savings could not be significant, in fact the opposite is the case.

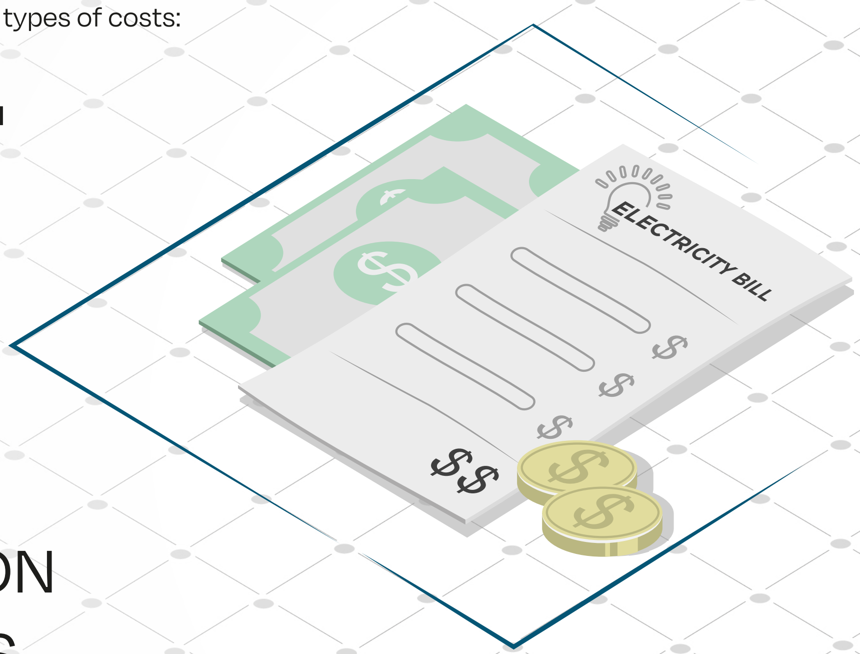
INTERPRET YOUR ELECTRICITY BILL

SUMMARY

When looking at your electricity bill there are all kinds of different charges: Energy or Retail Charges, Network Charges, Renewable or Environmental Charges, etc.

For large electricity consumers like abattoirs, these can typically be broken down into 3 types of costs:

- **Consumption-based**
- **Demand-based**
- **Fixed**



CONSUMPTION BASED COSTS

Consumption based costs and how to reduce them will be the focus of all energy efficiency opportunities (EEOs) which will be discussed here. These costs account for the net total amount of energy consumed by the site. You can identify them by the unit they are measured in, which is kWh, and the rate they are charged by, which is c/kWh.

By operating your refrigeration plant more efficient you will use less energy in total and with it pay less in consumption-based charges.

Large electricity consumers such as abattoirs typically pay different rates for energy consumption based on the time of day. These rates can be called "peak" and "off-peak" or even "shoulder" and "off-off-peak", etc. Note: Saving energy at times of high electricity rates (weekdays, daytime) will save you more money than saving energy at lower rates (nighttime or weekends).

Reducing consumption based charges, which make up the bulk of total electricity charges, is the main focus of each EEO presented in this series. Savings calculated with the help of the "AMPC-EEO Calculation Tool" will be solely based on consumption and consumption based charges.

AMPC

DEMAND BASED COSTS

Demand charges can make up a large part of the electricity costs of a site, even though they do not depend on the total amount of energy consumed. Rather, they depend on the peak power **demand** at a single point in time of the month they are charged for. The problem: The site could be disciplined and energy efficient for most of the month, but one unfortunate event, which draws high power for a short amount of time will determine the demand charges for the month. By reducing overall consumption, demand charges could be reduced by energy efficiency measures as well, however this is not a given.

Demand charges are most commonly found as part of the network charges. You can identify them by the unit they are measured in, which is kVA (or kW), and the rate they are charged by, which is $/kVA (or $/kVA/mth; $/kW)

Energy efficiency opportunities can help to reduce demand charges as well. By using less energy overall and reducing the energy demand of equipment which runs at all times, there is a good chance of drawing less power during the monthly charged peak demand as well. However, this is not guaranteed and other factors such as plant personnel behavior (turning on all equipment at once at a time when peak demand could be expected) might play a much larger role.

Two examples: The use of fan speed control to slow down evaporator fans at night will save energy and with it consumption charges during the night. But if fans run at full speed during the day and consume energy as usual when the peak in demand occurs, there will be no reduction in demand cost from fan speed control. In another scenario, replacing old worn equipment so refrigeration can be provided more efficiently on a consistent basis will help to reduce demand charges as this equipment will also use less energy during times of peak demand. Consider this when assessing an EEO as savings calculated with the help of the "AMPC-EEO Calculation Tool" might be enhanced due to a possible demand reduction.

FIXED/OTHER COSTS

These costs are, as the name might suggest, fixed. They are typically metering or access charges. Since they are fixed there is no possibility for savings by means of energy efficiency.

COMMERCIAL FREON SYSTEMS

The following pages provide additional information to further assess the EEOs which are presented in the **Commercial Freon Guidebook.** Instructions on how to use the **AMPC-EEO Calculation Tool** to calculate high-level savings for commercial freon systems where applicable are also provided.

This section should only concern you, if you have commercial freon refrigeration on site. If you have an industrial ammonia plant instead, you can skip this section and jump to **"INDUSTRIAL AMMONIA SYSTEMS".**

AMPC

CALCULATION TOOL

USE FOR COMMERCIAL SYSTEMS

B

SUMMARY

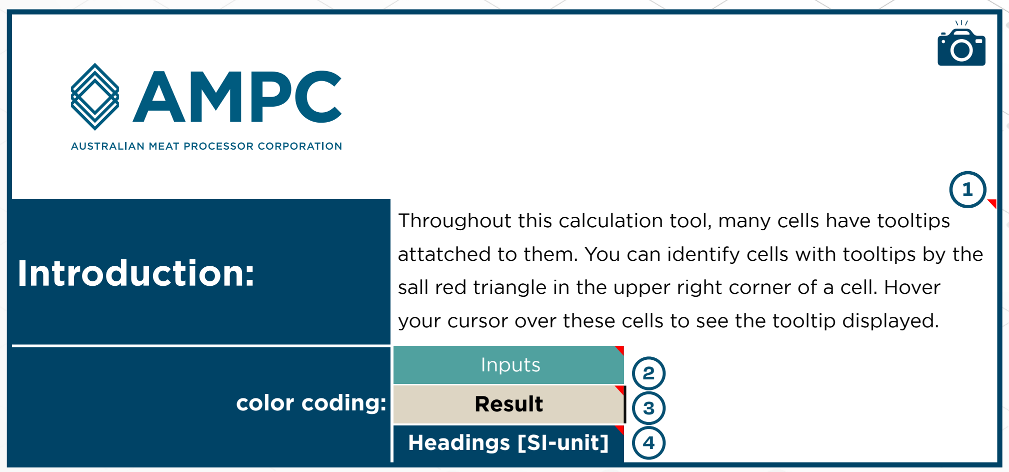
Some EEOs can be calculated to achieve high-level results with some rough inputs. Follow the instructions on the following pages to do so. Resulting savings totals will be shown on the Dashboard-Sheet, along other useful information, once all respectively needed inputs for each EEO have been made. Results specific to each compressor & evaporator are shown on the respective Results-Sheets.

Sheet: Site

Introduction

Besides the first round of inputs, the first sheet of the calculation tool, also gives you a short explanation about the color-coding used within the tool and the tooltips.

1. Try hovering the cursor over this text to see the tooltip for the cell displayed.
2. These teal-coloured cells signal that input is required.
   Tooltips for each input list which EEOs require the respective input. If you only wish to calculate certain EEOs, you can ignore those inputs which are not needed for them.
3. These tan-coloured cells contain the results from inputs priorly made.
4. Headings might also specify the SI-unit of the inputs or results they refer to. SI-units are surrounded by [...] brackets, e.g. [kW]. Make sure inputs are made in the required SI-Unit. If your measurement readings are in another unit you first must convert them into the SI-unit required (e.g. absolute pressure [kPa] --> gauge pressure [kPa (g)]).



Site

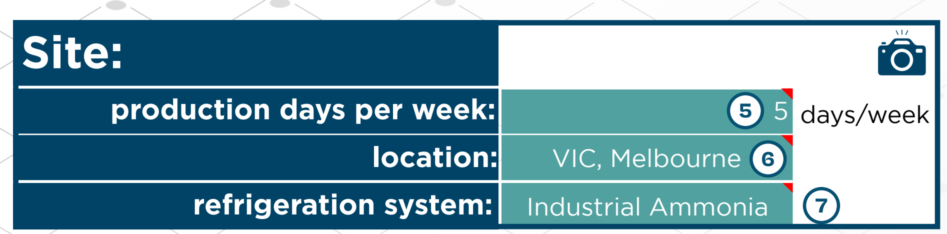
The very first inputs needed from you provide some basic information about the site.

5 **Input:**
Production days per week - How many days per week does production run? Typically, 5 days; Might be 6 days with production running on Saturdays, might also be less.

6 **Choose from drop-down:**
Location - If you cannot find your location, choose one that is closest to you or has similar climate conditions.

7 **Choose from drop-down:**
Refrigeration system - What type of refrigeration plant do you have on site? An industrial ammonia system with evaporative condensers or commercial freon systems with air-cooled condensers?
If you have both, you will have to use this tool twice. Once to calculate EEOs for ammonia systems and again for freon systems.
Choosing 'Industrial Ammonia' lets you calculate applicable EEOs presented in the guidebooks 'INDUSTRIAL AMMONIA SYSTEMS PART 1 & 2'.
'Commercial Freon' lets you calculate applicable EEOs from the 'COMMERCIAL FREON SYSTEMS' guidebook.

In this case we want to calculate commercial freon systems, so choose 'Commercial Freon' from the drop-down menu.



Electricity Charges

In this section you need to provide information about your electricity costs, so energy savings can be translated into monetary savings.

8 **Input:**
Time span - How many months worth of electricity bills do you enter into the cells below? For minimum effort, you could use a single bill covering a time span of just one month. In this case enter '1' in this cell. However, for a more accurate electricity breakdown, seen on the 'Dashboard', it is recommended to enter at least a year or 12 months worth of electricity bills. In that case enter '12'.

9 **Input:**
Total charges (ex. GST) - sum of total electricity charges (ex. GST) over specified time span

10 **Input:**
Demand charges - sum of all demand charges over the specified time span

Carefully go through your electricity bills, sum up all demand related charges and enter the sum here. You can identify demand charges by the unit they are charged in (kVA or kW). Attention: Do not just take all network charges as these will most likely also include some consumption related charges.

11 **Input:**
Other charges - sum of all other/fixed charges over specified time span

These are neither consumption nor demand related and typically make up a small portion of the bill, which is why they can be ignored/counted towards consumption charges for minimum effort. In case you want to do the latter leave this cell blank.

12 **Input:**
Total consumption - sum of total power consumption over specified time span in kWh

Your bill might show you consumption for peak and off-peak hours. Careful, do not use those numbers here (unless you add them up). You can find your total consumption either in the summary of your bill, or for example, environmental charges are billed for total kWh of consumption.

Electricity Charges:				
time span:		12	months	8
total charges (ex.GST):	$	300,000		9
demand charges:	$	50,000		10
Other charges:	$	10,000		11
total consumption:		1,333,333	kWh	12
consumption charges:	$	240,000		13
average consumption cost:		18.00	c/kWh	14

Result: 13
Consumption charges - total consumption related charges over specified time span

Result: 14
Average consumption cost - average cost per kWh of electricity consumed in c/kWh

Fuel Charges

You only need to fill this section, if you want to calculate possible savings from **heat recovery** and **heat pumps** as these save fuel. This is only applicable to boilers that **do not serve for rendering,** as rendering requires higher temperatures which cannot be provided by heat recovery or heat pumps as of today (possibly in future) and often comes with its own form of heat recovery for wash-down water.

All inputs regarding fuel are only required, if you wish to calculate: 15
Heat recovery
heat pumps

Savings from these EEOs are only applicable, if hot water is only used for wash-down or sterilisation (no rendering).

Choose from drop-down:
Fuel type - What type of fuel is burned inside the boiler to generate hot water for wash down and/or sterilisation?

Result: 16
Unit - This cell automatically shows the unit the selected fuel is usually charged in. If this is not the case for you, select 'other' and enter unit into cell to the right.

B

Fuel Charges:			
fuel type:	natural gas		15
unit:	GJ		16
heating value per unit:	277.78	kWh/GJ	17
time span:	12	months	18
total charges (ex. GST):	$ 165,000		19
total consumption:	10,000	GJ	20
average consumption cost:	$ 16.50	$/GJ	21
boiler efficiency:	80%		22
percentage sterilisation water:	30%		23
percentage wash-down water:	70%		24

17 **Result:**
Heating value per unit - This cell automatically shows to the typical heating value of selected fuel. If this value is not representative of your fuel, select 'other' and enter heating value.

18 **Input:**
Time span - How many months worth of fuel bills do you enter into the cells below? For minimum effort, you could use a single bill covering a time span of just one month. In this case enter '1' in this cell. However, for a more accurate annual fuel consumption estimate, it is recommended to enter at least a year or 12 months worth of fuel bills. In that case enter '12'.

19 **Input:**
Total charges (ex. GST) - sum of total fuel charges (ex. GST) over specified time span

20 **Input:**
Total consumption - sum of total fuel consumption over specified time span in respective unit

21 **Result:**
average consumption cost - average cost per unit of fuel

22 **Input:**
Boiler efficiency - percentage of heating value from burning fuel that is effectively transferred to the water to heat it up

If you do not know the boiler's efficiency assume 70-80 %. You can change values and see how they affect results.

Input: 23
Percentage sterilisation water - percentage of hot water generated by boiler used for sterilisation (95 °C) before it is diluted (at boiler outlet temperature) in percent

If you do not need any sterilisation water and all water is used <60 °C, enter 0.

Result: 24
Percentage wash-down water - percentage of hot water generated by boiler used for wash-down of processing areas and other hot water needs <60 °C before it is diluted (at boiler outlet temperature) in percent

It is assumed that this is all hot water except for the sterilisation water (no rendering), hence:
percentage wash-down water = 100 % - percentage sterilisation water.

Sheet: Compressors

Set Temperatures

Specify the set condensing temperature of systems on site to calculate **Floating Head Pressure** Control and the adiabatic trigger temperature, if you wish to calculate savings from **Adiabatic Cooling.**

Only required for: 25
Floating Head Pressure Control

Input:
Set condensing temperature - fixed set-point condensing temperature of the freon systems on site

This temperature input is used for all compressors which are entered below. The results for floating head pressure control are an accumulation of savings if applied to all compressors entered. If you wish to get a result for a single system or the set-point condensing temperatures vary between the systems, only enter compressors of the system you want to calculate below and note down each result individually. Then change the set-point condensing temperature here if needed to calculate each system by itself.

AMPC

B

26 **Only required for:**
Adiabatic Cooling

Input:
Adiabatic trigger temperature - temperature at which water pumps for adiabatic cooling are triggered and turn on the water

This temperature input is used for all compressors which are entered below. The results for adiabatic cooling are an accumulation of savings if applied to all compressors entered. If you wish to get a result for a single system or the trigger temperatures would vary between the systems, only enter compressors of the system you want to calculate below and note down each result individually. Then change the trigger temperature here if needed to calculate each system by itself.

Set Temperatures			
set condensing temperature:	35.0	°C	25
adiabatic trigger temperature:	30.0	°C	26

Compressors

These inputs are needed to calculate **Compressor Speed Control & Staging, Adiabatic Cooling,** and **Floating Head Pressure Control.** They will also provide an electricity consumption breakdown of total compressor power (of compressors filled in here) vs. everything else on site on the Dashboard.

27 **Input:**
Compressor name - serves to identify savings specific to each compressor

If a compressor never runs and only serves as a stand-by unit, it does not need to be mentioned here.

28 **Choose from drop-down:**
Capacity control - How is compressor capacity controlled? Mechanical unloading via slide-valve control or cylinder switch-off? Or speed controlled via VSD?

Input: 29
Avg. load when running production day [%] - average compressor load due to unloading (mechanically or speed-driven) on a production day in percent

In case of industrial ammonia plants, you should be able to use slide-valve positions (mechanical unloading) or VSD frequencies/compressor speeds (speed control) from your SCADA/monitoring system to approximate compressor loads. Refer to 'Control & Monitoring Upgrade' in the guidebooks, if that is not the case.

In case of commercial freon systems, such monitoring systems are most likely not available, so loads have to be estimated. Here is an example:
If a compressor runs an estimated total of 16 hours per day, an estimated 6 of those fully loaded (100 %) and 10 hours unloaded at 67 % by switching off 1/3 of its cylinders, then the average load when running is:
100 % * 6 h / 16 h + 67 % * 10 h / 16 h = 79 %.

'When running' means that you should only average the load when the compressor is actually operating. For example, if using the slide-valve position as an approximation for the load, do not count the slide-valve position towards the average when the compressor is not running. A compressor which is operated in simple on-off fashion therefor always runs at 100 % load when running.

These calculations are rough estimates, so the same can be applied to the inputs. You can roughly estimate loads here and come back to change them to see how results may vary.

Compressors	capacity control	avg. load when running production day [%]
Rack 1 Compressor 1	mechanical unloading	100%
Rack 1 Compressor 2	mechanical unloading	100%
Rack 1 Compressor 3	mechanical unloading	79%
27	28	29

AMPC

30 **Input:**
Avg. run hours production day [h] - average time the compressor is turned on per production day in hours

In case of industrial ammonia plants, you should be able to use current transducer signals from your SCADA/monitoring system to approximate run hours. Refer to 'Control & Monitoring Upgrade' in the guidebooks, if that is not the case.
In case of commercial freon systems, such monitoring systems are most likely not available, so average run time has to be estimated.

If you rotate compressor duties weekly, make sure to account for that here. An example:
A compressor runs an average of 16 hours per day for one week and then does not run for an entire week afterwards because its duty is taken over by another compressor. After the 2 weeks the cycle repeats itself. Then the average run hours are on average 16 / 2 = 8.

These calculations are rough estimates, so the same can be applied to the inputs. You can roughly estimate the run time and come back to change it to see how results may vary.

31 **Input:**
Avg. load when running weekend [%] - average compressor load due to unloading (mechanically or speed-driven) on a weekend day in percent

Same as 'avg. load when running production day [%]', but instead for weekend days.

32 **Input:**
Avg. run hours weekend [h] - average time the compressor is turned on per weekend day in hours

Same as 'avg. run hours production day [h]', but instead for weekend days. If the compressor does not run on weekends, simply put 0.

avg. run hours production day [h]	avg. load when running weekend [%]	avg. run hours weekend [h]	current at full load [A]
24.00	100%	24.00	23.0
24.00	0%	0.00	23.0
16.00	0%	0.00	23.0
30	31	32	33

Input: 33
Current at full load [A] - electric current in a single phase of a three-phase system (all compressor motors are assumed to be three-phase motors) at grid supply voltage of the compressor when running fully loaded, measured in ampere

This needs to be measured. Only use the single-phase current measured when the compressor is running fully loaded, do not use part load measurements here. Also, make sure the measurement is taken at grid voltage, meaning if you have an electric current signal from a VSD or a current transducer which sits in between a VSD and the compressor you might not be able to use this as a measurement, as VSDs vary the supply voltage. In that case, make sure to take the measurement up-stream of the VSD where there is grid voltage.

In case of industrial ammonia plants, you should be able to use current transducer measurements from your SCADA/monitoring system to determine the compressor current.

In case of commercial freon systems, such monitoring systems are most likely not available, so the current must be measured by a qualified electrician using an ammeter.

Sheet: Condensers

Condensers

These inputs concern condensers and are only required if you wish to calculate **Condenser Fan Speed Control.**

Input: 34
Condenser name - only for reference

Input: 35
Total current [A] - electric current in a single phase of a three-phase or single-phase system (respective motor-type) at grid supply voltage of all fans of the respective condenser combined, measured in ampere

This needs to be measured. Only use current measured when the condenser is fully loaded, meaning all fans of the respective condenser are running at full-speed. Since this is meant to calculate savings from VSDs for fan speed control, it is assumed, that the condenser fans are not yet equipped with a VSD and therefore run full-speed all the time when turned on.
You might be able to override the condenser fan control to run all fans at once for a short period just as long as you are taking the measurement.

B

36 **Choose from drop-down:**
Motor-type - What type of motors drive the condenser fans? Three-phase or single-phase?

Condensers	total current [A]	motor-type
Rack Condenser	7	three-phase
34	35	36

Sheet: Evaporators

Evaporators

All inputs on this sheet are only required if you wish to calculate savings from **Evaporator Fan Speed Control.**

37 **Input:**
Evaporator name - serves to identify savings specific to each evaporator

38 **Input:**
Total current [A] - electric current in a single phase of a three-phase or single-phase system (respective motor-type) at grid supply voltage of all fans of the respective evaporator combined running at full-speed, measured in ampere

This needs to be measured. Only use current measured when all fans of the respective evaporator are running at full-speed. Since fans are running full-speed during normal operation, if they are not yet equipped with speed control, you simply can take a measurement when fans of respective evaporator are running.

39 **Choose from drop-down:**
Motor-type - What type of motors drive the evaporator fans? Three-phase or single-phase?

Choose from drop-down: 40
Room temperature - Is the respective evaporator located inside a chiller (intermediate temperature) or a freezer (low temperature)?

Evaporators	total current [A]	motor-type	room temperature
Large Freezer	16.5	three-phase	Low (freezing)
37	38	39	40

Result: 41
Run hour sense check - This tells you, if current run hours and future total run hours at different speeds are equal, larger, or smaller than each other.

You could possibly run the fans less or more overall, but to compare savings from speed control vs. fixed speed, you should use the same amount of total run hours current and future, as running different totals of hours would contort consumption.

Input: 42
Current run hours per week (100% speed) [h] - weekly run hours at full-speed (no speed control) with the current set-up

How many hours per week do the evaporator fans run?
Two examples: Fans inside a freezer room run all the time except during defrosts which take up 3 hours in total each day:
current run hours per week = (24 - 3) h/day * 7 days/week = 147 h/week
A beef chiller runs a 40-hour chilling cycle three times a week and holds temperature another 24 hours over the weekend:
current run hours per week = 40 h * 3 /week + 24 h/week = 144 h/week

AMPC

B

43 **Input:**

Speed X [%] - one of multiple speed settings at which the fans can run in future with fan speed control in percent of normal (grid frequency) speed

With fan speed control you can run evaporator fans at different speed settings. Enter up to 8 different speeds for speed 1, speed 2, speed 3... up to 8 different speed inputs possible

Of course, fans can still be operated at 100 % speed. This does not save energy but may be required for example at the beginning of a carcass chilling cycle or even periodically, for example in a freezer, for short bursts to insure air circulation in every corner of the room. It might even be required all day during production when product is coming in with fans only slowing at night or only during the weekends on blast freezers, etc. This can still save considerable amounts of energy especially on large fans like blast freezers. But small fans which only require small cheap VSDs or EC-motors might still add up significantly even if speed is only reduced part of the time. Of course, larger savings are achieved, if fan speed is constantly reduced. A small reduction by only 20 % down to 80 % fan speed would cut fan power almost in half.

For example, a 40 hour grainfed beef chillier cycle might require the fans to run at 100 % speed for the first 24 hours but after that fan speed is reduced by 10 % every 3 hours down to 60 % where the fans are held until the end of the cycle and over the weekend. In that case enter speed 1 = 100 %, speed 2 = 90 %, speed 3 = 80 %, speed 4 = 70 %, speed 5 = 60 %. Leave the others blank.

run hour sense check	current run hours per week (100% speed) [h]	speed 1 [%]	run hours per week at speed 1 [h]	speed 2 [%]	run hours per week at speed 2 [h]	speed 3 [%]	run hours per week at speed 3 [h]
current = future	168.0	100%	90.0	70%	30.0	60%	48.0
	41		42		43		44

Input: 44

Run hours per week at speed X [h] - one of multiple run hour settings for each specified speed in hours

Enter future weekly run hours at the speeds you have specified.

For the same example of a 40 hour grainfed beef chillier cycle, which runs 3 times per week with the fans holding the cold carcasses an additional 24 h over the weekend: Fans run at 100 % speed for the first 24 hours of the cycle, but after that fan speed is reduced by 10 % every 3 hours down to 60 %, where the fans are held until the end of the cycle and over the weekend. In that case enter:

run hours 1 (@100 %) = 3 * 24 = 72 h,
run hours 2 (@90 %) = 3 * 3 = 9 h,
run hours 3 (@80 %) = 3 * 3 = 9 h,
run hours 4 (@70 %) = 3 * 3 = 9 h,
run hours 5 (@60 %) = 3 * 7 + 24 = 45 h.
Leave the others blank.

AMPC

EVAPORATOR

FAN SPEED CONTROL

1

SUMMARY

Reducing the speed of any fan is a very effective way to cut energy use as only a small speed reduction generates substantial savings. The saving can be increased by 25-30 % through reduced compressor energy, as the compressors no longer needed to work that hard to remove the heat introduced by the fans.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool. Besides the electricity rates, this EEO only requires inputs to be made for 'Sheet: Evaporators'.
- Calculated savings assume all condensers are equipped with VSDs for speed control.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Fan speed control can be implemented in several ways:

1. Replacing fans with Electronically Commutated (EC) Fans. This avoids the need for additional VSDs or shielded cabling but is more costly as retrofit.
2. Fitting VSDs to the existing fan motors, either individually or one VSD per evaporator. Some older fan motors are not suited to variable speed operation, however.
3. Voltage control of smaller (shaded pole) motors which are not suited to VSD retrofit. This is inexpensive but less energy efficient than 1) or 2).

- In addition to implementing a means of speed control, consideration should be given to the following instrumentation:
  - a. Additional room temperature sensors to monitor room temperature uniformity. This is especially useful in larger storage chiller and freezer rooms.
  - b. Access door switches, to detect door movement. Fan speed can be reduced in some cases when doors have been shut for long enough.

AMPC

CONDENSER

FAN SPEED CONTROL, LOCATION & REPLACEMENT

2

SUMMARY

Direct energy savings are easily achieved by operating condenser fans at variable speed, rather than on/off. Additional savings are possible by replacing degraded condensers and ensuring the condensers are installed in the right location.

Air cooled condenser with EC fans

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.
- Calculated savings assume all condensers are equipped with VSDs for speed control.

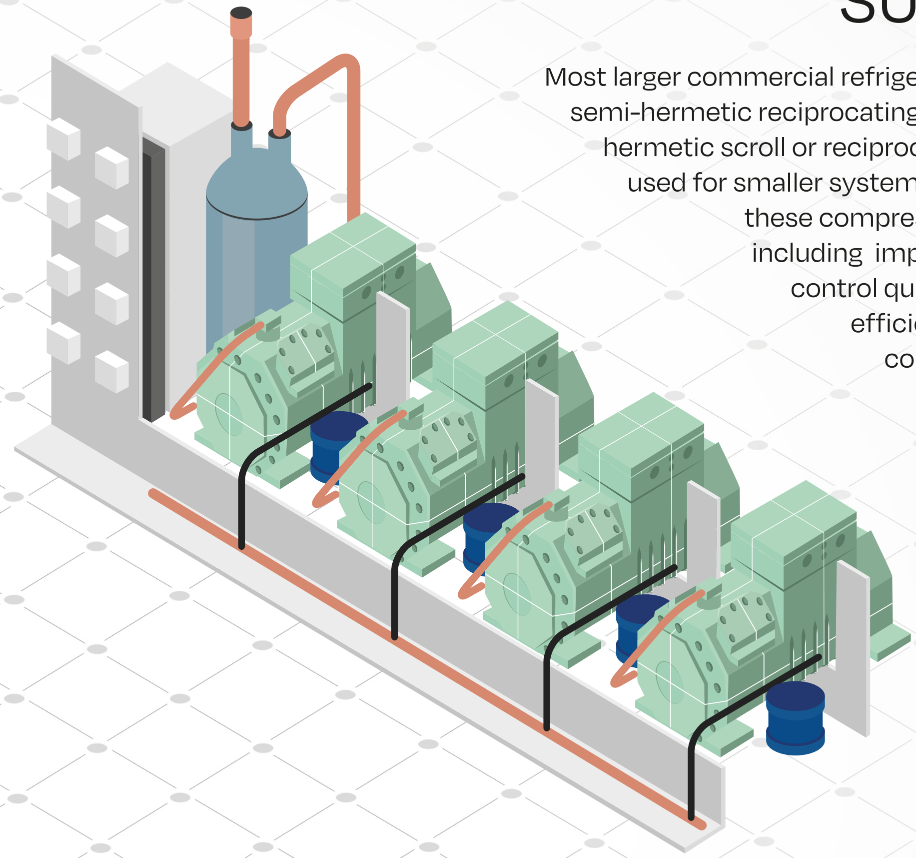
IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

The temperature test and visual inspections as shown in the Guidebook will help identifying degraded/undersized or poorly located condensers.

1. Reselect a new condenser, ideally for a design temperature difference of <10K.
2. Consider ordering a condenser with adiabatic cooling factory supplied (see EEO #4)
3. Ensure that any replacement condenser is supplied with EC fans. This will be cheaper than retrofitting VSDs, and requires less space and cabling.
4. Ensure that the control system used (PLC or commercial microprocessor) is correctly set up to control the fan speed, running all fans together.
5. Ensure a condenser location is selected that
   - a. Is well ventilated with ambient air
   - b. Is shaded, especially from afternoon sun
   - c. Is either roof mounted, or mounted well off ground level, to protect the fins from dirt.

COMPRESSOR

SPEED CONTROL & STAGING

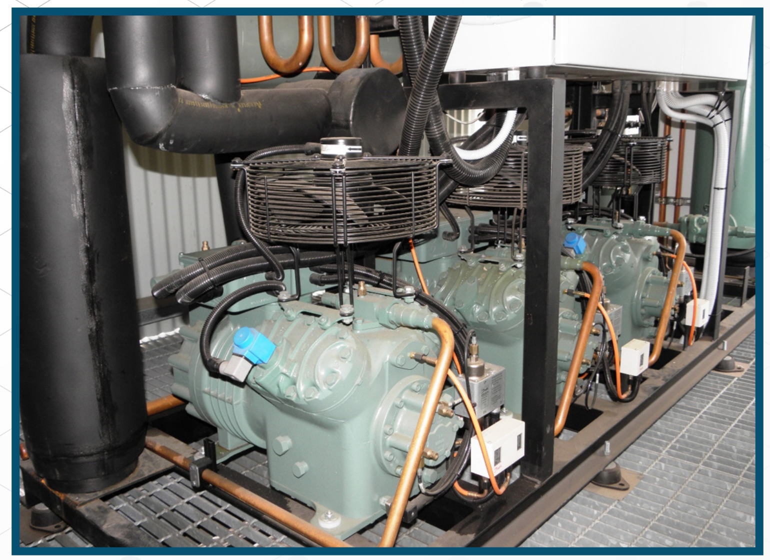


SUMMARY

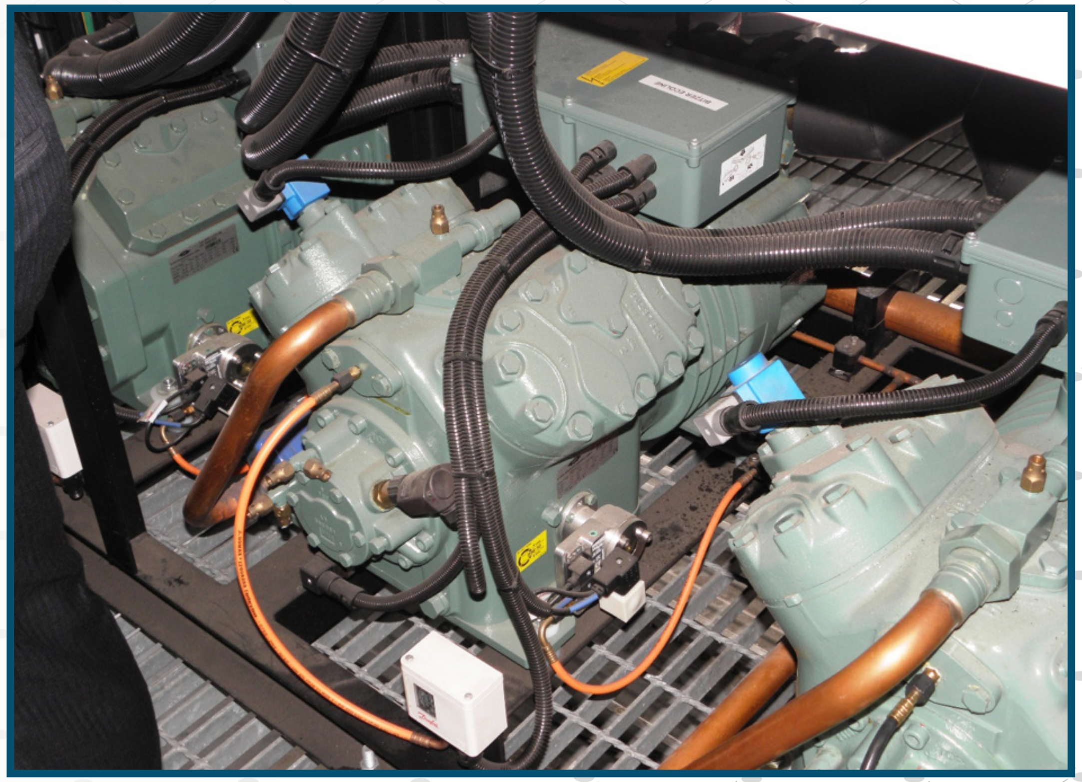
Most larger commercial refrigeration systems use semi-hermetic reciprocating compressors, with hermetic scroll or reciprocating compressors used for smaller systems. Speed control of these compressors offer benefits including improved temperature control quality, greater energy efficiency and enhanced compressor longevity.

Single compressor condensing unit

Multiple compressor rack with semi-hermetic compressors



Semi-hermetic compressor



WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.
- Calculated savings assume all energy losses due to mechanical unloading are avoided with the help of compressor speed control. Meaning all compressors run mechanically fully loaded with one or more compressors modulating the load via VSD/speed control. This does not include potential additional savings form avoiding on/off cycling and its associated high start-up currents, which would be added on top of this number. This is especially relevant to commercial freon systems which cycle compressors often.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

- On multiple compressor racks, install VSDs on the largest compressor.
- Size VSDs generously to suit maximum current draw from the compressor motor.
- If the VSDs is sized to suit (+20%), the compressors could run at 60Hz, increasing available capacity
- Ensure cabling is suitable shielded and the VSDs have harmonic filtration to suit site needs
- Most modern commercial microprocessor controller have the ability to interface with a compressor VSD and contain standard control logic to properly utilized the VSD.
- Check the maximum temperature rating of the VSD to ensure that it is suited to the installation location. Some VSDs are only rated to +45 °C, which can easily be exceeded in some plant rooms in summer.
- Check air filtration of cooling air. In dirty environments, additional external filtration of the cooling supply air may be required.

ADIABATIC COOLING

4

SUMMARY

Adiabatic cooling is a beneficial addition to most air-cooled condensers, except on very small units and in tropical climate zones and can save significant energy and demand costs by cooling the air entering the condenser on hot days, when condensing pressure would otherwise rise to high levels.

Adiabatic system using wetted mesh at condenser inlet

Adiabatic sprays fitted to condenser

WHAT DATA/INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.

Calculated savings assume power of all compressors for which inputs are done is reduced due to head pressure reduction according to weather data at chosen location with water sprays turning on once adiabatic trigger temperature is exceeded. These savings do not account for any extra water use, which could reduce savings.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Where possible, order new condensers with factory supplied adiabatic cooling as this will offer a greater certainty of performance and reliability compared to retrofit options.

Do not retrofit adiabatic systems to undersized or degraded condensers – upgrade condenser first (see EEO #2)

3 Also do not retrofit to condenser that are not well ventilated – this will reduce the effectiveness of adiabatic cooling significantly. Relocate condenser to better location (see EEO #2).

4 Ensure that the adiabatic systems installed do NOT wet the finned surface, unless de-ionised water is used. Wetting the coil with untreated water will quickly deteriorate the coil.

Coil damaged by sprays

5 Ensure that the control system is able to properly control the adiabatic cooling system to prevent wasteful use of water.

a Only activate the adiabatic system when the refrigeration unit is running and when ambient temperatures exceed a minimum threshold or trigger temperature (typically 28 °C).

b Carefully consider control logic when combined with fan speed control:

i. Adiabatic cooling should be triggered by ambient temperature, not condensing pressure. You will need an ambient temperature sensor connected to the control system to do this.

ii. Fan speed should be controlled in response to condensing pressure (see also floating head pressure control EEO #5).

6 Do not forget to include inspection and maintenance of the adiabatic cooling system in your scheduled maintenance system.

AMPC

5 EXVs & FLOATING HEAD PRESSURE CONTROL

SUMMARY

Replacing thermostatic expansion valves with electronic expansion valves (EXVs) and applying floating head pressure control is an effective energy saving technique, for several reasons.

Evaporator with electronic expansion valve

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.

Calculated savings assume all compressors for which inputs are done run at reduced condensing temperature according to weather data from chosen location instead of permanently running at fixed set condensing temperature (floating head pressure). It is also assumed that condensers have enough capacity to run at a temperature difference of 10 Kelvin. Calculated savings only include reduced compressor consumption. Possible energy penalties, due to higher fan use are neglected, which might reduce actual savings. However additional savings from the EXV, for example defrost optimisation (see EEO #6) are not accounted for in the calculation result and would add to the savings.

5

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

The temperature test and visual inspections as shown in the Guidebook will help identifying degraded/undersized or poorly located condensers (see EEO #2).

1. Generally, this EEO is NOT viable for retrofit to existing small single-compressor systems.
   - a. Where the site has multiple single compressor systems, it is probably better to consider replacing these with a single rack system, and then applying EXVs and floating head pressure control to that system.
   - b. Better still, consider a plant upgrade to CO_2 (or possibly low charge ammonia) when rationalizing or replacing multiple single compressor units (see EEO #8). Beside the long-term benefits of using a refrigerant that will not be phased out, this offers great benefits for hot water generation to offset site fule use (see EEO #9).
2. If small condensing units cannot be conveniently combined, consider using smart condensing units which incorporate EXVs and floating head pressure (see EEO #37), but recognize that these are only available for HFC/HFO refrigerants.
3. Consider small CO_2 condensing units as alternative to the smart condensing units as another plant upgrade option, where combining several condensing units into one system is not feasible. Such CO_2 units also use EXVs and float head pressure as this is inherent in all CO_2 system controls.
4. Where the existing rack and condenser system are in good condition:
   - a. Retrofit EXVs to all evaporators. This should not be the only action, however!
   - b. Ensure that the rack controller supports floating head pressure control, and make sure it is properly commissioned. Upgrade rack controller, if floating head pressure control is not supported.
   - c. Note installation and commissioning tips as note in Guidebook under "good to know".

6

DEFROST OPTIMISATION

SUMMARY

Conventional defrost routines conduct evaporator heating at regular intervals, for fixed defrost periods. As these are tuned for worst-case ice buildup, excess defrosting causes room heating and excess system energy use. Defrost optimisation is designed to minimize this.

WHAT DATA/ INFORMATION IS NEEDED?

Although the energy savings are likely to be significant, significant monitoring and analysis is required to estimate energy savings in every case.

Defrost optimisation is likely to be viable the facility has freezer rooms or chiller rooms operating at <+4°C with evaporators that are conventionally defrosted (fixed interval and duration).

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Defrost optimisation requires that defrost is conducted only when needed (on demand) and only for as long as needed (defrost termination).

Each evaporator coil should befitted with one (or more) defrost termination sensors thatdetect the coil surface temperature (not air temperature) ideally at the location with the greatest frost accumulation. Specialized clip-on sensors are commercially available that detect fin temperature, but alternatively conventional probes can be used as long as good fin contact is ensured. Some coil manufacturers can supply coils with defrost termination sensors inbuilt.

Defrost optimisation then requires the following control logic items to be programmed in the PLC:

1 **Run counter:**

Where evaporator capacity is regulated by controlling liquid feed rate to the evaporator (as opposed to regulating pressure), implement a run counter to totalize the hours of open-valve operation. The ice accumulation on the coil is approximately proportional to this totalized run period. Reset the counter whenever defrost commences.

2 **Defrost start:**

Start a new defrost cycle ONLY when enough run hours have accumulated, otherwise skip scheduled defrost event. Some trial & error will be required to determine the minimum number of run hours for each evaporator to require defrost.

Tip: Have regular (more regular than usual) planned defrost events per evaporator as "reserved slots", then skip if not enough run hours have accumulated. For example: If daily defrosts are currently being done, schedule these at 12 hour intervals in future.

3 **Defrost termination:**

Terminate defrost on every evaporator when the defrost termination sensor reaches 10 °C, rather than running each defrost for the full set duration.

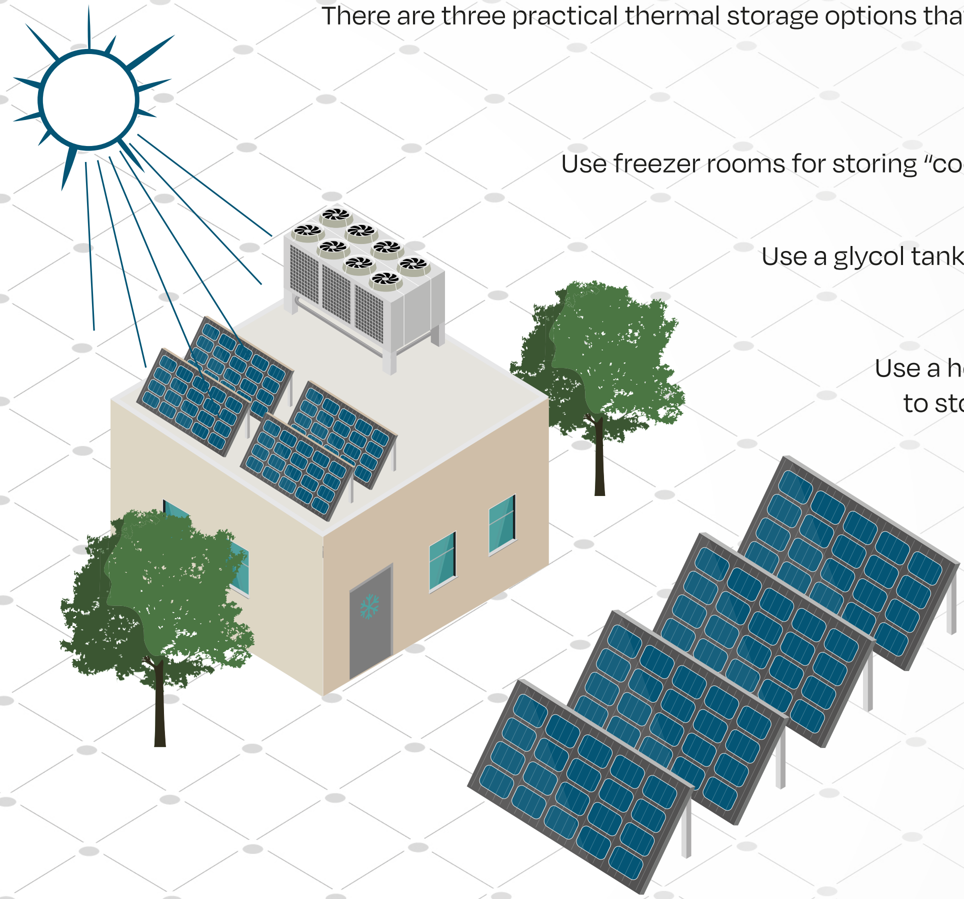
Tip: Set defrost duration a bit longer than before to accommodate extra-heavy frost formation when defrosts are skipped. For example: If defrost duration is currently 30 minutes, extend this to 45 minutes if termination is done on temperature.

SOLAR PV & THERMAL STORAGE

SUMMARY

Installing solar PV power generation in combination with thermal storage can be a better solution that only installing solar PV to reduce power bills. There are three practical thermal storage options that can be applicable to meat processors:

1. Use freezer rooms for storing "cooling" energy.
2. Use a glycol tank to store cold glycol.
3. Use a hot water tank to store hot water.



IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

1. If suitable roof space is available, install the maximum amount of solar PV to suit the site energy use profile. Most PV solar installers can recommend suitable sizing (typically 1/3 of peak daytime power use). The PV array can be expanded in future if it is fully utilized.
2. When using freezer rooms for thermal storage:
   a. Program the room temperature controls to reduce room temperature when solar generation starts (typically around 9am) and raise room temperature when solar generation reduces (typically around 3pm).

b. If possible, automate these controls by measuring solar generation using a current transducer on the solar system. Then trigger room temperature reduction when solar generation is high, or raise temperature when it drops too low.

3. When using a glycol system for thermal storage:

a. Ensure the glycol tank has multiple temperature sensors so the amount of cold glycol can be measured.

b. Return warm glycol to the top of the tank, and cold glycol to the bottom of the tank.

c. When there is enough solar power (or use a timer), run the glycol chiller at full capacity to charge the tank.

d. When solar power drops (or on timer), turn off the chiller and run off stored glycol.

e. Turn on the chiller only when most of the tank has warmed up. If the tank is large enough, this may not be necessary and then the chiller only runs when there is solar power. Otherwise the chiller will use cheaper off-peak power.

4. When using a hot water system for thermal storage:

a. Ensure the hot water tank has multiple temperature sensors so the amount of hot water can be measured.

b. Return hot water to the top of the tank, and supply town water to the bottom of the tank.

c. When there is enough solar power (or use a timer), run the heat pump at full capacity to charge the tank.

d. When solar power drops (or on timer), turn off a heat pump (see EEO #10) and run off stored hot water.

e. Turn on the heat pump only when most of the hot water in the tanks has been used up. If the tank is large enough, this may not be necessary and then the heat pump only runs when there is solar power. Otherwise the heat pump will use cheaper off-peak power.

PLANT REPLACEMENT TO CO_2 AND/OR NH_3

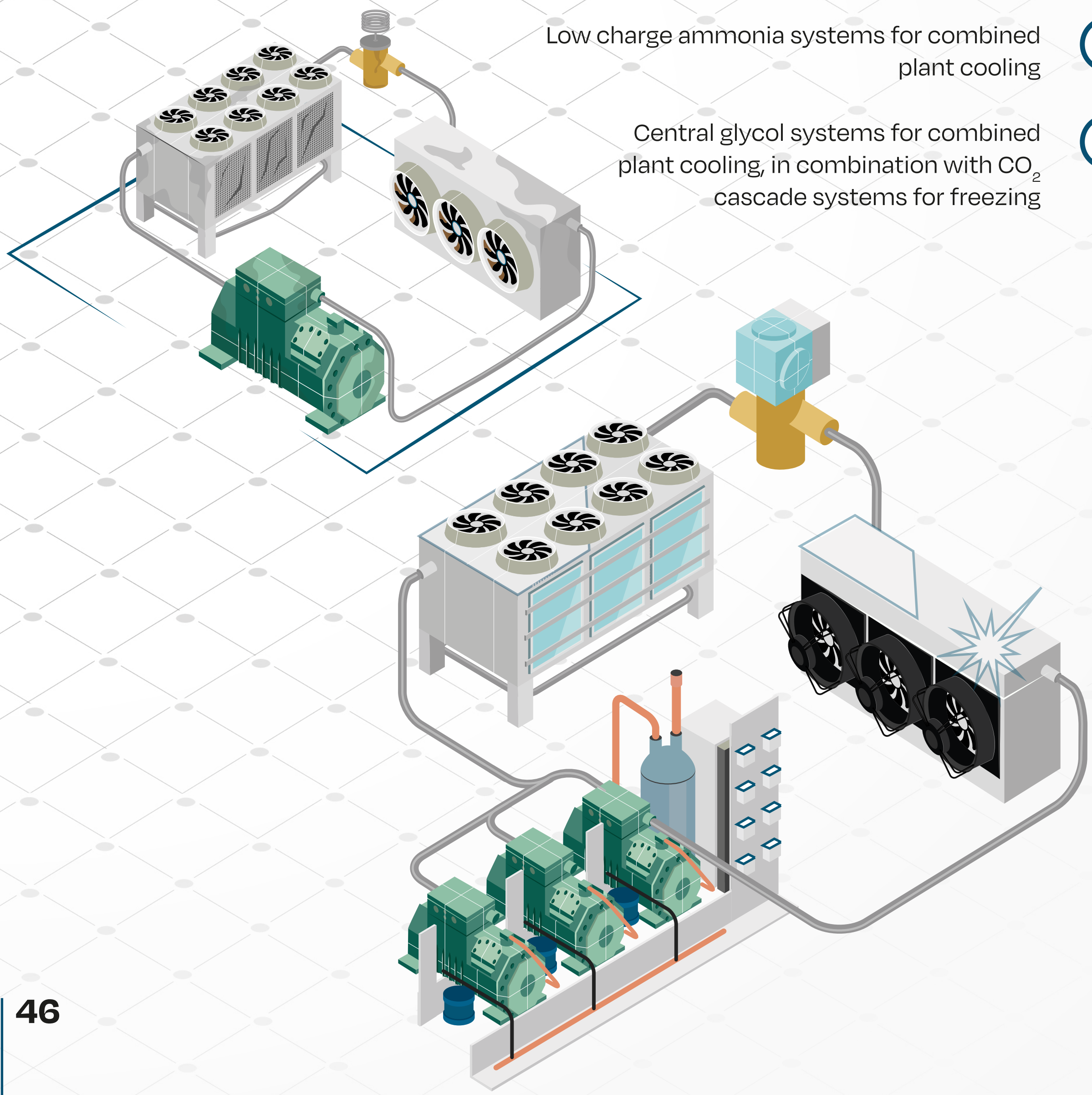
SUMMARY

Synthetic refrigerant systems are not long term options, and besides, new refrigeration systems using CO_2 or ammonia can also offset heating fuel use, making them often the best choice anyway.

Therefore synthetic refrigerant systems should be replaced with a suitably designed natural refrigerant system to best suit site needs.

Options for plant upgrade include:

- Central CO_2 systems for combined plant cooling.
- CO_2 condensing units for individual or remote cooling loads
- Low charge ammonia systems for combined plant cooling
- Central glycol systems for combined plant cooling, in combination with CO_2 cascade systems for freezing



WHAT DATA/INFORMATION IS NEEDED?

There are many considerations that will inform the decision as to the best solution for every site. Key information needed to assess the options include:

1. Location of cooling loads. Most meat processors have cooling areas adjacent to each other (carcass chillers, boning rooms, storage chillers, etc) and therefore are well suited to a central system (CO_2 or ammonia). Remote units in adjacent buildings are problematic and may need an individual CO_2 unit.
2. Total cooling loads. Smaller total loads are generally more economically met with CO_2 or glycol systems, whereas larger systems can favour ammonia.
3. Available service support. Very remote sites may have limited local service expertise for CO_2 or ammonia systems. These sites may be best suited to a central glycol system served by a standard chiller, which could still be a synthetic refrigerant or an ammonia chiller.
4. Site safety concerns and regulations. Direct ammonia systems cannot be used for processing areas (only CO_2 or glycol possible). Also, compliance costs for ammonia systems may be unusually high on some sites due to council requirements or proximity of neighbours/populated areas.
5. Hot water requirements. Sites that use expensive fuel (Diesel, LPG) for generating wash-down or sterilizer water would benefit from a central CO_2 system to offset this fuel.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Upgrading from synthetic refrigeration systems to any of the above plant options is essentially a "remove and replace" exercise.

1. Synthetic refrigeration systems use copper tube material, which is unsuitable for ammonia (corrosion) and CO_2 (pressure rating).
2. Existing pipework sizing is not suited (glycol lines need to be larger, CO_2 lines smaller)
3. Control systems as used for synthetic refrigeration systems require too many changes to make their re-use for new plant plausible.

Therefore, on high level a plant upgrade requires

a. Design of the replacement systems, to suit current and future cooling loads (and hot water needs). Note that a like-for-like replacement is almost always not the best solution.
b. Decommission and remove existing plant, in stages if needed.
c. Install new systems, in stages if needed.
d. Progressively commission the new plant.

The following general guidance may be useful:

a. CO_2 systems can overcome far greater line lengths than synthetic refrigerant or ammonia. Hence, often even small remote loads can be accommodated on a central plant.
b. CO_2 systems can generate 90-95 °C water quite easily, meeting sterilizer water needs in many cases.
c. Glycol chillers can be upgraded in future without any change to the glycol system. Hence, a lower cost chiller can be installed initially, and upgraded to better systems down the track.
d. Low charge ammonia systems are generally the most energy efficient option, especially in warm or humid climates.

HEAT RECOVERY

SUMMARY

Heat recovery from refrigeration can offset electricity or fuel used for generating hot water.

WHAT DATA/ INFORMATION IS NEEDED?

Some commercial refrigeration systems are able to provide useful amounts of hot water, typically up to 60 °C (washdown). This may be feasible to retrofit, if the equipment is in good condition.

Single compressor refrigeration units are generally not suited to heat recovery due to their intermittent operation.

Identify existing systems that:

1. Serve multiple loads and run more or less continuously. Multi-compressor racks could be suitable
2. Are located close to existing hot water systems, such as gas-fired or electric boilers.
3. Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.
4. Even though heat recovery is possible with some freon systems, savings for this EEO are only calculated for heat recovery from a full-CO_2 replacement system (see EEO #8). CO_2 allows for up to 100 % of discharge heat to be recovered at temperatures up to 90 °C (wash-down & sterilization water needs could be covered). Calculated savings assume all discharge heat currently generated by all the compressors for which inputs were made, could be used for heat recovery from a future full-CO_2 plant which replaces these compressors.
5. If you already have heat recovery from rendering cookers this is probably not applicable.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

If the site is likely to undergo a plant upgrade (EEO #8), then plan to incorporate heat recovery from the new unit. CO_2 systems are able to deliver hot water at up to 90 °C without additional energy use.

If a suitable existing compressor rack reasonably close to existing hot water generation has been identified, proceed as follows:

Once the undersized evaporator has been identified it becomes and engineering exercise to select a replacement unit to better suit the room conditions. This can be done in several ways, or a combination:

1. Reroute the common rack discharge line to a heat recovery heat exchanger. It is recommended to install two ball isolation valves and a bypass line also fitted with a ball valve.
2. Install a suitably sized hot water tank if not already available on site. Ensure that the tank has cold town water feed into the bottom and hot water offtake on the top, and that it is designed for thermal stratification.
3. Circulate water from the tank through the heat exchanger and back into the tank using a speed controlled pump, controlled off delivery temperature.
4. Route hot water supply from the top of the tank via the existing hot water heater to the point of use. By using a pressurised hot-water tank, no hot water feed pump is required.

AIR SOURCE HEAT PUMPS

10

SUMMARY

Heat can be absorbed from ambient air by means of a dedicated CO_2 heat pump and then discharged into hot water at temperatures up to 95 °C, thus offsetting fuel or direct electric heating as sterilizer water.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section B for instructions on how to use the tool and which inputs are needed.
- Heat pumps consume electricity rather than fuel. So, electricity use will go up.
- Calculated electricity use is needed to provide all the hot water (below 95 °C; no rendering!) needed on site, which was previously generated by the boiler.
- If all hot water needs are at 95 °C and below (no rendering), the entire fuel consumption can be offset.
- Savings assume all hot water (95 °C and less) is generated entirely by heat pumps.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

CO_2 heat pumps are stand-alone devices and can be located close to point of use (for example boning room). In most cases, CO_2 heat pumps would be used to provide instantaneous demand (hence NO hot water storage), but in some cases a storage tank can be used to overcome differences between peak heat production and peak hot water usage (see EEO #7). Their modular design generally allows the site to install multiple units and add more as hot water demand grows.

AMPC

INDUSTRIAL AMMONIA SYSTEMS

The following pages provide additional information to further assess the EEOs which are presented in the **Industrial Ammonia Systems Part 1 & 2 Guidebooks.** Instructions on how to use the **AMPC-EEO Calculation Tool** to calculate high level savings where applicable are also provided.

SUMMARY

Some EEOs can be calculated to achieve high-level results with some rough inputs. Follow the instructions on the following pages to do so. Resulting savings totals will be shown on the Dashboard-Sheet, along other useful information. Results specific to each compressor & evaporator are shown on the respective Results-Sheets.

Sheet: Site

Introduction

Besides the first round of inputs, the first sheet of the calculation tool, also gives you a short explanation about the color-coding used within the tool and the tooltips.

1. Try hovering the cursor over this text to see the tooltip for the cell displayed.

2. These teal-coloured cells signal that input is required.

   Tooltips for each input list which EEOs require the respective input. If you only wish to calculate certain EEOs, you can ignore those inputs which are not needed for them.

3. These tan-coloured cells contain the results from inputs priorly made.

4. Headings might also specify the SI-unit of the inputs or results they refer to. SI-units are surrounded by [...] brackets, e.g. [kW]. Make sure inputs are made in the required SI-Unit. If your measurement readings are in another unit you first must convert them into the SI-unit required (e.g. absolute pressure [kPa] --> gauge pressure [kPa (g)]).

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Introduction:	Throughout this calculation tool, many cells have tooltip (1) attatched to them. You can identify cells with tooltips by the sall red triangle in the upper right corner of a cell. Hover your cursor over these cells to see the tooltip displayed.	
color coding:	Inputs	(2)
	Result	(3)
	Headings [SI-unit]	(4)

Site

The very first inputs needed from you provide some basic information about the site.

5. **Input:**
production days per week - How many days per week does production run?
Typically, 5 days;
Might be 6 days with production running on Saturdays, might also be less.

6. **Choose from drop-down:**
location - If you cannot find your location, choose one that is closest to you or has similar climate conditions.

7. **Choose from drop-down:**
refrigeration system - What type of refrigeration plant do you have on site?
An industrial ammonia system with evaporative condensers or commercial freon systems with air-cooled condensers?
If you have both, you will have to use this tool twice. Once to calculate EEOs for ammonia systems and again for freon systems.
Choosing 'Industrial Ammonia' lets you calculate applicable EEOs presented in the guidebooks 'INDUSTRIAL AMMONIA SYSTEMS PART 1 & 2'.
'Commercial Freon' lets you calculate applicable EEOs from the 'COMMERCIAL FREON SYSTEMS' guidebook.

In this case we want to calculate industrial ammonia systems, so choose 'Industrial Ammonia' from the drop-down menu.

Site:		
production days per week:	(5) 5	days/week
location:	VIC, Melbourne (6)	
refrigeration system:	Industrial Ammonia (7)	

Electricity Charges

In this section you need to provide information about your electricity costs, so energy savings can be translated into monetary savings.

8 **Input:**

time span - How many months worth of electricity bills do you enter into the cells below? For minimum effort, you could use a single bill covering a time span of just one month. In this case enter '1' in this cell. However, for a more accurate electricity breakdown, seen on the 'Dashboard', it is recommended to enter at least a year or 12 months worth of electricity bills. In that case enter '12'.

9 **Input:**

total charges (ex. GST) - sum of total electricity charges (ex. GST) over specified time span

10 **Input:**

demand charges - sum of all demand charges over the specified time span

Carefully go through your electricity bills, sum up all demand related charges and enter the sum here. You can identify demand charges by the unit they are charged in (kVA or kW). Attention: Do not just take all network charges as these will most likely also include some consumption related charges.

11 **Input:**

demand charges - sum of all demand charges over the specified time span

Carefully go through your electricity bills, sum up all demand related charges and enter the sum here. You can identify demand charges by the unit they are charged in (kVA or kW). Attention: Do not just take all network charges as these will most likely also include some consumption related charges.

12 **Input:**

total consumption - sum of total power consumption over specified time span in kWh

Your bill might show you consumption for peak and off-peak hours. Careful, do not use those numbers here (unless you add them up). You can find your total consumption either in the summary of your bill, or for example, environmental charges are billed for total kWh of consumption.

Electricity Charges:			
time span:	12	months	8
total charges (ex.GST):	$ 300,000		9
demand charges:	$ 50,000		10
Other charges:	$ 10,000		11
total consumption:	1,333,333	kWh	12
consumption charges:	**$ 240,000**		13
average consumption cost:	**18.00**	**c/kWh**	14

Result: 13

consumption charges - total consumption related charges over specified time span

Result: 14

average consumption cost - average cost per kWh of electricity consumed in c/kWh

Fuel Charges

You only need to fill this section, if you want to calculate possible savings from heat recovery and heat pumps as these save fuel. This is only applicable to boilers that do not serve for rendering, as rendering requires higher temperatures which cannot be provided by heat recovery or heat pumps as of today (possibly in future) and often comes with its own form of heat recovery for wash-down water.

All inputs regarding fuel are only required, if you wish to calculate: 15

heat recovery

heat pumps

Savings from these EEOs are only applicable, if hot water is only used for wash-down or sterilisation (no rendering).

Choose from drop-down:

fuel type - What type of fuel is burned inside the boiler to generate hot water for wash down and/or sterilisation?

Result: 16

unit - This cell automatically shows the unit the selected fuel is usually charged in. If this is not the case for you, select 'other' and enter unit into cell to the right.

C

Fuel Charges:			
fuel type:	natural gas		15
unit:	GJ		16
heating value per unit:	277.78	kWh/GJ	17
time span:	12	months	18
total charges (ex. GST):	$ 165,000		19
total consumption:	10,000	GJ	20
average consumption cost:	$ 16.50	$/GJ	21
boiler efficiency:	80%		22
percentage sterilisation water:	30%		23
percentage wash-down water:	70%		24

17 **Result:**
heating value per unit - This cell automatically shows to the typical heating value of selected fuel. If this value is not representative of your fuel, select 'other' and enter heating value.

18 **Input:**
time span - How many months worth of fuel bills do you enter into the cells below? For minimum effort, you could use a single bill covering a time span of just one month. In this case enter '1' in this cell. However, for a more accurate annual fuel consumption estimate, it is recommended to enter at least a year or 12 months worth of fuel bills. In that case enter '12'.

19 **Input:**
total charges (ex. GST) - sum of total fuel charges (ex. GST) over specified time span

20 **Input:**
total consumption - sum of total fuel consumption over specified time span in respective unit

21 **Result:**
average consumption cost - average cost per unit of fuel

22 **Input:**
boiler efficiency - percentage of heating value from burning fuel that is effectively transferred to the water to heat it up

If you do not know the boiler's efficiency assume 70-80 %. You can change values and see how they affect results.

Input: 23
percentage sterilisation water - percentage of hot water generated by boiler used for sterilisation (95 °C) before it is diluted (at boiler outlet temperature) in percent

If you do not need any sterilisation water and all water is used <60 °C, enter 0.

Result: 24
percentage wash-down water - percentage of hot water generated by boiler used for wash-down of processing areas and other hot water needs <60 °C before it is diluted (at boiler outlet temperature) in percent

It is assumed that this is all hot water except for the sterilisation water (no rendering), hence:
percentage wash-down water = 100 % - percentage sterilisation water.

Sheet: Compressors

System Pressures

Specify the set system pressures to calculate savings from Variable Head Pressure Control, Dedicated Hot Gas Compressor and Bottle Neck Removal & Suction Pressure Optimisation for the high and low stage of the ammonia plant.

Only required for: 25
Dedicated Hot Gas Compressor
Variable Head Pressure Control

Input:
high stage discharge pressure - fixed set-point high stage discharge/head/condensing pressure of the ammonia system from SCADA/monitoring system in kPa(g)

Only required for: 26
High Stage Suction Pressure Increase (Bottle Neck Removal & Suction Pressure Optimisation)

Input:
high stage suction pressure - fixed set-point high stage suction/intercooler pressure of the ammonia system from SCADA/monitoring system in kPa(g)

Only required for: 27
Low Stage Suction Pressure Increase (Bottle Neck Removal & Suction Pressure Optimisation)

Input:
low stage suction pressure - fixed set-point low stage suction/accumulator pressure of the ammonia system from SCADA/monitoring system in kPa(g)

C

System Pressures			
high stage dischage pressure:	25	1050.0	kPa(g)
high stage suction pressure:	26	140.0	kPa(g)
low stage suction pressure:	27	-30.0	kPa(g)

Hot Gas

To calculate savings from using a Dedicated Hot Gas Compressor provide information regarding the hot gas needs on site and a possible reduction in discharge/head pressure.

28 **Only required for:**
Dedicated Hot Gas Compressor

Input:
hot gas hours production - total amount of time hot gas is needed for defrosts and carcass reheats per production day in hours

29 **Only required for:**
Dedicated Hot Gas Compressor

Input:
hot gas hours weekend - total amount of time hot gas is needed for defrosts on a weekend day in hours

30 **Only required for:**
Dedicated Hot Gas Compressor

Input:
reduced discharge pressure - If it was not for the need of high hot gas temperatures which are required for defrosts and carcass reheats, what reduced high stage discharge/head pressure could the rest of the high stage run at?
E.g., 900 kPa(g) instead of 1050 kPa(g) in kPa(g)

Hot Gas			
hot gas hours production:	28	12.0	h/day
hot gas hours weekend:	29	6.0	h/day
reduced discharge pressure:	30	900.0	kPa(g)

AMPC

Suction Pressure Increase

Suction pressures could possibly be increased, if they are set too low or bottle necks are removed which prevent the plant to run at higher suction pressures. Specify raised suction pressures to get a feel for the possibly significant savings that could be achieved from raising suction pressure with Suction Pressure Optimisation & Bottle Neck Removal.

Only required for: 31
High Stage Suction Pressure Increase (Bottle Neck Removal & Suction Pressure Optimisation)

Input:
raised high stage suction pressure - If bottle necks where removed and the high stage suction pressure could be raised, what raised high stage suction pressure could the plant be operated at? E.g. 170 kPa(g) instead of 130 kPa(g) in kPa(g)

Suction Pressure Increase			
raised high stage suction pressure:	31	170.0	kPa(g)
raised low stage suction pressure:	32	-8.0	kPa(g)

Only required for: 32
Low Stage Suction Pressure Increase (Bottle Neck Removal & Suction Pressure Optimisation)

Input:
raised low stage suction pressure - If bottle necks where removed and the low stage suction pressure could be raised, what raised low stage suction pressure could the plant be operated at? E.g. -8 kPa(g) instead of -30 kPa(g) in kPa(g)

High Stage Compressors & Low Stage Compressors

These inputs are needed for all EEOs except, Evaporator and Condenser Fan Speed Control. Take the time to make the inputs for all compressors in your plant. There are two almost identical input sections on this sheet. One for high stage compressors and one for low stage compressors. Compressors, which belong to the high stage are entered on the left side. Scroll further to the right to enter inputs regarding low stage compressors. Also, once all inputs are done for each compressor, you are provided with some helpful energy breakdowns Dashboard-Sheet.

33 **Input:**
compressor name - serves to identify savings specific to each compressor

If a compressor never runs and only serves as a stand-by unit, it does not need to be mentioned here.

34 **Input:**
capacity control - How is compressor capacity controlled? Mechanical unloading via slide-valve control or cylinder switch-off? Or speed controlled via VSD?

High Stage Compressors	capacity control	avg. load when running production day [%]
Compressor 1	mechanical unloading	70%
Compressor 2	mechanical unloading	80%
Compressor 3	mechanical unloading	95%
33	34	35

35 **Input:**
avg. load when running production day [%] - average compressor load due to unloading (mechanically or speed-driven) on a production day in percent

In case of industrial ammonia plants, you should be able to use slide-valve positions (mechanical unloading) or VSD frequencies/compressor speeds (speed control) from your SCADA/monitoring system to approximate compressor loads. Refer to 'Control & Monitoring Upgrade' in the guidebooks, if that is not the case.

In case of commercial freon systems, such monitoring systems are most likely not available, so loads have to be estimated. Here is an example:
If a compressor runs an estimated total of 16 hours per day, an estimated 6 of those fully loaded (100 %) and 10 hours unloaded at 67 % by switching off 1/3 of its cylinders, then the average load when running is:
100 % * 6 h / 16 h + 67 % * 10 h / 16 h = 79 %.

'When running' means that you should only average the load when the compressor is actually operating. For example, if using the slide-valve position as an approximation for the load, do not count the slide-valve position towards the average when the compressor is not running. A compressor which is operated in simple on-off fashion therefor always runs at 100 % load when running.

These calculations are rough estimates, so the same can be applied to the inputs. You can roughly estimate loads here and come back to change them to see how results may vary.

36 **Input:**
avg. run hours production day [h] - average time the compressor is turned on per production day in hours

In case of industrial ammonia plants, you should be able to use current transducer signals from your SCADA/monitoring system to approximate run hours. Refer to 'Control & Monitoring Upgrade' in the guidebooks, if that is not the case.
In case of commercial freon systems, such monitoring systems are most likely not available, so average run time has to be estimated.

If you rotate compressor duties weekly, make sure to account for that here.
An example:
A compressor runs an average of 16 hours per day for one week and then does not run for an entire week afterwards because its duty is taken over by another compressor. After the 2 weeks the cycle repeats itself. Then the average run hours are on average 16 / 2 = 8.

These calculations are rough estimates, so the same can be applied to the inputs. You can roughly estimate the run time and come back to change it to see how results may vary.

37 **Input:**
avg. load when running weekend [%] - average compressor load due to unloading (mechanically or speed-driven) on a weekend day in percent

Same as 'avg. load when running production day [%]', but instead for weekend days.

38 **Input:**
avg. run hours weekend [h] - average time the compressor is turned on per weekend day in hours

Same as 'avg. run hours production day [h]', but instead for weekend days.
If the compressor does not run on weekends, simply put 0.

avg. run hours production day [h]	avg. load when running weekend [%]	avg. run hours weekend [h]	current at full load [A]
24.00	0%	0.00	690.0
24.00	0%	0.00	700.0
24.00	60%	24.00	700.0
36	37	38	39

39 **Input:**
current at full load [A] - electric current in a single phase of a three-phase system (all compressor motors are assumed to be three-phase motors) at grid supply voltage of the compressor when running fully loaded, measured in ampere

This needs to be measured. Only use the single-phase current measured when the compressor is running fully loaded, do not use part load measurements here. Also, make sure the measurement is taken at grid voltage, meaning if you have an electric current signal from a VSD or a current transducer which sits in between a VSD and the compressor you might not be able to use this as a measurement, as VSDs vary the supply voltage. In that case, make sure to take the measurement up-stream of the VSD where there is grid voltage.

In case of industrial ammonia plants, you should be able to use current transducer measurements from your SCADA/monitoring system to determine the compressor current.

In case of commercial freon systems, such monitoring systems are most likely not available, so the current must be measured by a qualified electrician using an ammeter.

AMPC

Compressor Age

These inputs concerning compressor age serve to estimate compressor deterioration and are only required, if you wish to calculate **Compressor Block Replacement.**

Only required for: 40
Compressor Block Replacement

Input:
age [a or h] - compressor block age in years [a] or total run hours [h] depending on what you chose in the adjacent drop-down list

If you have run hour counters, use run hours. It is assumed that the compressor loses 20 % of its efficiency every 100,000 h of operation.
Otherwise use age in years. It is assumed that a compressor loses 1.5 % efficiency each year in normal operation.

Only required for: 41
Compressor Block Replacement

Choose from drop down:
years [a] or run hours [h] - How do you want to estimate compressor degradation?

Choose run hours, if you have a run hour counter for the respective compressor. Otherwise choose years. Make your input in the cell to the left accordingly.

age [a or h]	years [a] or run hours [h]
63,000	run hours
103,000	run hours
116,000	run hours
40	41

C

Motor Efficiencies & Dedicated Hot Gas Compressor

Motor efficiencies of old and new motors are only needed to calculate savings from **high efficiency motors.** Designating which compressor/s would be used as hot gas compressors is needed to calculate savings from a **Dedicated Hot Gas Compressor.**

42

Only required for:
High Efficiency Motors

Input:
old motor efficiency [%] - efficiency of the currently existing old motor in percent

If you cannot find out the motors efficiency, use an examplary number such as 92 %. This will help you understand how much savings can be achieved from only a few % efficiency gain for a given compressor. Savings are higher the more the compressor runs

43

Only required for:
High Efficiency Motors

Input:
new motor efficiency [%] - efficiency of a hypothetical new replacement motor

Use an examplary number such as 95.5 % or even as high as 98 % on larger motors. This will help you understand how much savings can be achieved from only a few % efficiency gain for a given compressor. Savings are higher the more the compressor runs.

44

Only required for:
Dedicated Hot Gas Compressor

Choose from drop-down:
dedicated hot gas compressor - If you were to dedicate a compressor to run at higher head pressure (current head pressure setting) to cover hot gas duties, while other compressors can run at reduced head pressure, which compressor/s would that be?

If you dedicate multiple hot gas compressors (recommended for redundancy), still only choose "yes" for compressors that would provide hot gas at the same time. Choose "no" for back-up hot gas compressors.

old motor efficiency [%]	new motor efficiency [%]	dedicated hot gas compressor
92.00%	95.50%	no
92.00%	95.50%	no
92.00%	95.50%	yes
(42)	(43)	(44)

AMPC

Sheet: Condensers

Condensers

These inputs concern condensers and are only required if you wish to calculate **Condenser Fan Speed Control.**

Input:
condenser name - only for reference 45

Choose from drop-down: 46
motor-type - What type of motors drive the condenser fans? Three-phase or single-phase?

Condensers	total current [A]	motor-type
Condenser 1	35	three-phase
(45)	(46)	(47)

Input: 47
total current [A] - electric current in a single phase of a three-phase or single-phase system (respective motor-type) at grid supply voltage of all fans of the respective condenser combined, measured in ampere

This needs to be measured. Only use current measured when the condenser is fully loaded, meaning all fans of the respective condenser are running at full-speed.
Since this is meant to calculate savings from VSDs for fan speed control, it is assumed, that the condenser fans are not yet equipped with a VSD and therefore run full-speed all the time when turned on.
You might be able to override the condenser fan control to run all fans at once for a short period just as long as you are taking the measurement.

Sheet: Evaporators

Evaporators

All inputs on this sheet are only required if you wish to calculate savings from **Evaporator Fan Speed Control.**

48 **Input:**
evaporator name - serves to identify savings specific to each evaporator

49 **Input:**
total current [A] - electric current in a single phase of a three-phase or single-phase system (respective motor-type) at grid supply voltage of all fans of the respective evaporator combined running at full-speed, measured in ampere

This needs to be measured. Only use current measured when all fans of the respective evaporator are running at full-speed. Since fans are running full-speed during normal operation, if they are not yet equipped with speed control, you simply can take a measurement when fans of respective evaporator are running.

50 **Choose from drop-down:**
motor-type - What type of motors drive the evaporator fans? Three-phase or single-phase?

51 **Choose from drop-down:**
room temperature - Is the respective evaporator located inside a chiller (intermediate temperature) or a freezer (low temperature)?

Evaporators	total current [A]	motor-type	room temperature
Large Freezer	16.5	three-phase	Low (freezing)
(48)	(49)	(50)	(51)

Result: 52
run hour sense check - This tells you, if current run hours and future total run hours at different speeds are equal, larger, or smaller than each other. You could possibly run the fans less or more overall, but to compare savings from speed control vs. fixed speed, you should use the same amount of total run hours current and future, as running different totals of hours would contort consumption.

Input: 53
current run hours per week (100% speed) [h] - weekly run hours at full-speed (no speed control) with the current set-up

How many hours per week do the evaporator fans run?
Two examples: Fans inside a freezer room run all the time except during defrosts which take up 3 hours in total each day:
current run hours per week = (24 - 3) h/day * 7 days/week = 147 h/week
A beef chiller runs a 40-hour chilling cycle three times a week and holds temperature another 24 hours over the weekend:
current run hours per week = 40 h * 3 /week + 24 h/week = 144 h/week

Input: 54
speed X [%] - one of multiple speed settings at which the fans can run in future with fan speed control in percent of normal (grid frequency) speed

With fan speed control you can run evaporator fans at different speed settings. Enter up to 8 different speeds for speed 1, speed 2, speed 3... up to 8 different speed inputs possible

Of course, fans can still be operated at 100 % speed. This does not save energy but may be required for example at the beginning of a carcass chilling cycle or even periodically, for example in a freezer, for short bursts to insure air circulation in every corner of the room. It might even be required all day during production when product is coming in with fans only slowing at night or only during the weekends on blast freezers, etc. This can still save considerable amounts of energy especially on large fans like blast freezers. But small fans which only require small cheap VSDs or EC-motors might still add up significantly even if speed is only reduced part of the time. Of course, larger savings are achieved, if fan speed is constantly reduced. A small reduction by only 20 % down to 80 % fan speed would cut fan power almost in half.

For example, a 40 hour grainfed beef chillier cycle might require the fans to run at 100 % speed for the first 24 hours but after that fan speed is reduced by 10 % every 3 hours down to 60 % where the fans are held until the end of the cycle and over the weekend. In that case enter speed 1 = 100 %, speed 2 = 90 %, speed 3 = 80 %, speed 4 = 70 %, speed 5 = 60 %.
Leave the others blank.

C

55 **Input:**
run hours per week at speed X [h] - one of multiple run hour settings for each specified speed in hours

Enter future weekly run hours at the speeds you have specified.

For the same example of a 40 hour grainfed beef chillier cycle, which runs 3 times per week with the fans holding the cold carcasses an additional 24 h over the weekend: Fans run at 100 % speed for the first 24 hours of the cycle, but after that fan speed is reduced by 10 % every 3 hours down to 60 %, where the fans are held until the end of the cycle and over the weekend. In that case enter:
run hours 1 (@100 %) = 3 * 24 = 72 h,
run hours 2 (@90 %) = 3 * 3 = 9 h,
run hours 3 (@80 %) = 3 * 3 = 9 h,
run hours 4 (@70 %) = 3 * 3 = 9 h,
run hours 5 (@60 %) = 3 * 7 + 24 = 45 h.
Leave the others blank.

run hour sense check	current run hours per week (100% speed) [h]	speed 1 [%]	run hours per week at speed 1 [h]	speed 2 [%]	run hours per week at speed 2 [h]	speed 3 [%]	run hours per week at speed 3 [h]
current = future	168.0	100%	90.0	70%	30.0	60%	48.0

52 53 54 55

AMPC

ESSENTIALS

LAYING OUT THE FOUNDATION OF AN EFFICIENT PLANT

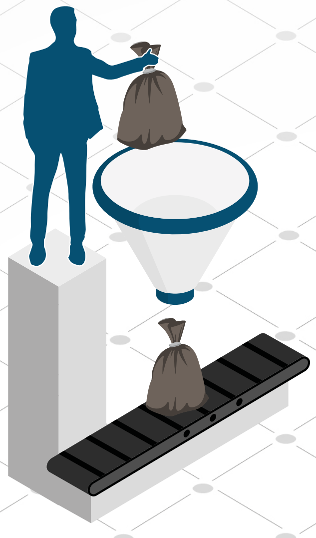
The Essentials cover a range of EEOs that focus on plant stabilisation and bringing your plant into a good running order. Possible issues are resolved, controls enhanced and more efficient ways of operating the equipment used. This includes laying the groundwork to enable you to identify plant issues.These EEOs should be high on your priority list if not already implemented.

CONTROLS & MONITORING UPGRADE

SUMMARY

"Junk in junk out" and "You can only control what you measure"- theses old wisdoms hold true for PLCs and SCADA systems on refrigeration plants.

Ensure the PLC/SCADA system and associated condensers is technologically up to date and accurate as essential pre-cursor to most energy savings opportunities.

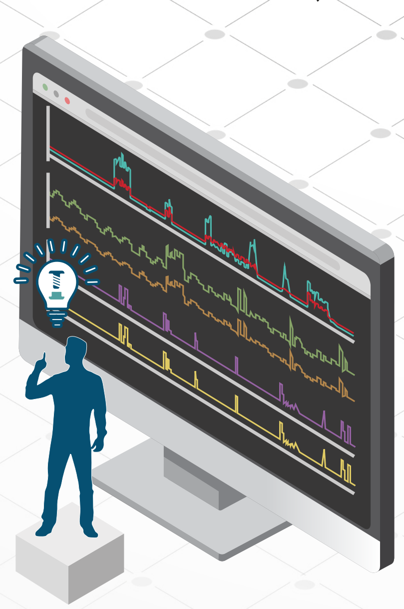


WHICH STEPS NEED TO BE TAKEN?

Upgrade PLC hardware to a current, well-supported model, with available expansion componentry.

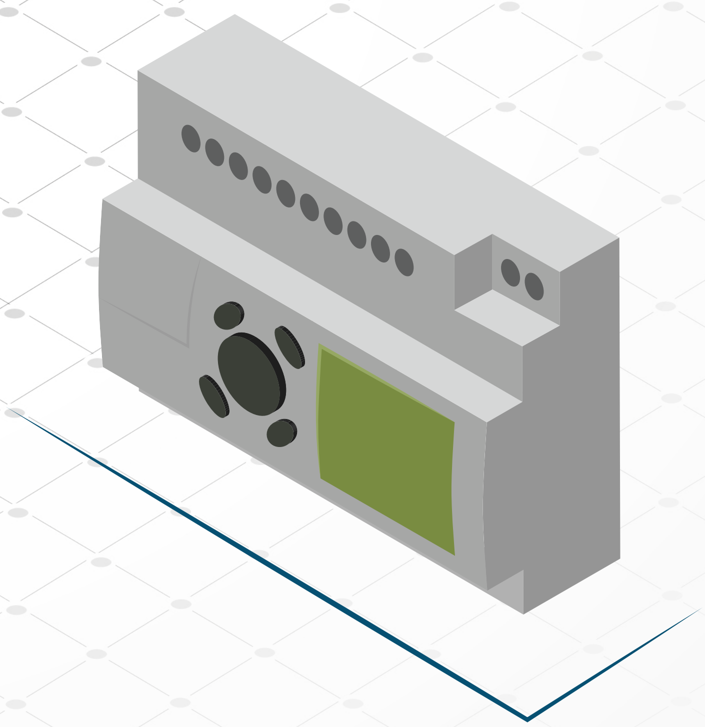
Install enough sensors to fully monitor the plant, including

1. Current transducers on all compressor motors. Alternatively, full power metering per compressor.
2. Slide position transducers on all screw compressors.
3. Ambient temperature and humidity sensor (locate on South side, out of direct sun).
4. Liquid level sensors on all vessels.
5. Pressure transducers on every vessel.
6. Suction/discharge pressure transducers on every compressor and all common dry suction/discharge headers.
7. Discharge temperature sensor on every compressor



Regularly check and calibrate ALL sensors.

1. Liquid level sensors on all vessels.
2. Pressure transducers on every vessel.
3. Suction/discharge pressure transducers on every compressor and all common dry suction/discharge headers.
4. Discharge temperature sensor on every compressor
5. Ambient temperature and humidity sensors



AMPC

PLANT STABILISATION

12

SUMMARY

An unstable plant is difficult to control and to operate efficiently, and many EEOs just do not work well if applied to an unstable plant. This is an essential energy efficiency opportunity.

WHAT DATA/ INFORMATION IS NEEDED?

Identifying unstable plant operation might not be easy.

1. Check compressor currents and compressor loads (slide-valve positions or VSD frequencies/speeds) on the monitoring system (SCADA).
   - Are compressor currents and loads fluctuating heavily? This would be the first sign of an unstable plant. Unstable compressor operation means inefficient compressor operation, therefore the plant must be stabilized.
   - Do compressors turn on and off for short periods? This would be the worst case as big screw compressors as used for industrial refrigeration need some time to start up. During start-up they are mechanically completely unloaded, so they do not contribute to the cooling load at all, while using high start up currents. Short-cycled compressors burn energy without giving anything in return while compressor and motor wear (high start-up currents) are exacerbated.
2. Check suction pressures.
   - Fluctuating compressor operation can almost certainly be traced back to fluctuations in the suction pressure, since compressor control responds to suction pressure. These pressures must be stabilized, if not stable already.
   - Are ending defrosts observable in the suction pressure? You might be able to see small spikes in the suction pressure when a defrost ends. Does this force compressors to respond?
3. Check high stage discharge/head pressure and if available, condenser fan currents and frequency/speed (if equipped with VSD).
   - Is the high stage discharge/head pressure unstable or changes in steps? This might indicate condenser fans which control this are not doing a good job.
   - Are fans constantly ramping up and down? Maybe fan control is good enough to straighten out the pressure fluctuations coming from the compressors. But if fans constantly need to ramp up and down they will use much more energy compared to running steadily.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Stabilizing a plant requires some skill to first recognise what is causing the fluctuations. The most common causes of instability are one / more of the following:

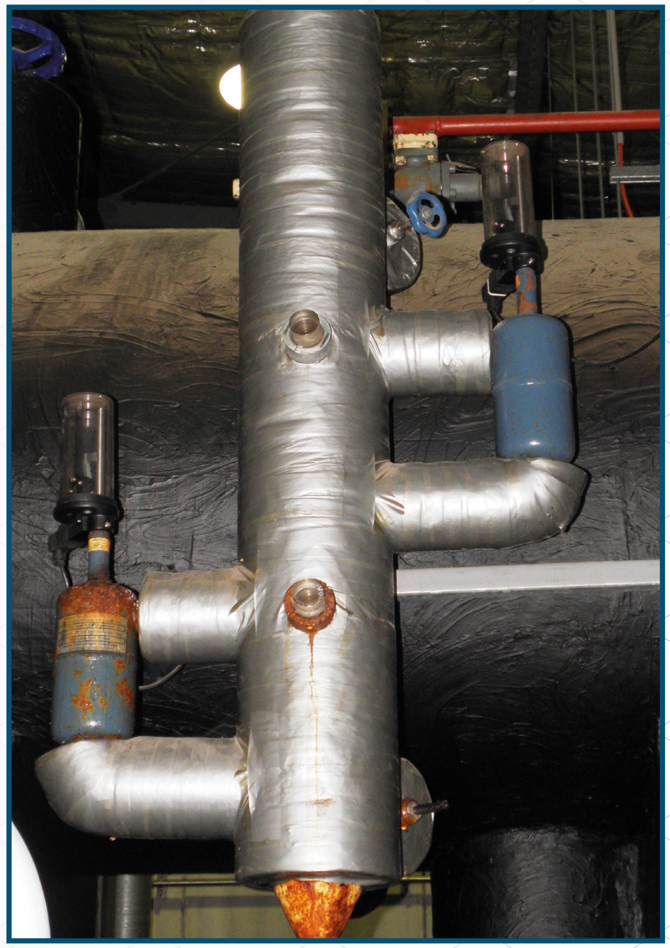
1. On/Off operation of condenser fans. This will cause a step change in condensing pressure, which in turn affect compressor capacity, liquid feed rate to vessels, and so on. Fit VSDs to condenser fans (see EEO #14).
2. Pressure regulated (also called blow-through) hot gas defrost of coil heating for carcass reheat. This causes a false load on the high stage compressors, causing these to load up, then drop off when defrost terminates. (See EEOs #21 & #29)
3. Defrost relief to the low stage compressors aggravates the destabilising effect of pressure regulated defrost, as both the low stage and the high stage compressor are forced to respond. (See EEO #28)
4. On/Off liquid feed to vessels (low stage accumulators, intercooler and economiser vessels) will cause sudden flash gas feed to the compressor (causing them to load up) followed by a stop of flash gas, causing the compressors to then unload again. (see EEO#3)
5. Insensitive or overly sensitive controls that cause the PLC to respond to quickly or slowly to load changes. Review the PID (proportional / integral / differential) control settings on suction and discharge pressure control loops, and also on the temperature control loops of major plant cooling loads. Pure proportional control without integral or differential component will cause continuous fluctuations, for example. Compressor speed control via VSD is much quicker, more responsive and more sensitive compared to slide-valve unloading (see EEO #15).

There may also be other harder-to-spot destabilizing effects that may require some observation of plant trend line to identify.

VESSEL LIQUID LEVEL CONTROL

13

SUMMARY



When liquid is fed into the intercooler or low side accumulator, flash-gas is generated which creates a load on the respective compressor. Intermittent filling, such as caused by the old-style vessel filling controls, causes load and unload cycles that can destabilize the entire refrigeration plant, raising energy use and complicating automatic control logic.

High/Low level switch control

WHAT DATA/ INFORMATION IS NEEDED?

Identifying unstable plant operation might not be easy.

1. Check liquid filling controls on all vessels.

   - Are there still old-style vessel filling controls in place? High/low level switches are an easy indication but even modern level sensors might be used in simple high/low level controls which fully open or shut the feed-valve. Make sure this is not the case.

2. Check suction pressures and if available vessel liquid levels on the monitoring system.

   - Look if suction pressure fluctuations coincide with changes in liquid levels. Does suction pressure rise shortly after liquid in a vessel is topped up? This destabilizing effect should be more pronounced at lower cooling loads. Check night-time and weekends especially.
   - If you can trace back suction pressure fluctuations to liquid level control, it is a good indication for less ideal vessel liquid control which needs to be resolved.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Upgrading from old-style intermittent feed control to modern proportional feed control can be done in two ways:

Valve upgrade

- Retrofit a suitable level sensor to provide a 0-100% level indication on the PLC. This can be done either with a level sensor fitted to the signal column, or using a differential pressure sensor to measure liquid pressure at the bottom of the vessel.
- Upgrade the solenoid + hand-regulating valve control arrangement (On/Off) with a modulating control valve that can be set to any feed ration between 0% to 100% via a signal from the PLC.

Proportional band control

- Retain the existing high and low level switch + solenoid valve arrangement
- Reprogram the control of the solenoid valve so that it opens for a part of a 15-30 second control cycle (for example 5 seconds open every 15 seconds).
- Whenever the liquid level reaches the High level, reduce the open time (e.g. reduce to 3 seconds per 15 seconds)
- Whenever the liquid level reaches the Low level, increase the open time (e.g. increase back to 5 seconds per 15 seconds).
- This control results in a quasi-steady feed rate (but a varying liquid level, as before), with much more steady flash gas production.

Modern level sensor

Modern motorised liquid feed valve installation

CONDENSER FAN SPEED CONTROL

SUMMARY

Condenser fans are traditionally cycled on/off in response to load changes. Controlling condenser (and fluid cooler/cooling tower) fans by controlling motor speed, rather than On/Off has immediate energy savings benefits, but also serves to stablize the rest of the refrigeration plant.

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool**. Refer to section C for instructions on how to use the tool and which inputs are needed.

Calculated savings assume all condensers are equipped with VSDs for speed control.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Install VSDs on ALL condenser fans to meet electrical requirements (filters, shielded cable, etc). These could be either a single VSD per condensers (one VSD serving multiple fans) or a VSD per fan.

Interface each VSD to the PLC, either via digital interface or analog signal so that % speed signal can be given by PLC.

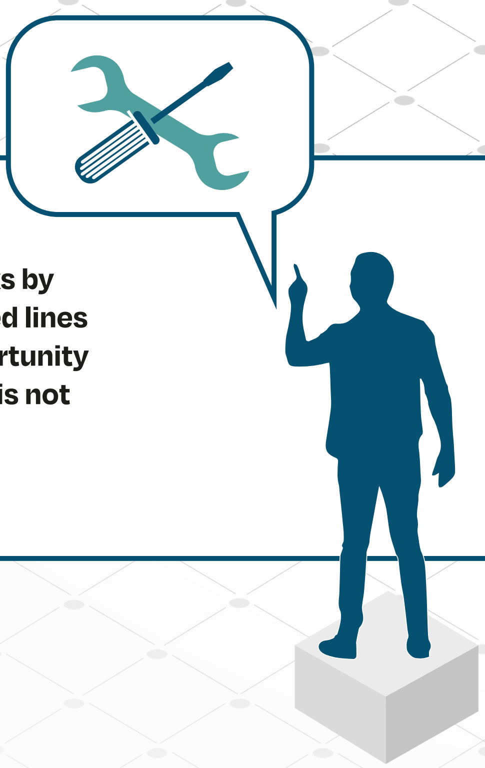
Calibrate maximum VSD speed to suit specific condenser efficiency (see Opportunity #23). Some inefficient condensers may be limited to run <50Hz at 100% to improve overall condenser fan energy efficiency.

Program PLC to operate ALL condenser fans in parallel from min to 100% speed. Note that 100% speed can be <50Hz on inefficient condensers and it may be necessary (especially if condenser capacity is know to be marginal) to program a high summer mode that speeds up inefficient condenser to 50Hz only when target head pressure setpoint is exceeded during hot weather.

If minimum head pressure limitations exist, it MAY be necessary to program fan staging at minimum fan speed to control head pressure >minimum during cold winter weather. See Note below

Note: Some bottlenecks may limit the minimum head pressure that a plant can operate on. These include:

1. Too low oil feed pressures on screw compressors
2. Poor oil separator efficacy on screw compressors at low discharge pressure
3. Too low liquid feed pressure from receiver.
4. Need for higher pressures during hot gas defrost.



It is important to resolve these bottlenecks by upgrading the compressor units, liquid feed lines and using hot gas compressors (see Opportunity #20) so that the minimum head pressure is not limited at any time.

AMPC

15

COMPRESSOR SPEED CONTROL & STAGING

SUMMARY

Screw compressors are notorious energy wasters if unloaded mechanically (by slide-valve). Fitting a variable speed drive to a screw compressor improves the efficiency substantially and even offer the opportunity to overspeed the compressor and gain additional capacity, efficiently.

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool**. Refer to section C for instructions on how to use the tool and which inputs are needed.

Calculated savings assume all energy losses due to mechanical unloading are avoided with the help of compressor speed control. Meaning all compressors run mechanically fully loaded with one or more compressors modulating the load via VSD/speed control. This does not include potential additional savings form avoiding on/off cycling and its associated high start-up currents, which would be added on top of this number.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Install VSDs on at least the largest suitable compressor in every stage (High and Low). In some instances, two compressors per stage may require VSDs to ensure enough capacity overlap with lag compressors.

Consider if operation at 60Hz is desirable and upgrade compressor motor if necessary. Often a higher speed can be achieved even with existing motors as these are generally slightly oversized.

Size VSD generously to cope with highest current draw possible from motor.

Fit VSDs to meet electrical requirements (filters, shielded cable, etc).

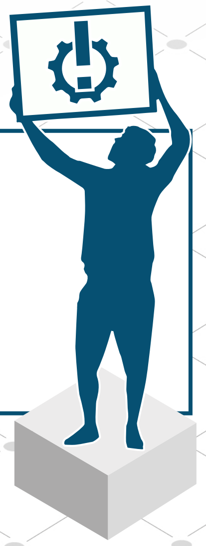
Interface each VSD to the PLC, either via digital interface or analog signal so that % speed signal can be given by PLC.

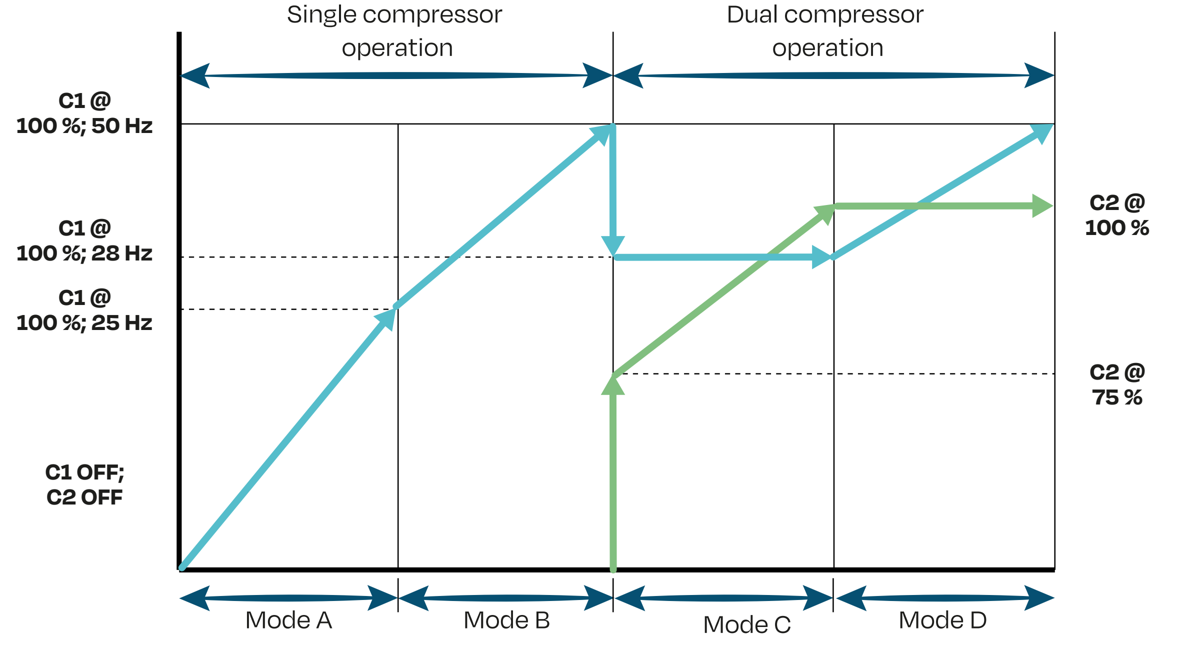
15

Program PLC to operate the speed-controlled compressors as lead machines, using the speed control to regulate the respective suction pressures. Add in (or drop) additional compressors as needed to prevent the compressor from operating at full (or minimum) speed for extended periods. Refer to Note below regarding current limit control option.

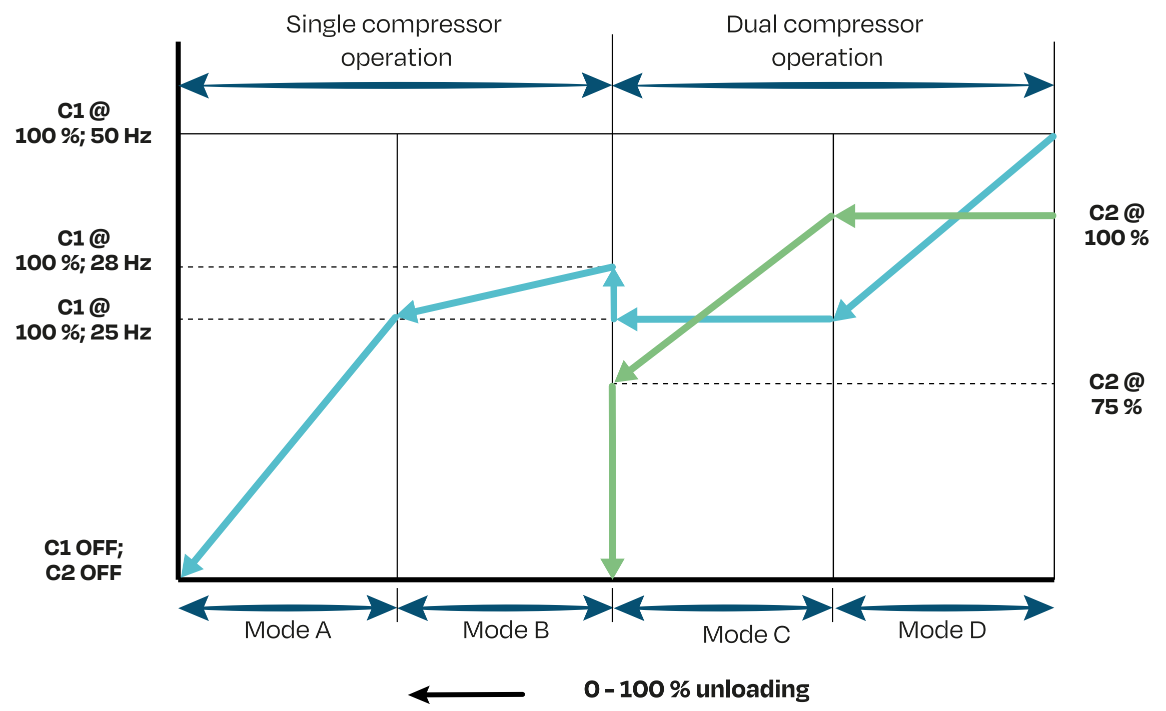
Ensure that a suitable hysteresis is programmed into the control logic to prevent compressor cycling and ensure rotation of lag machines.

Note: If variable head pressure control (see Opportunity #25) is implemented, lead High Stage Compressors can at times be operated at high speed (>50 Hz) due to reduced power draw. This will require a more sophisticated speed control logic that responds to maximum motor current, but this may further improve energy savings.





Example of two compressor speed control & staging logic - loading (C1 w/ VSD, C2 w/o; slide-position in %; frequency/speed in Hz)



Example of two-compressor speed control and staging logic - unloading

Example of large VSD used for screw compressor speed control (Rockwell Automation Powerflex 700L AC Drive)

AIR & WATER REMOVAL

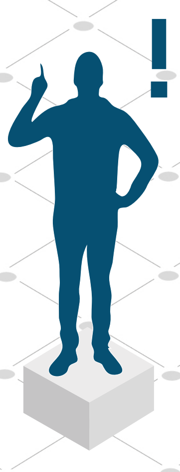
16

SUMMARY

Removal of air and water from ammonia systems is needed to maintain condenser performance (air) and low temperature performance (water).

WHAT DATA/INFORMATION IS NEEDED?

- Air and water generally enter the system either during major service works or when low stage compressor shaft seals or other devices develop a leak. Some operator action will be required after any such event.
- As a rule, if low side suction pressures are not lower than -30 °C, the risk of a leak causing air/water ingress is low because system pressure are then above atmospheric pressure. For this reason, Suction Pressure Optimisation (Opportunity #26) allowing low suction pressure to be raised above -30 °C can be very beneficial.
- Regular (annual) testing of water content in the liquid ammonia in all low-side accumulators is recommended. If water content >200ppm is identified, action is required to remove the water.
- A useful additional indicator is the presence of water in oil drained from low accumulators. If any water is found in the oil pot, additional water testing is recommended.



IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Water and air removal is best managed using suitable air and water removal systems that are commercially available:

- Single point air purgers (Hansen, Grasso, Armstrong) are widely used.
- Upgrading to Multi-point purging is highly recommended in conjunction with PLC-controlled purge control solenoids to ensure that purging is done alternately at all accumulation points on the system.
- Water purgers (also called Anhydrators) are used to remove water from the low-pressure accumulators and are highly recommended for plants operating at <-30 °C.

AMPC

Air removal well done

OIL INJECTION OPTIMISATION

17

SUMMARY

Incorrectly adjusted oil injection on screw compressors can lead to excessive power use.

WHAT DATA/ INFORMATION IS NEEDED?

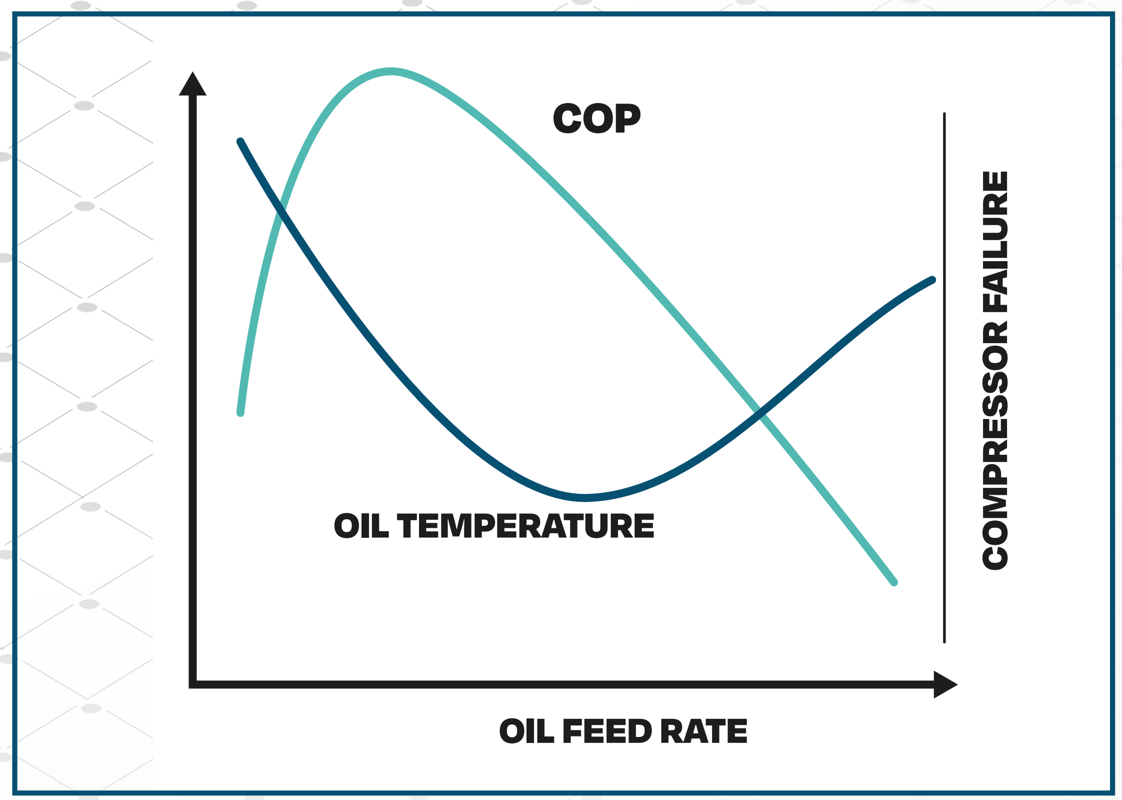
- Oil flow rate to the injection port cannot be measured directly and the effect of oil injection must be observed indirectly. Both over- and under-supply of oil will cause the compressor discharge temperature to increase, for different reasons (see Guidebook for more explanation).
- Oil injection optimisation therefore requires the measurement of the compressor discharge temperature, ideally via a permanently installed, calibrated temperature sensor with values displayed on the SCADA (See Opportunity #11) but alternatively with a hand-held sensor.

AMPC

- Simultaneous measurement or observation of compressor current draw during adjustment is recommended.
- There are different schools of thought as to the correct process to adjust oil injection valves – either to achieve a set temperature (50 °C for low stage and 70 °C for high stage compressors, for example), or by finding the flow rate that gives the minimum temperature.

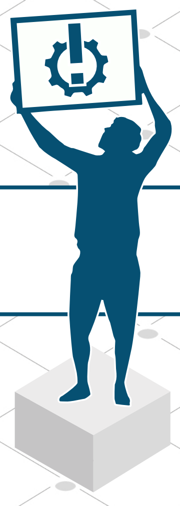
IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

No further hardware than is typically supplied with every screw compressoris required as hand-held temperature and motor current sensors can be used during the adjustment is recommended.



Indicative relationship between oil feed rate, oil temperature and efficiency (COP)

- Ensure the compressor is running fully loaded at full speed and at stable suction/discharge conditions.
- First reduce the oil flow before then increasing.
- Observe both motor current and discharge temperature whilst adjusting.
- Set the flow to the lowest oil temperature that does NOT cause motor current to rise. Err on the low injection flow side if the compressor is speed controlled as oil flow will be relatively higher during low speed operation.
- If possible, recheck the oil injection setting at compressor minimum speed. It may be necessary to accept a compromise setting.



Consult with the compressor supplier on any additional guidance for the specific model used.

HARD YARDS

BIG INVESTMENTS,
BIG RETURNS

The Hard Yards cover a range of EEOs that mostly focus on replacing inefficient hardware and processes with better more efficient ones. Lost efficiency on old worn equipment is retrieved and bottle necks of an aging plant which are holding it back are stamped out. These are bigger investments that require new hardware and labour to put it in. These are the Hard Yards you have to fight for but that have the potential to give you major savings and let you do giant leaps towards your ultimate goal of a highly efficient plant.

SUCTION FLOW METERS

18

SUMMARY

Flow meters in every dry suction header (High stage, low stage and high stage economiser (if installed)) allows the accurate calculation of compressor wear at any time, by comparing the actual mass flow rate (= refrigeration capacity) with the expected mass flow rate for the compressors at their current load state. For example, if the fully loaded compressor is supposed to provide 500kWR at the current operating conditions, but the flow meters only pick up the equivalent of 400kWR, then the compressors are 20% worn.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Flow meters that employ the hydrodynamic principle (e.g. Veris Verabar) are proven for use with ammonia vapour and are very accurate.

- Fitting the hydrodynamic sensors to a dry suction lines requires that a penetration is cut into the pipe and a pipe stub fitted to mount the sensor.
- The sensor is then fitted through this stub and secured with a screw fitting.
- It is recommended that pressure and temperature sensors are fitted with the flow meter as one assembly.
- Connect the sensors signals to PLC input cards and calibrate/scale the signals as per manufacturers instruction.

Further steps:

- Program PLC to trend actual mass flow in each suction line.
- Program PLC to calculated expected mass flow rate from current compressor load state.
- Program PLC to trend ration of actual to expect mass flow. If less than 1.0 this indicates compressor wear on one or more of the operating compressors.

AMPC

COMPRESSOR BLOCK REPLACEMENT

19

SUMMARY

Worn screw compressors lose efficiency by gas leakage within the compressor. Consider the economics of either a full compressor block replacement or a full rebuild (to include rebore and retipping) to re-instate efficiency levels.

WHAT DATA/ INFORMATION IS NEEDED?

- It is not possible to determine the wear condition of a screw compressor through external examination only. Measuring the actual volume of flow at given suction conditions and comparing that to expected/theoretical flow rate is the most reliable method, but requires the prior installation of suction flow meters. Dismantling and then measuring rotor, bore and tip clearances and comparing to manufacturers specifications is possible but obviously requires the removal of the compressor to a workshop. This should be done when compressor wear is expected or a major overhaul of the compressor is scheduled.

- Once removed and rotors and housing are available for inspection, the presence of damage (scoring of rotor bores or slide, wear or breakage of rotor tips) can be observed.

- Possible savings for this EEO can be calculated using the **Calculation Tool** with compressor wear estimates based on age. Without measuring compressor wear with the help of suction flow meters (see EEO #18) this is an indication only. Refer to section C for instructions on how to use the tool and which inputs are needed.

- Calculated savings assume all energy losses due to estimated efficiency loss from compressor wear are avoided with new unworn compressor blocks. This result depends on the plant's operation (load and run hours of each compressor) and is larger, if worn compressors run a lot. Check out "Compressor Results" for a breakdown by compressor. The latter might give you an indication, if you should rearrange the compressor staging sequence and run worn compressors less.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Compressor block replacement (like-for-like) to be done by qualified technician to established service procedures – isolate, vent ammonia, disassembled and remove, replace, reassemble, recommission.

If the compressor is to be re-built, it is recommended to:

1. Record current suction flow rates together with operating suction and discharge pressures and motor currents prior to compressor removal.
2. Visually assess condition of compressor housing, slide valve and rotors. Do not progress with rebuild unless these are in good condition or can be refurbished. Obtain guarantee of rebuild efficiency from contractor.
3. Refurbish and re-instate compressor.
4. Check suction flow rates with operating conditions after recommissioning. Compare to conditions prior to refurbishment and new conditions (as per manufacturer software).
5. Replace compressor block if refurbishment has not achieved substantial re-establishment of compressor efficiency.

DEDICATED HOT GAS COMPRESSOR

20

SUMMARY

By fitting one or more compressors with on/off discharge pressure regulators, high hot gas pressures needed for defrost or re-heat can be achieved without lifting the discharge pressure of the entire refrigeration plant.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool**. Refer to section C for instructions on how to use the tool and which inputs are needed.
- Calculated savings assume all high stage compressors which were not designated as hot gas compressors permanently run at reduced discharge pressure instead of permanently running at the current high stage discharge pressure, assuming the latter is maintained higher because of hot gas needs. Compressors which were designated as hot gas compressors are assumed to keep running at the current high stage discharge pressure for as many hours per day as specified by the inputs. All other hours they also run at reduced discharge pressure.

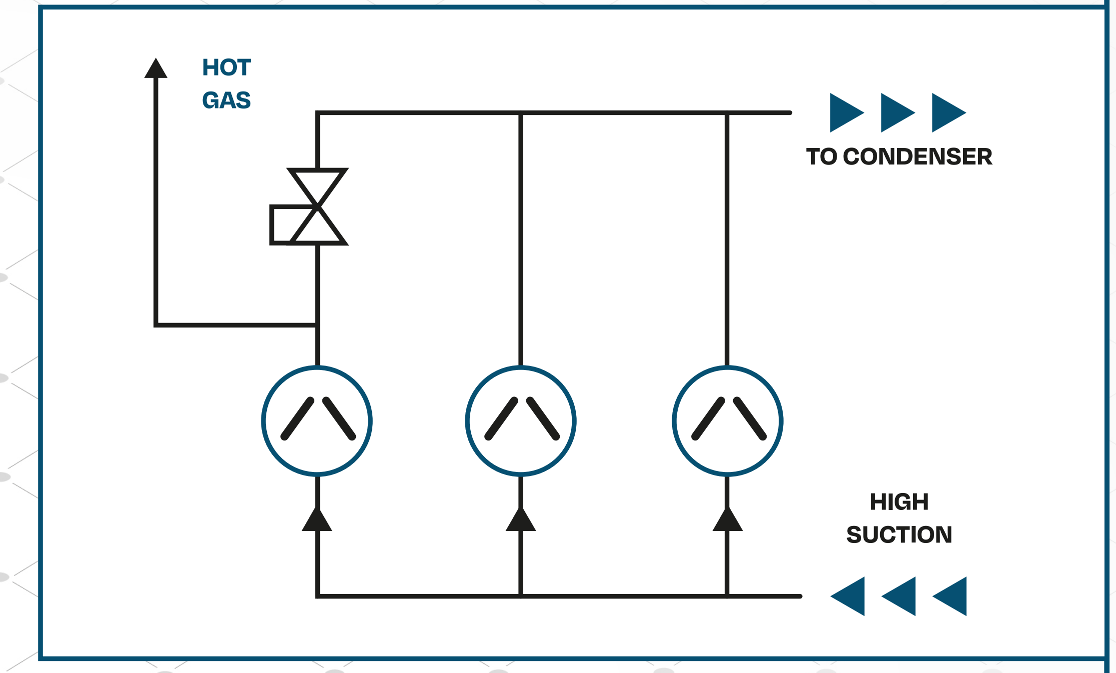
IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

In addition to the control system (see EEO #11), implementing a dedicated hot gas compressor requires:

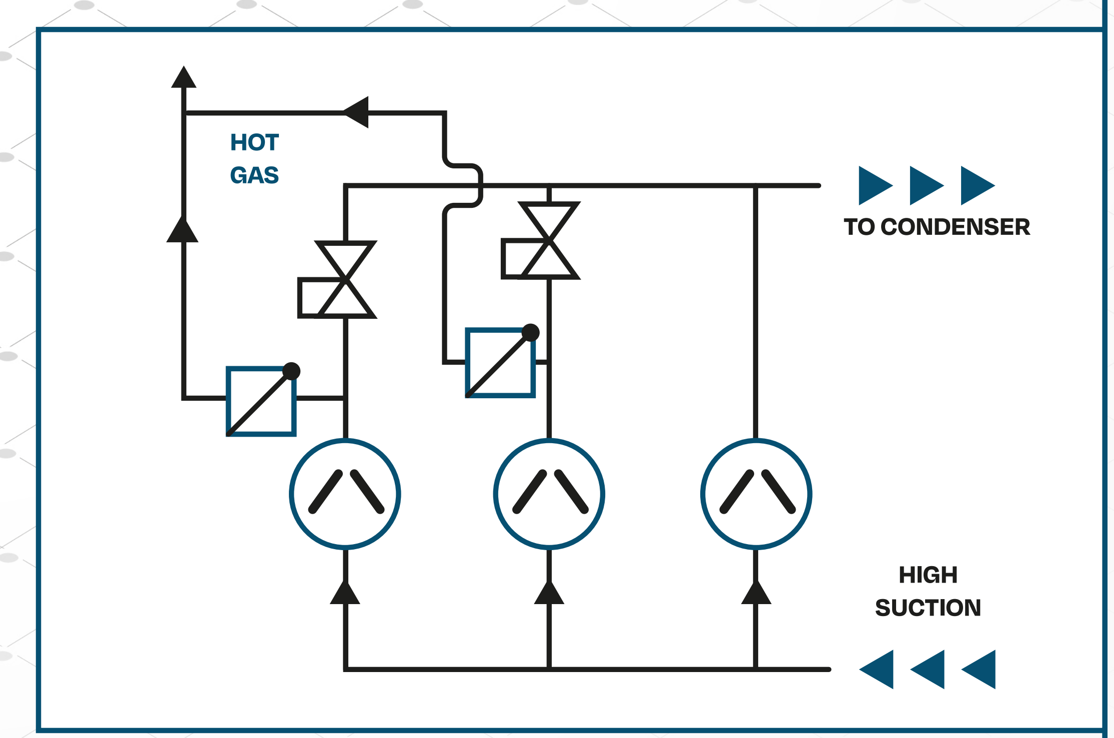
- Fitting a discharge pressure regulator valve with wide-open function actuated via a solenoid, to the chosen compressor.
- Reconnect the supply of hot gas to a point upstream of the pressure regulator.
- If multiple compressors are selected to serve as hot gas compressors, add check valves to the discharge feed lines to prevent high pressure gas passing back to compressors not operating at high pressure.
- Program the PLC controls to ensure that the preferred hot gas compressor is running and the regulator valve activated a few minutes prior to the commencement of any hot gas process, and de-activated once the defrost is concluded.

AMPC

Single hot gas compressor



Multiple hot gas compressors

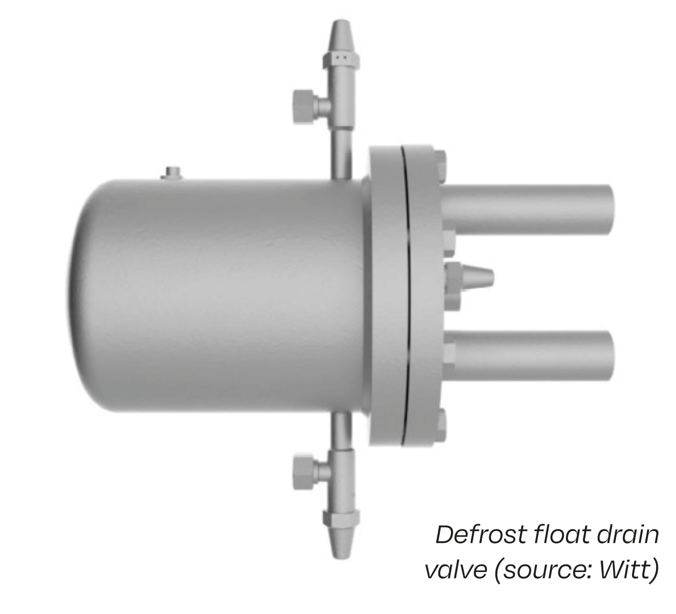


HOT GAS
FLOAT VALVES

21

SUMMARY

Conventional pressure regulated or "blow-through" hot gas defrost when used to reheat rooms causes a significant false-load and hence energy penalty on refrigeration plants. Using defrost drain valves avoids the bypassing of gas to the compressors and accelerates defrost and reheat.



Defrost float drain valve (source: Witt)

WHAT DATA/ INFORMATION IS NEEDED?

Although the energy savings are likely to be significant, monitoring and analysisis required to estimate energy savings in every case. Conversion of evaporatorsto float defrost drain valves is likely to be more energy efficient whenever:

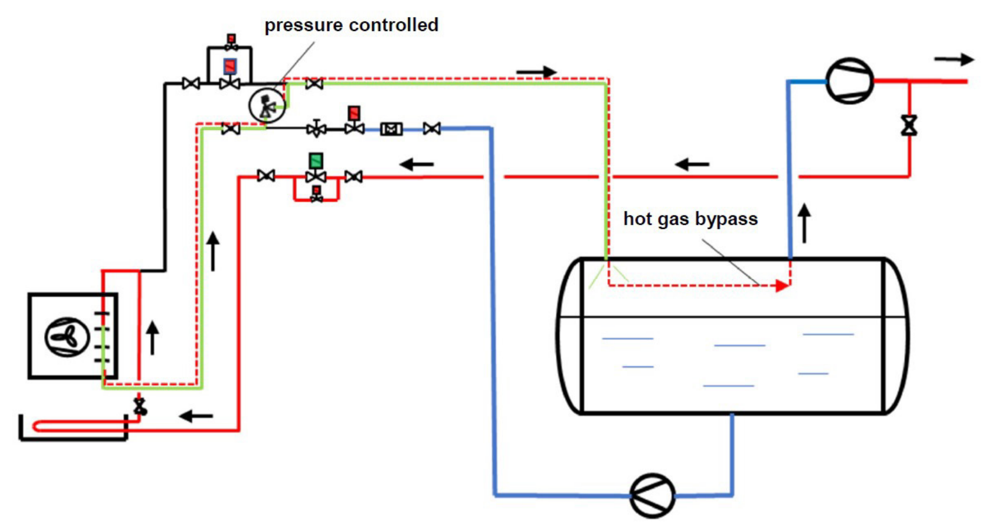
1. Frequent hot gas reheat is conducted on carcass chillers to soften carcasses prior to boning.
2. Hot gas defrost is used on freezer or chiller room evaporators (as opposed to water defrost).

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Conversion of existing "blow-through" defrost arrangements require reconfiguration of the defrost valve arrangement as per the valve arrangements below (source: Witt):

Conventional "Blow through" valve arrangement

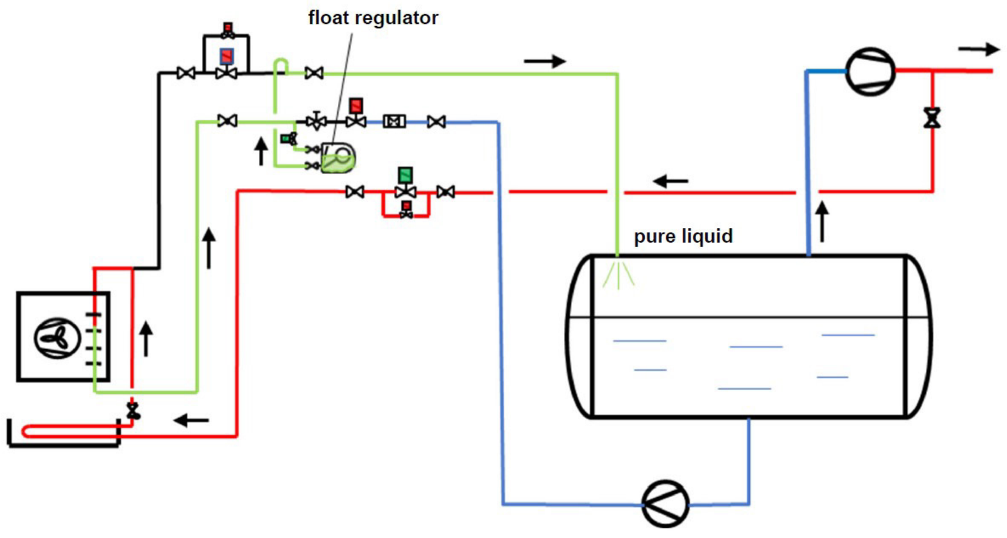


source: WITT

When the set pressure is achieved within the evaporator, liquid AND vapour is then relieved back to the return suction line.

Alternative valve arrangement with defrost drain (float valve).

The float drain valve arrangement comprises typically the float drain valve and a solenoid valve that opens on commencement of defrost.



source: WITT

Generally the conversion to float drain for hot gas control requires:

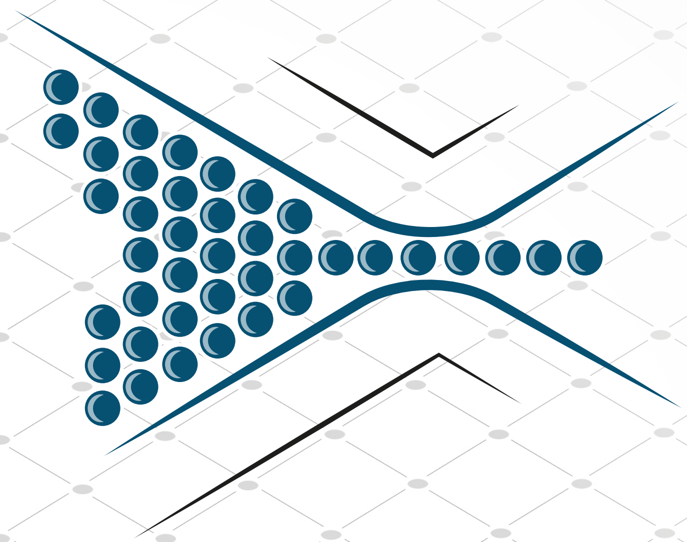
1. **Removal of the pressure relief regulator.**
2. **Installation of defrost float drain valve set to the bottom of the coil.**
3. **Reprogram PLC controls to suit the alternative mechanism.**

Note: Details of changes to valve arrangements will require the input of a competent refrigeration design engineer.

BOTTLENECK REMOVAL

SUMMARY

Bottle necks of all sorts may keep the plant from running more efficient. Identifying them is not always an easy task. Some of the bottle necks more commonly found in older industrial plants are presented in the following pages along with information on how they should be addressed.



WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool and which inputs are needed.

The savings in this case are not titled "Bottle Neck Removal" after this EEO, but "High Stage Suction Pressure Increase" and "Low Stage Suction Pressure Increase". The tool allows to calculate savings for the entire respective stage (after all inputs for all compressors in that stage have been made), after a bottle neck is removed so that suction pressure can be increased.

Calculated savings assume all low or high stage compressors (depending on where the bottle neck is removed) permanently run at raised suction pressure instead of the current suction pressure.

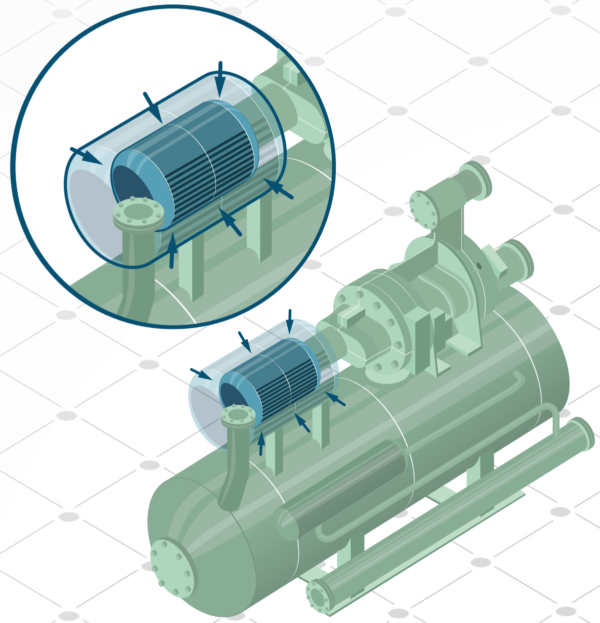
UNDERSIZED COMPRESSOR MOTORS

22.1

SUMMARY

If a compressor is fitted with a too-small motor, it cannot operate fully loaded at higher discharge pressures. This limits the plant operating range and may cause inefficient compressor operation by forcing compressors to unload in order to reduce motor current.

Undersized motor upgrade is another important plant stabilisation measure as forced-unloading of compressors (which may cause another compressor to start up) is avoided.



Undersized motors should be addressed at an early stage, irrespective of any other upgrade work

WHAT DATA/ INFORMATION IS NEEDED?

- Understanding the currents drawn on all compressor motors is important, and therefore having current transducers on all compressors with values visible via SCADA is an important first step towards understanding/identifying any motor current restrictions.
- Compare observed current draw to the motor nameplate currents and ensure that the protection devices are correctly rated.
- Under what conditions do motor currents begin to approach name-plate maximums? Are these conditions caused by other site problems (e.g. undersized condensers, see EEO #22.3).
- Are there other conditions that are raising compressor energy use above expectations? Excessive oil feed to screw compressors can be the cause and should be checked (see EEO #17).

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

- If high motor currents cannot be avoided by other means (condenser upgrade, oil injection optimisation, etc) a motor upgrade is required:
- Select a suitable motor capacity to suit the actual conditions. Often this is just one size up from the current motor size.
- Check motor frame details to check what modifications (if any) are required to the motor supports or drive couplings.
- Upgrade motor electric cable and overloads/contactors if required.

Ensure that any replacement motor is high efficiency (see EEO #27) and is suited for VSD operation if the compressor is selected for lead operation during compressor staging (see EEO #15)

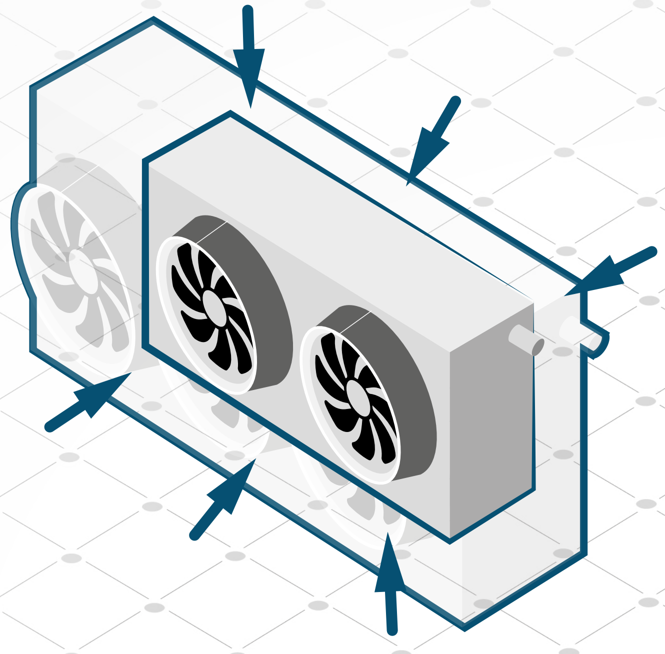
AMPC

UNDERSIZED EVAPORATORS

22.2

SUMMARY

Undersized room evaporators can cause compressors to operate at lower suction pressure than needed. This is a classic bottleneck.



Checking for undersized room evaporators is an important first stage during energy efficiency improvement.

WHAT DATA/ INFORMATION IS NEEDED?

Undersized evaporators need to operate at too-high temperature difference to maintain room temperature. The easiest way to identify if an evaporator requires a too-high temperature difference, is to start raising the system suction pressure (see EEO #26). Those rooms with undersized evaporators will be the first to show signs of loss of temperature control.

Once the problematic rooms are identified, proceed as follows:

1. Check the suction pressure at each evaporator. The corresponding saturated vapour temperature should not be more than 2-3 °C higher than the corresponding vessel as this may indicate a different problem such as undersized suction lines or valves (see EEO #22.4)

2. If the suction pressure at the evaporator is OK and similar to the suction pressure at other evaporators on the same suction level, then the issue is most likely do to an undersized evaporator. A generoulsy sized evaporator should be able to maintain room temperature <5 °C above the respective suction pressure. In other words, with -10 °C suction the evaporator should be able to hold a room temperature of -5 °C unless undersized.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once the undersized evaporator has been identified it becomes and engineering exercise to select a replacement unit to better suit the room conditions. This can be done in several ways, or a combination:

1. If known, assess the original design conditions of the undersized coil to scale the actual capacity required. For example, if the original coils was selected for say 100kW and a temperature difference (LMTD) of 5K, but it now needs to operate at 8K to hold room temperature, then the coil should be replaced with a 8/5 x 100 = 130kW coil.

NOTE: Check the physical condition of the evaporator coil to ensure that is has not degraded over time. A degraded coil may appear undersized!

2. Alternatively, if the room operating and load conditions are well known, re-calculate the load to determine a better design capacity.

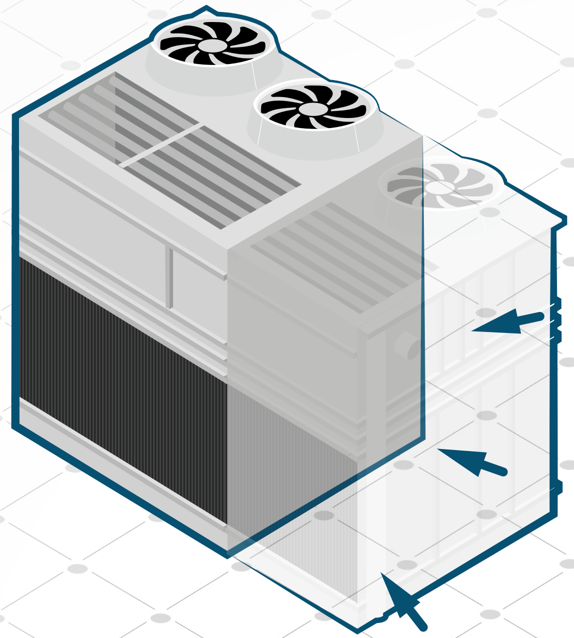
3. If possible, do both 1) and 2) to check that the results align, for added confidence.

4. Ensure that the replacement coil is well suited to the application in terms of dimensions, defrost method, etc. Use this opportunity to purchase a coil with speed controlled fans (see EEO #24) and with defrost termination sensors (see EEO #30).

5. Purchase the new coil and replace as per normal practice.

UNDERSIZED CONDENSERS

22.3



SUMMARY

Undersized condensers can cause the high side compressors to operate at excessively high discharge pressure during high plant loads. This is a classic bottleneck.

Checking for undersized condensers is an important first stage during energy efficiency improvement.

WHAT DATA/ INFORMATION IS NEEDED?

This is also an engineering and service exercise to determine the condenser deficit and select a replacement or additional condenser to obtain the required condensing capacity.

It is important to conduct some observations ideally during full load (or near full-load) plant operation (which may be easily done if a well instrumented PLC/SCADA systems is available see EEO #11) as follows:

1. Observe or record the load state of all operating high stage compressors, noting model, slide position and speed.
2. Also note power (amps) drawn
3. Observe or record the operating discharge pressure and ambient wet bulb temperature.
4. Repeat observation several times or over longer periods to improve data accuracy.

Then calculate :

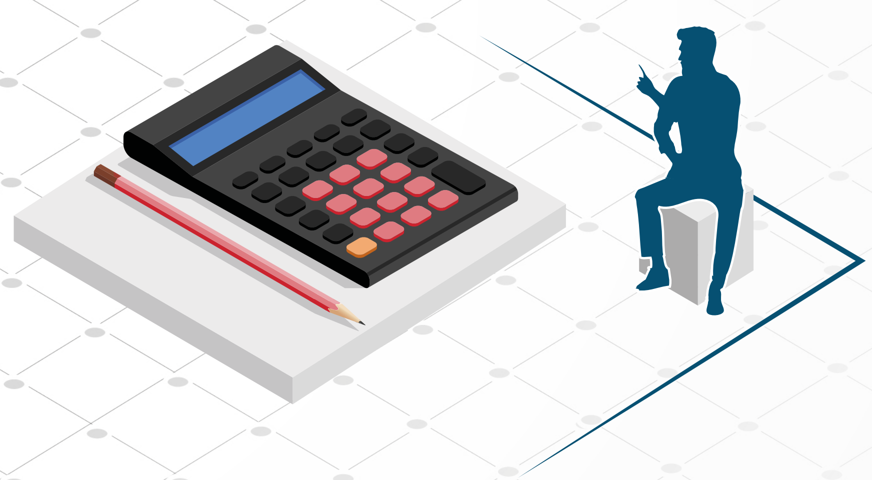
a. The operating condenser temperature difference (= saturated discharge temperature – wet bulb temperature).

b. The total refrigeration capacity (this will require compressor software)

c. The total motor power.

The total condensing capacity = total refrigeration capacity + total motor power.

If (for example), the current condensers are operating at 10K and rejecting 1,000kW, but the condensing pressure is say 4K over design maximum (39 °C instead of 35 °C), then increase condensing capacity to 10/(10-4) x 1,000kW = 1,670kW by installing a further 670kW of condensing. This should reduce condensing temperature to 35 °C under the same ambient and full load conditions as before.



IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once an additional or replacement condenser has been sized, select a suitable model to suit site constraints and preferences. At this time, ensure that an efficient condenser model with a high kWR/kW fan ratio is chosen (refer EEO #23).

Install new/replacement condenser to normal industry procedure. Ensure at this time that all new/replacement condensers are fitted with variable speed fans (see EEO #14).

PRESSURE LOSSES

22.4

SUMMARY

Suction pressure losses cause the compressor suction pressure to be lower than needed, reducing the available compressor capacity and increasing compressor energy use.

They can be caused by the following bottle necks:

1 **LONG WET SUCTION LINES**

- Even if the wet suction lines are correctly sized to suit the load, compressor power is used to transport liquid refrigerant a long way. This is not an efficient process.

2 **WET SUCTION RISERS**

- Lifting liquid refrigerant through unnecessary wet risers causes avoidable suction pressure losses.

3 **HIGH LINE & VALVE PRESSURE LOSSES**

- Undersized refrigerant lines and valves as well as redundant valves cause pressure losses.
- They can also occur in discharge lines, where pressure losses cause the high stage compressors to operate at excessively high discharge pressure during high plant loads.

Example of wet riser installed to overcome a fire wall

These are all classic bottlenecks. Checking for them and resolving them is an important first stage during energy efficiency improvement.

AMPC

WHAT DATA/ INFORMATION IS NEEDED?

Typically, this is an engineering and service exercise to determine the pressure drop between the evaporator and the respective accumulator. Excessive suction pressure drops are easily identified by measuring the pressure at the evaporator (downstream of any control valves on the evaporator) and then comparing this to the pressure in the corresponding accumulator vessel in the plant room (from SCADA).

Well-designed systems should not have more than 2-3 °C in equivalent pressure drop. If the pressure difference is found to exceed 2-3 °C in saturated temperature equivalent, this is probably due to one of the mentioned bottle necks or even a combination of them.

The questions should be asked in two steps:

1 What is the current pressure drop in the suction line that includes the potential bottle neck?

2 Does the pressure at the evaporator need to be as low as it is? This is suction pressure optimisation (see EEO #26).

Discharge line pressure drops between the compressor discharge and the condensers should not be more than 1-2 °C in equivalent pressure drop for well-designed systems.

3 What is the current pressure drop in the discharge line during low and high-load operation? This can be checked via direct measurement (manually) or by observing the pressure readings on the SCADA (if calibrated pressure sensors on each compressor discharge and on condenser inlet are available – refer EEO #11).

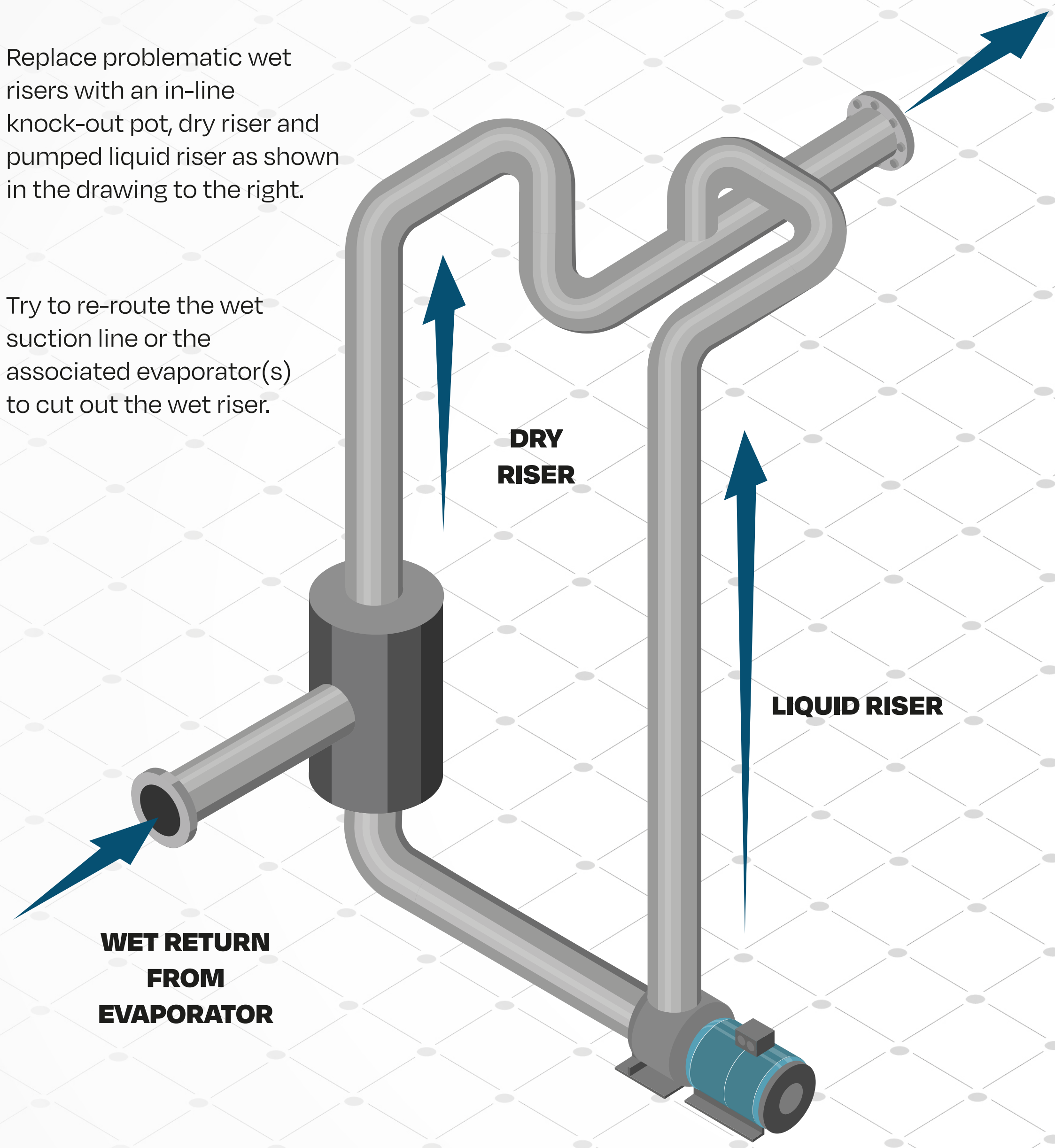
IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

If excessive suction pressure drop is measured (>3 °C) an engineering assessment of the system design is required, which will result in recommendations to fix the problem.

There are several possible and alternative solutions, including:

1. Replace problematic wet risers with an in-line knock-out pot, dry riser and pumped liquid riser as shown in the drawing to the right.

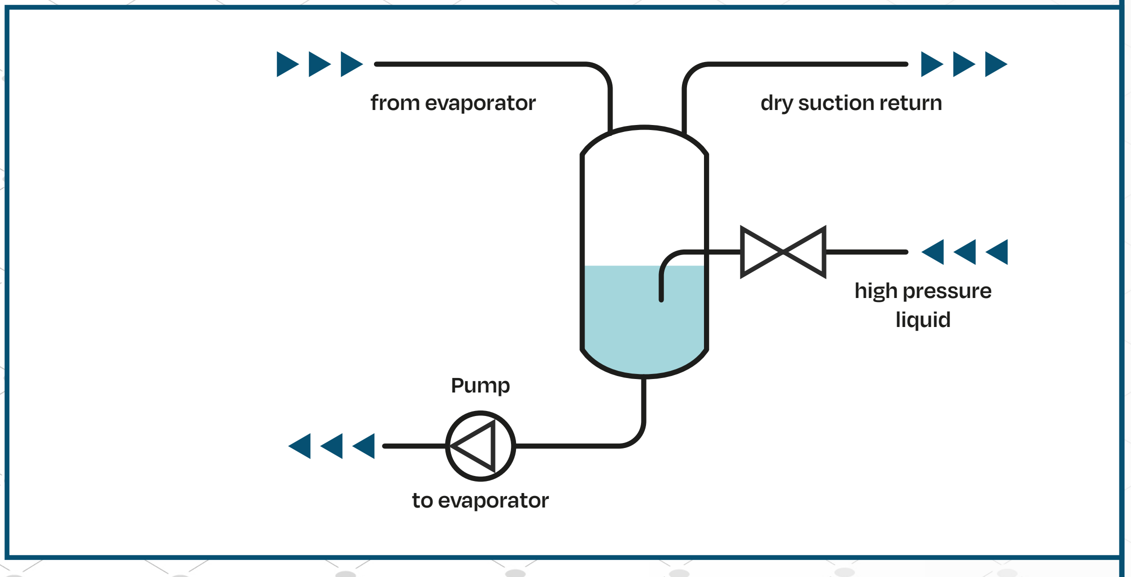
2. Try to re-route the wet suction line or the associated evaporator(s) to cut out the wet riser.



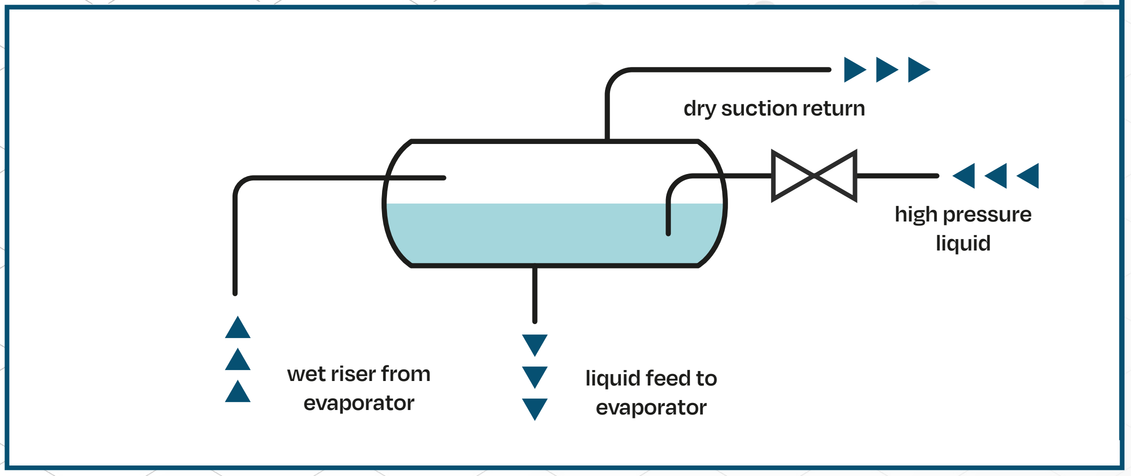
Note: The services of a competent refrigeration design engineer will be required to correctly design the liquid lifting station.

3. Replace excessively long wet suction lines and wet risers with remote separation and liquid return. This can be done in two ways:

a. Install a local pumped accumulator vessel closer to the evaporator with a dry suction return.



b. Convert the evaporator to gravity flooded design with a dry suction return.



If discharge pressure drop is substantially greater during full load, and exceeds 2 °C equivalent, then action is recommended. Up-size existing discharge lines, if these are found to operate at too-high gas velocities. Typically, issues are found with discharge header sizing, but in some cases the discharge lines from individual compressor can be undersized.

CONDENSER UPGRADE

23

SUMMARY

Condensers, even within the product range of a single supplier, vary significantly (in some cases by a factor of 5 (!)) in relation to the amount of fan power use per kW of energy rejected. Inefficient condensers use too much fan energy to reject heat, which severely restricts other energy savings opportunities.

Sites are encouraged to upgrade their condenser farm, not only to avoid an absolute condenser shortfall (see EEO #22.3 - Undersized Condensers), but to install a surplus of condenser capacity in order to gain a further energy efficiency benefit from further lowering condensing pressure during normal operation (see EEO #25).

This surplus capacity then allows the site to derate condenserers identified as inefficient to gain a nett fan power saving.

WHAT DATA/ INFORMATION IS NEEDED?

It is important to understand the relative efficiency of existing condensers already installed on site, as well as to assess the efficiency of any new condensers purchased to replace old condensers or increase total condenser farm capacity. For all existing and any proposed new condensers:

1. Check the rated fan motor power on each condenser and if possible check the full speed power draw for each condenser fan.
2. Obtain the design condenser capacity rating as provided by the supplier.
3. Calculate the amount of condenser capacity per kW of fan power by dividing the condenser capacity (in kW) by the total fan power of that condenser (also in kW). This ratio can vary from around 100kWC/kWf in tropical areas to >200kWC/kWf in dry climates for efficient condensers, but can be as low as 1/5 of that for inefficient models.
4. During weather extremes, which may result in excessive discharge pressures even with all fans operating at the set limits, it may be necessary to override the controls to operate all condensers at full fan speed. This should only be done under exceptional conditions.

AMPC

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once an inefficient condenser has been identified, the energy penalty can be reduced by:

1. Determine the maximum efficient fan speed for the condenser. For example, increasing the condenser efficiency from 50kWC/kWf to 100kWC/kWf requires a reduction of fan power by 50% and therefore fan speed on that condenser will be limited to 80% or 40Hz.
2. Set the maximum fan speed for that condenser to the value calculated above. We shall refer to that as the maximum permissible speed. In other words, the fans for the inefficient condenser referred to above will operate at 40Hz when the PLC calls for 100% fan speed (and not at 50 Hz)
3. Control all condenser fans across their permissible speed range to control head pressure either to fixed head pressure of variable head pressure (see Opportunity #25). Efficient condensers will be permitted to operate to full speed (50Hz), whereas inefficient condensers will be capped to operate at the maximum permissible fan speeds as above.

REFINEMENT

BEST FOR LAST

After laying out the foundation of an efficient plant with the "ESSENTIALS" and overcoming the "HARD YARDS", all the enablers have been unlocked to put the finishing touches onto the refrigeration plant to achieve the objective of a truly energy efficient plant.

AMPC

EVAPORATOR FAN SPEED CONTROL

SUMMARY

Reducing the speed of any fan is a very effective way to cut energy use as only a small speed reduction generates substantial savings. The saving can be increased by 25-30 % through reduced compressor energy, as the compressors no longer needed to work that hard to remove the heat introduced by the fans.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool. Besides the electricity rates, this EEO only requires inputs to be made for 'Sheet: Evaporators'.
- Calculated savings assume evaporator fans are run at different speeds according to inputs made instead of running at full-speed. Savings include direct energy savings from fan motors as well as from reduced heat loads introduced into the cold spaces.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Fan speed control can be implemented in several ways:

1. Replacing fans with Electronically Commutated (EC) Fans. This avoids the need for additional VSDs or shielded cabling but is more costly as retrofit.
2. Fitting VSDs to the existing fan motors, either individually or one VSD per evaporator. Some older fan motors are not suited to variable speed operation, however.
3. Voltage control of smaller (shaded pole) motors which are not suited to VSD retrofit. This is inexpensive but less energy efficient than 1) or 2).

- In addition to implementing a means of speed control, consideration should be given to the following instrumentation:
  - a. Additional room temperature sensors to monitor room temperature uniformity. This is especially useful in larger storage chiller and freezer rooms.
  - b. Access door switches, to detect door movement. Fan speed can be reduced in some cases when doors have been shut for long enough.

AMPC

VARIABLE HEAD PRESSURE CONTROL

SUMMARY

Variable head pressure control reduces the high stage compressor head pressure in response to compressor load state and ambient conditions. During cool weather, even during summer, significant compressor motor energy can be saved.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool. In order to calculate this, inputs for all high stage compressors (load, run hours, max. current) have to be made, as variable head pressure control affects them all.
- Calculated savings assume all high stage compressors run at reduced discharge/head pressures according to weather data from chosen location instead of permanently running at fixed set-point high stage discharge pressure. It is also assumed that condensers have enough capacity to run at an **average** temperature difference of 7 Kelvin. Calculated savings only include reduced compressor consumption. Possible energy penalties, due to higher fan use are neglected, which might reduce actual savings.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once the Enablers (refer to synergies in the guidebook) have been implemented, taking the step to variable head pressure control is a PLC programming exercise only. The actual algorithm referenced below needs to be developed specifically for each combination of high stage compressors, condensers and climatic conditions and cannot be generalized here:

- Calculate actual wet bulb temperature using ambient temperature and humidity sensors.
- Calculate target condensing temperature as function of the current wet bulb temperature and % plant load.
- Control condenser fan speeds to achieve the target condensing pressure setpoint.
- During very cold winter conditions, it may be necessary to cycle some condenser fans OFF to prevent under-speed operation of the fans.

Some known hurdles can occur even with all enablers fully implemented, and will need to be addressed if they arise, including:

- Some compressors (like early Stal units) may show increased oil loss when operated at low discharge pressure.
- In some cases the resultant low discharge compressors may cause lubrication issues if full lubrication pumps are not used.
- Undersized liquid feed lines (supplying liquid ammonia from the high pressure receiver to the intercooler) or associated valves may cause liquid level problems in the intercooler.

AMPC

26

SUCTION PRESSURE OPTIMISATION

SUMMARY

Many plants run fixed suction pressure levels (low and high) regardless of site activity, and very often lower than needed. Progressively raise suction levels generally to the extent possible, and especially during low-load periods.

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool. In order to calculate this, inputs for all compressors (load, run hours, max. current) have to be made, as suction pressure affects them all. Savings from both, a permanent high stage suction pressure increase and a permanent low stage suction pressure increase, can be calculated.
- Calculated savings assume all high/low stage compressors permanently run at raised high/low stage suction pressure instead of the current high/low stage suction pressure. In case of a high stage suction pressure increase, low stage compressors use a bit more energy since they have to compress to this raised pressure, which is accounted for.
- These savings are not labeled "Suction Pressure Optimisation", but "High/Low Stage Suction Pressure Increase". They serve to calculate savings from this EEO and Bottle Neck Removal (EEO #22), as removing bottle necks will allow for suction pressure to be raised/optimized.
- If you wish to calculate savings from a non-permanent suction pressure increase (low-load period optimisation), take the result and multiply it by a factor of:

$$\frac{\textit{hours per week at increased suction pressure}}{\textit{168 hours per week}}$$

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Suction pressure optimisation is a trial and error method requiring some re-programming of suction pressure setpoints to make these time or load dependent rather than permanently fixed.

1. **Maximum daytime suction pressures:**

   Progressively and gradually raise suction pressure setpoints (say 1 °C increase every week per suction level) and observe effect. Identify if any temperature control issues arising are persistent (not only due to temporary operational matters, like doors left open) and local or across multiple cooling points:

   a. If persistent local issues only arise, check if these are due to further unresolved suction bottlenecks (EEO #22) and address these if possible.

   b. If persistent issues arise across multiple cooling points, reduce suction setpoint and check if issues resolved. This then sets the minimum going forward.

2. **Maximum after-hour pressures:**

   Set different and higher suction setpoints for scheduled known low-load periods (e.g. early morning hours weekdays, or Sundays). Follow same process as above to find maximum setpoint that does not cause issues.

3. **Maximum low-load pressures:**

   Set low-load setpoints (these could be identical to the after-hour pressures) that are activated if compressor loads drop below a set load level. This could be useful to automatically cater for events like RDOs and public holidays unless the PLC program can be set up to treat these as Sundays.

EFFICIENT COMPRESSOR MOTORS

SUMMARY

Older model electric motors generally are less efficient than modern high-efficiency motors, and a simple motor replacement can have an immediate energy savings even if no other site changes are undertaken.

Where motors are undersized (see EEO #22.1) motor replacement is an opportunity to address this deficit.

WHAT DATA/INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool. In order to calculate this, inputs for all compressors (load, run hours, max. current) have to be made, along with inputs for efficiencies of old and new replacement motors.

Calculated savings assume all energy needed to drive given compressors is supplied more efficiently by new motors according to inputs. Hence, compressors that run most of the time at high load and therefore use most of the energy, profit most from a more efficient motor. Check Sheet:Compressor Results for a breakdown by compressor. This might give you an indication, which compressors should be equipped with high efficiency motors first and have the shortest pay-backs.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

1. Check motor capacity and frame size (refer motor nameplate) to ensure compatibility.
2. Check new motor to ensure at least F-class insulation and preferably use ceramic bearings if speed control is intended. Consult with motor supplier.
3. Check motor protection gear to ensure compatibility with new motor, especially if the motor is upsized (refer EEO #22.1)
4. Swop old vs new motor according to known good practice, ensuring correct shaft alignment.

DEFROST DRAIN TO HIGH STAGE SUCTION

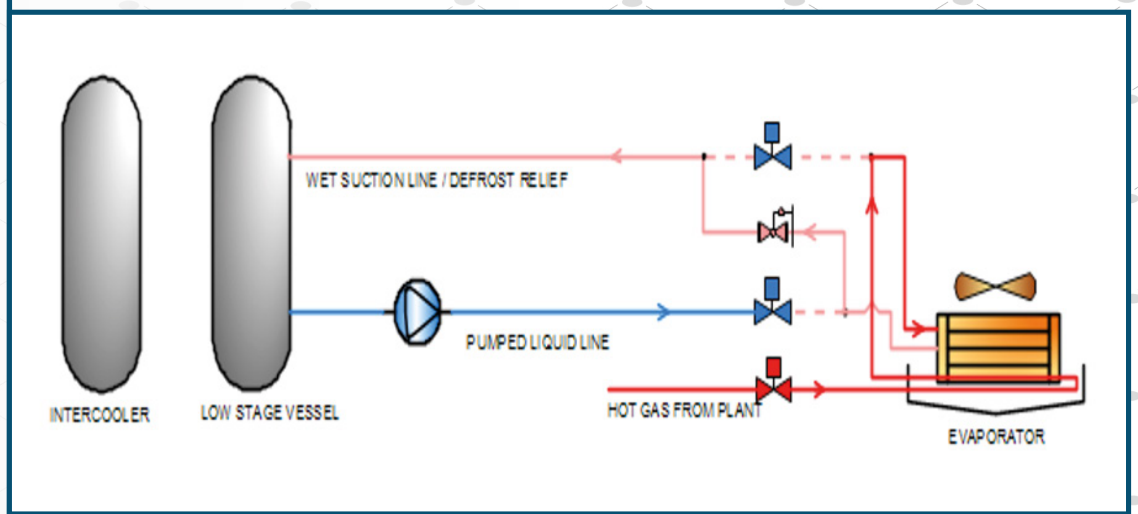
28

SUMMARY

During defrost, accumulated liquid and vapour must be vented from the evaporator to sustain the defrost process. On low stage (freezer) evaporators, this venting is often done to the low suction, causing an additional an unnecessary load on the low side compressors, especially with "blow-through" defrost processes. Diverting the venting to high stage suction saves energy.

WHAT DATA/ INFORMATION IS NEEDED?

- Although energy savings are likely to be significant, significant monitoring and analysis is required to estimate energy savings in every case.
- Review current defrost relief arrangements (consult P&ID). If defrost relief on any low temperature evaporators is into the low suction return, then this opportunity applies.

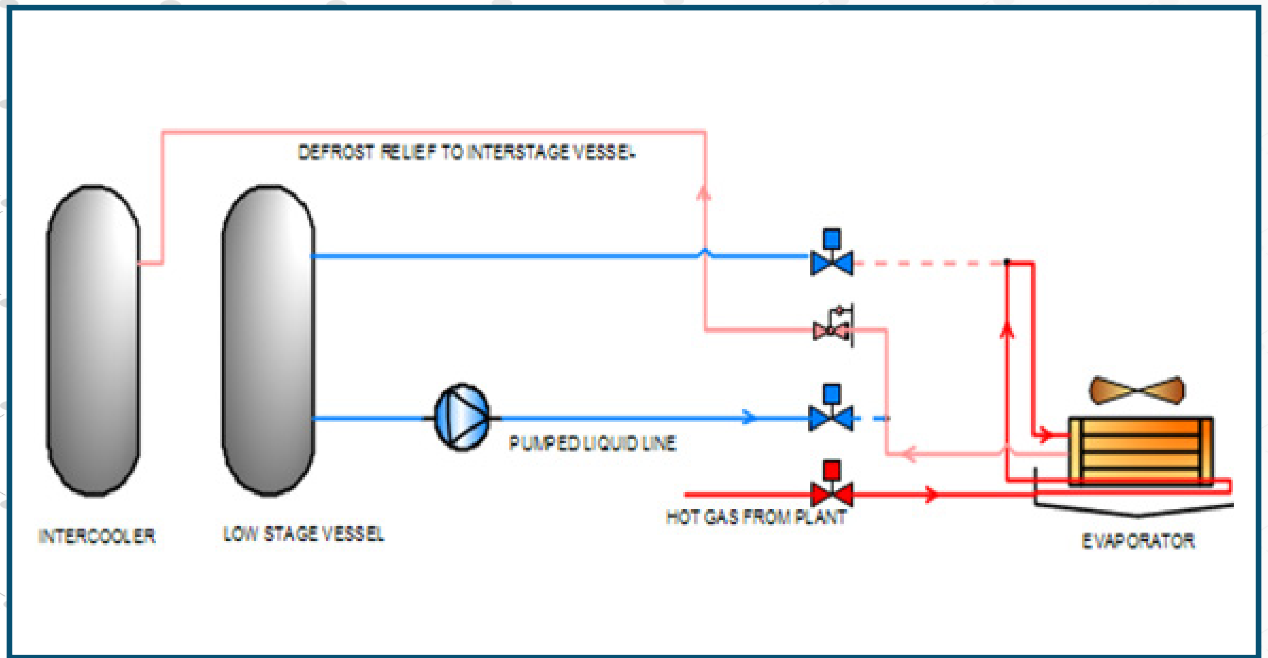


- **Low stage defrost relief into low stage suction**

  Upgrading the defrost relief into high stage suction is likely to be viable unless extensive pipework installation is required to direct the relief to the high stage vessel (intercooler).
- Note that defrost float drain valves (see EEO #21) substantially reduce gas bypass during defrost and partially resolve the requirement for redirecting the defrost vent. However, it is strongly recommended that any upgrade to the use of defrost float drain valves should be combined with redirection of these vent lines to the high side.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

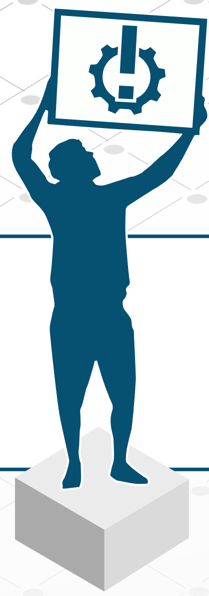
The objective of this opportunity is simple: Redirect all defrost relief to the high stage / Intercooler. In most cases the implementation is a re-plumbing exercise only with no impact on the operation or control of the plant.



This is an engineering and service exercise to determine if sufficient capacity in any existing high stage suction lines exists to accommodate the addition flow resulting from redirected defrost vents.

Several considerations apply:

1. When upgrading to float drain valves, upgrade vent lines to high side at that opportunity.
2. If possible, try to combine this opportunity with EEO #21.
3. All vent lines to be insulated.



Note that the disturbance/destabilisation that currently occurs on both low side AND high side compressors will still occur, but will be limited to the high stage.

DEFROST OPTIMISATION

SUMMARY

Conventional defrost routines conduct evaporator heating at regular intervals, for fixed defrost periods. As these are tuned for worst-case ice buildup, excess defrosting causes room heating and excess system energy use. Defrost optimisation is designed to minimize this.

WHAT DATA/ INFORMATION IS NEEDED?

Although the energy savings are likely to be significant, significant monitoring and analysis is required to estimate energy savings in every case.

Defrost optimisation is likely to be viable the facility has freezer rooms or chiller rooms operating at <+4°C with evaporators that are conventionally defrosted (fixed interval and duration).

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Defrost optimisation requires that defrost is conducted only when needed (on demand) and only for as long as needed (defrost termination).

Each evaporator coil should befitted with one (or more) defrost termination sensors thatdetect the coil surface temperature (not air temperature) ideally at the location with the greatest frost accumulation. Specialized clip-on sensors are commercially available that detect fin temperature, but alternatively conventional probes can be used as long as good fin contact is ensured. Some coil manufacturers can supply coils with defrost termination sensors inbuilt.


SOURCE: LOGIX

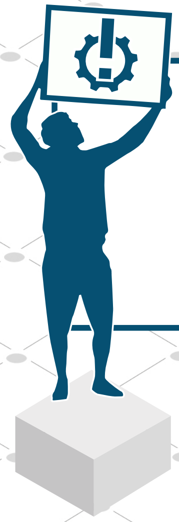
Defrost optimisation then requires the following control logic items to be programmed in the PLC:

Run counter: 1

Where evaporator capacity is regulated by controlling liquid feed rate to the evaporator (as opposed to regulating pressure), implement a run counter to totalize the hours of open-valve operation. The ice accumulation on the coil is approximately proportional to this totalized run period. Reset the counter whenever defrost commences.

Defrost start: 2

Start a new defrost cycle ONLY when enough run hours have accumulated, otherwise skip scheduled defrost event. Some trial & error will be required to determine the minimum number of run hours for each evaporator to require defrost.



Tip: Have regular (more regular than usual) planned defrost events per evaporator as "reserved slots", then skip if not enough run hours have accumulated. For example: If daily defrosts are currently being done, schedule these at 12 hour intervals in future.

Defrost termination: 3

Terminate defrost on every evaporator when the defrost termination sensor reaches 10 °C, rather than running each defrost for the full set duration.

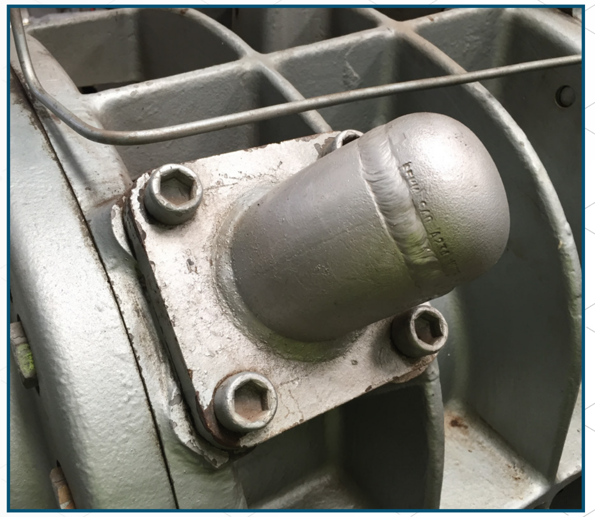
Tip: Set defrost duration a bit longer than before to accommodate extra-heavy frost formation when defrosts are skipped. For example: If defrost duration is currently 30 minutes, extend this to 45 minutes if termination is done on temperature.

HIGH STAGE ECONOMISER

30

SUMMARY

Screw compressors operating high stage can draw additional suction gas via their side or economiser port. An economiser arrangement can be used to subcool receiver liquid using this feature, thus reducing flashgas development in the intercooler and therefore saving compressor energy.



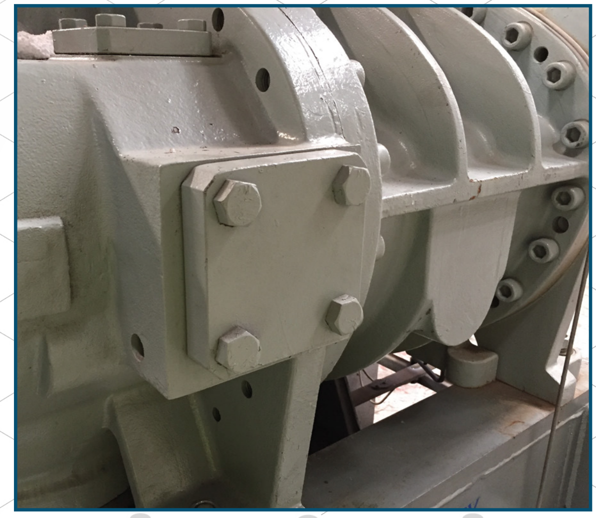


photo of screw compressor side port blanked off

WHAT DATA/ INFORMATION IS NEEDED?

- Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool. In order to calculate this, inputs for all high stage compressors (load, run hours, max. current) have to be made.
- Calculated savings assume the entire high stage runs 7 % (rule-of-thumb) more efficient than without economiser. Note that compressors must not be mechanically unloaded to achieve these savings.
  - prior implementation of compressor speed control via VSD.

AMPC

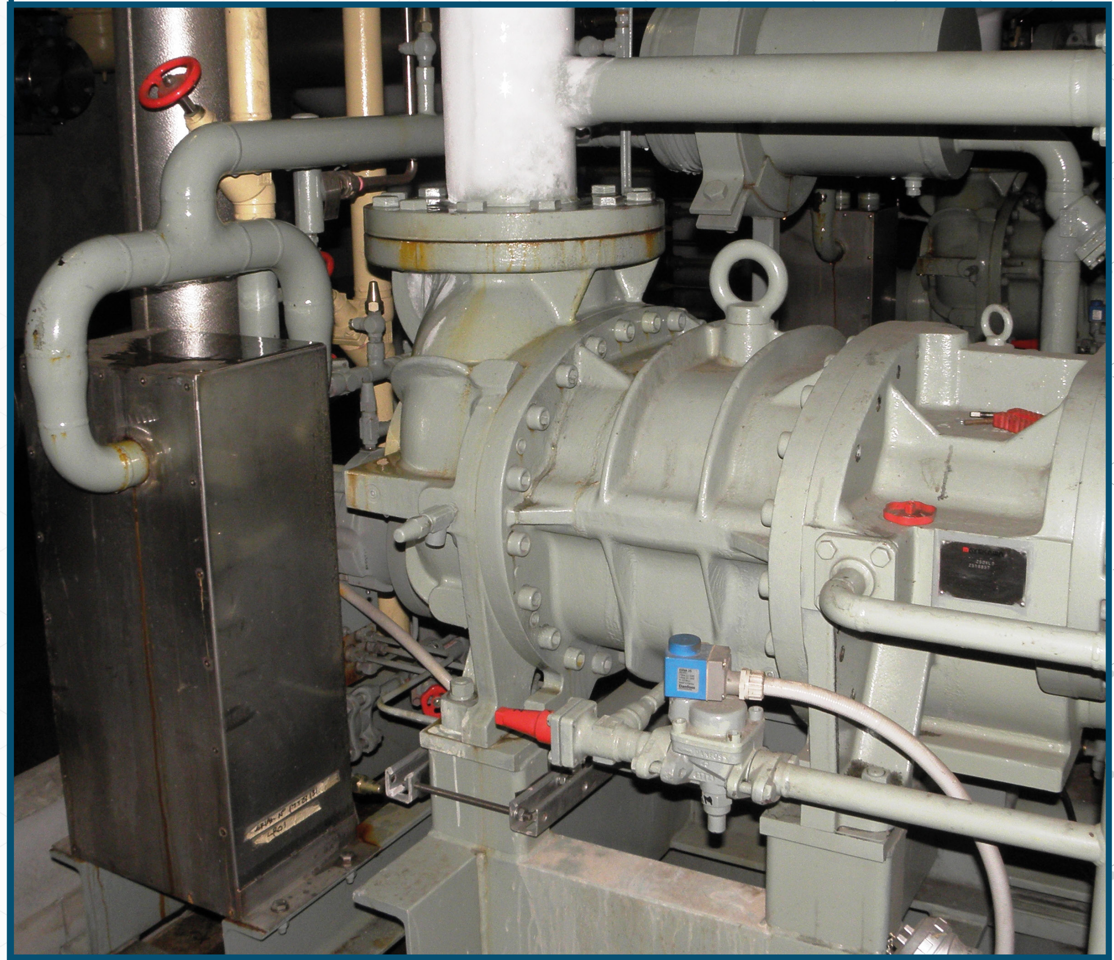
IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

There are several options for economiser design, and engineering assessment is required to determine the correct option in each case

1. Individual subcooling heat exchangers fitted to each high stage compressor.
2. A common open-flash economiser vessel connected to all high stage compressors.
3. A common coil-in-vessel or flooded plate subcooling economiser connected to all high stage compressors.

In most cases, economisers retrofitted to large ammonia systems are of type 2) due to the simple design, but this may require an upgrade of the liquid feed line and valve station ahead of the intercooler

Common open - flash economiser vessel



The essential components of an open flash economiser system include:

1. An insulated economiser vessel sized to suit the capacity, with usual liquid level control (see also EEO #13) and safety relief valves. Typically these are vertical vessels.

2. Liquid lines from the receiver to the economiser, and from the economiser to the intercooler. Existing feed lines from receiver to intercooler may need to be upgraded or replaced.

3. Screw compressor valve stations on each compressor, which would typically include:

   a. A regulator valve to maintain minimum economiser pressure
   b. A solenoid valve to shut the economiser suction
   c. A check valve to prevent reverse flow when the respective compressor is not in operation
   d. A gas damper to reduce gas pulses in the eco suction line.
   e. A suction strainer to protect the above valves and the compressor from dirt ingress
   f. A stop valve to isolate the valve train for service

Note 1: Economisers cannot be used with single-stage reciprocating compressors, which do not have the ability to draw suction gas at an intermediate pressure.

Note 2: Economiser vessels on two-stage reciprocating compressors (no longer in common use) cannot be combined with the economiser system on high stage screw compressors.

Gas damper and check valve on economiser port

INTEGRATION

MORE THAN JUST COOLING

Most heating needs of an abattoir can be provided by refrigeration if integrated into the refrigeration plant. Waste heat that would otherwise be disposed of can be used to generate hot water either directly or after it is upgraded to higher temperature via heat pumps.

HEAT RECOVERY

31

SUMMARY

Heat can be recovered from ammonia plants at temperatures of up to 65 °C, offsetting fuel burned in hot water generators or steam boilers to generate hot water for wash-down and other applications <65 °C.

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool and which inputs are needed. needed. Inputs regarding all high stage compressors are needed as well as fuel charges and wash-down water needs.

Savings assume 20 % of discharged heat (from all compressor for which inputs were made) can be recovered to supply 60 °C hot water for wash-down and other applications below 60 °C that would otherwise be generated by burning fuel.

If you already have heat recovery from rendering cookers this is probably not applicable.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Heat can be recovered from a two-stage screw compressor plant in at least four locations:

1. High stage compressor oil cooling
2. High stage compressor discharge gas desuperheating
3. Low stage compressor oil cooling
4. Low stage compressor discharge gas desuperheating

Significantly more heat is available from the high stage compressors and this is therefore the first choice for heat recovery. However, recovering heat from low stage discharge has the added benefit of reducing high stage energy use as this diverts heat from the high stage and causes the compressor load to reduce.

AMPC

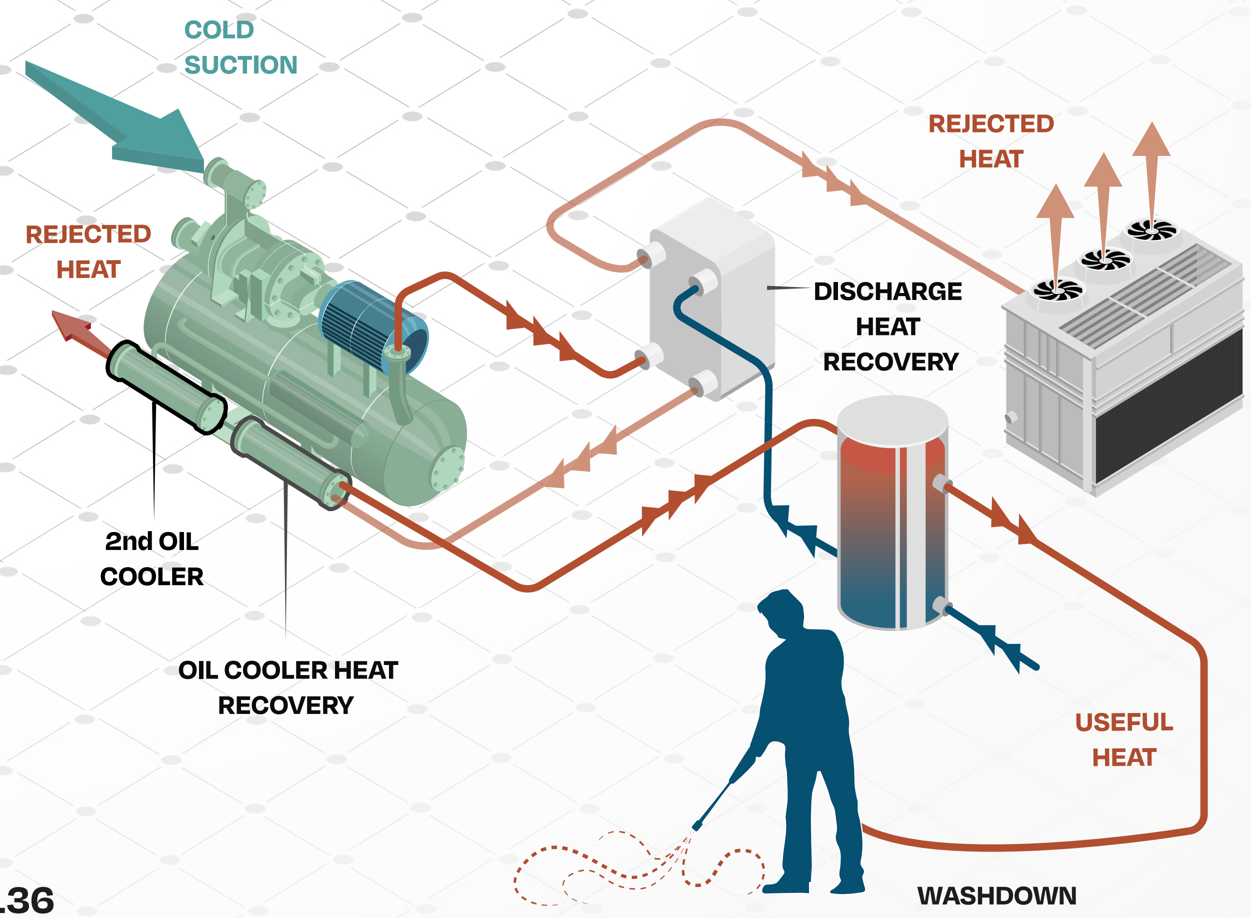
A high stage-only heat recovery system will typically require:

1. A second oil cooler upstream from the existing oil cooler on each compressor. An oil diverting control valve to prevent overcooling of the oil is required.
2. A common desuperheater/condenser located in the common discharge line.
3. A stratifed hot water storage tank.
4. A speed controlled hot water circulating pump, pumping water from the bottom of the tank(cold), via the desuperheater and the oil cooler, back to the top of the hot water tank.

Where multiple oil coolers are used, stat valves or similar control devices are required to divert water flows to each compressor at the right flow rates.

The pump is controlled at variable flow rate to ensure that the water heading back to the tank is warm enough. At low plant loads, the pumps will delivery less water flow to ensure that the temperatures are high enough.

The hot water tank should have several temperature sensors at different levels to display the amount of water storage.



INTEGRATED HEAT PUMP

32

SUMMARY

Heat can be recovered from the high stage compressor discharge gas by means of an integrated heat pump and then discharged into hot water at temperatures up to 95 °C, thus offsetting fuel or direct electric heating for all hot water needs (below 95 °C; no rendering!) or only for sterilization water needs.

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool and which inputs are needed.

Heat pumps consume electricity rather than fuel. So, electricity use will go up.

Different outcomes are calculated:

1. Savings from heat recovery for wash-down water (all hot water below 65 °C; 100 % waste heat from ammonia plant; no additional electricity for heat pump needed) + heat pump only used to provide sterilization water (up to 95 °C; no rendering!).
2. Savings, if ALL hot water (up to 95 °C; wash-down AND sterilization; no rendering!) is provided entirely by heat pumps, which require electricity.

If all hot water needs are at 95 °C and below (no rendering), the entire fuel consumption can be offset.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Integrated heat pumps are as the name suggests integrated into the refrigeration plant one way or another. Hence, they must be located close to the plant room rather than close to the location where the hot water is needed. As refrigerants both ammonia (see EEO/new technology #38) and CO_2 are plausible.

AMPC

AIR SOURCE HEAT PUMPS

33

SUMMARY

Heat can be absorbed from the ambient air by means of a heat pump and then discharged into hot water at temperatures up to 95 °C, thus offsetting fuel or direct electric heating for all hot water needs (below 95 °C; no rendering!) or only for sterilization water needs.

WHAT DATA/ INFORMATION IS NEEDED?

Possible savings for this EEO can be calculated using the **Calculation Tool.** Refer to section C for instructions on how to use the tool and which inputs are needed.

Heat pumps consume electricity rather than fuel. So, electricity use will go up.

Different outcomes are calculated:

1. Savings from heat recovery for wash-down water (all hot water below 65 °C; 100 % waste heat from ammonia plant; no additional electricity for heat pump needed) + heat pump only used to provide sterilization water (up to 95 °C; no rendering!).
2. Savings, if ALL hot water (up to 95 °C; wash-down AND sterilization; no rendering!) is provided entirely by heat pumps, which require electricity.

If all hot water needs are at 95 °C and below (no rendering), the entire fuel consumption can be offset.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Air source heat pumps are stand-alone devices and can be located close to point of use (for example boning room). In most cases, CO_2 heat pumps (see EEO/new technology #39) would be used to provide instantaneous demand (hence NO hot water storage), but in some cases a storage tank can be used to overcome differences between peak heat production and peak hot water usage. Their modular design generally allows the site to install multiple units and add more as hot water demand grows.

NEW TECHNOLOGIES

The **New Technologies** compliment the EEOs presented in the Guidebooks. Instead of replacing old systems with like-for-like these technologies can be used as more energy efficient alternatives. These technologies are market-ready, commercially available, and likely to be financially viable under the right circumstances.

CO_2 AS REFRIGERANT

IN CASCADE/SUB-CRITICAL SYSTEMS

SUMMARY

CO_2 cascade refrigeration systems are a useful tool for freezing loads on all size meatworks, both as replacement for synthetic refrigerant systems and to compliment ammonia systems.

WHAT DATA/ INFORMATION IS NEEDED?

Cascade CO_2 systems can be very useful specifically for the following applications and situations at meat processors:

1. New or existing low temperature cooling load far from a central plant.
   - Rather than run long low temperature suction lines a long way, a satellite CO_2 cascade system can be a much more cost effective and energy efficient option. This can be used to replace inefficient remote ammonia systems, or for new freezer additions.
2. In conjunction with a glycol system,, either where this is used as central plant or for boning/processing room cooling only.
   - It is easy to add a cascade CO_2 system if there is already a cooling source such as chilled glycol nearby.
3. As a safer option for new small to medium size plate freezers, as alternative to pumped ammonia systems.
   - This also enables plate freezing on sites without ammonia refrigeration plant.

Therefore, to assess if a CO_2 cascade is potentially viable for your site, evaluate the following:

a. **Does the existing plant has enough available low stage capacity?** If not, it may be more cost effective to add this capacity by way of a CO_2 cascade rather than expanding the low stage ammonia plant.

b. **Is the freezer load far from the plant room and or other freezer loads?** Running glycol or high stage cooling a long distance is much cheaper and more energy efficient than long low stage lines.

c. **Is there a space or structural limitation at the freezer site?** CO_2 systems are very compact and lightweight.

d. **Are there concerns about the amount of ammonia on site?** Replacing a freezer with CO_2 instead will reduce the ammonia charge and remove ammonia from the freezer space, improving safety and easing compliance

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Designing a new CO_2 cascade refrigeration plant, and interfacing this to either a new or existing high stage refrigeration is an engineering exercise best left to experience and trained refrigeration specialists. Note the information on cascade systems in the New Technology Handbook.

Some additional points of guidance include:

a. CO_2 suction lines and compressors are physically much smaller than equivalent ammonia or synthetic refrigerant equipment. The resultant reduced weight often makes roof-top installation a real option – saving ground floor space.

b. Check the quality and design of any CO_2/NH_3 heat exchanger, as a leak in this heat exchanger can badly affect both refrigeration systems. Using glycol chilled by the high stage system to cool the CO_2 separates the two refrigerants and reduces this risk. It also enables long distances between the ammonia plant (which could be restricted to the plant room) and the CO_2 plant (which could be close to the freezer load)

c. CO_2 is also a toxic gas, but much less so than ammonia. CO_2 detectors are required in spaces served by CO_2 evaporators, and these should be located at floor level as CO_2 is a dense gas and tends to accumulate at floor level first.

d. Safety relief valves on CO_2 cannot be fitted with relief lines to route the gas to the outside, as these may block with dry ice. Therefore, all relief valves need to be located outside and vent directly to air.

e. It may also be useful if site maintenance staff attend at least an information session on the use of CO_2 as a refrigerant. Some TAFEs and private training organisation (RTOs) offer this service.

CO_2 AS REFRIGERANT

FULL-CO_2 SYSTEMS

SUMMARY

Full CO_2 systems are ideal stand-alone alternatives to most synthetic refrigerant systems and are often substantially less expensive than equivalent small/medium ammonia systems.

WHAT DATA/ INFORMATION IS NEEDED?

Full-CO_2 systems are a very attractive option for small/medium meat processors if:

1. **Freezing, chilling and air-conditioning loads can all be served from one plant room.** Full-CO_2 systems offer excellent energy efficiency if they serve a range of temperature levels at the same time.

2. **Fuel is needed for hot water generation** (wash down and sterilisation) but not steam generation (rendering). Large amounts of water at up to 95 °C can be produced as by-product by full-CO_2 systems, often fully offsetting such fuel use.

3. **There are valid safety concerns regarding using ammonia refrigerant on the site.** Full-CO_2 systems require far less safety compliance than ammonia systems and hence are very attractive to sites with no ammonia currently present.

Therefore, to assess if a full-CO_2 system is potentially viable for your site, evaluate the following:

a. **Do you currently have multiple stand-alone or rack-based synthetic refrigerant systems all doing different duties?** Combining all freezer (LT), chiller (MT) and air-conditioning (HT) loads onto a single (or perhaps two) full-CO_2 systems will be cheaper to run and more reliable.

b. **Do you have multiple hot water heaters on LPG, or diesel fired boilers?** Full-CO_2 systems can generate both washdown water (60 °C) and steriliser water (95 °C) from the same unit, at no extra running costs.

c. **Do you currently NOT have ammonia plant on site because of safety concerns?** If you are looking to move away from current synthetic refrigerant systems for cost and environmental reasons, but cannot consider an upgrade to a central ammonia plant, a full CO_2 plant is ideal.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Designing a full CO_2 refrigeration plant, and interfacing this existing hot water systems is an engineering exercise best left to experienced and trained refrigeration specialists. Note the information on full-CO_2 systems in the New Technology Handbook.

Some additional points of guidance include:

a. CO_2 suction lines and compressors are physically much smaller than equivalent ammonia or synthetic refrigerant equipment. The resultant reduced weight often makes roof-top installation a real option – saving ground floor space.

b. CO_2 is also a toxic gas, but much less so than ammonia. CO_2 detectors are required in spaces served by CO_2 evaporators, and these should be located at floor level as CO_2 is a dense gas and tends to accumulate at floor level first.

c. Safety relief valves on CO_2 cannot be fitted with relief lines to route the gas to the outside, as these may block with dry ice. Therefore all relief valves need to be located outside and vent directly to air.

It may also be useful if site maintenance staff attend at least an information session on the use of CO_2 as a refrigerant. Some TAFEs and private training organisation (RTOs) offer this service.

LOW CHARGE AMMONIA SYSTEMS

36

SUMMARY

Low charge ammonia systems are the modern alternative to traditional pump-flooded ammonia systems, with significant safety and energy efficiency benefits. Rather than overfeed evaporators with liquid ammonia, low charge systems use modern dry-expansion technology, as used on most synthetic refrigerant or CO_2 systems.

Scantec low charge ammonia system

WHAT DATA/ INFORMATION IS NEEDED?

With the exception of some equipment that requires liquid overfeed (such as plate freezers), most cooling loads encountered on a meat processing plant can be served by modern, dry expansion evaporators including freezer and chiller rooms, carcass chillers, plate heat exchangers for glycol or water cooling, and even process rooms.

The usual information required for designing conventional ammonia systems are required for low-charge systems, including room dimensions and temperatures, product flow information, details of all equipment and processes in each room, etc.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Designing a low-charge refrigeration plant is an engineering exercise best left to experienced and trained refrigeration specialists, with specific expertise in this area. More so than conventional pump-flooded ammonia systems, low charge ammonia systems require careful selection of instrumentation and attention to detail on control and commissioning.

Some additional points of guidance include:

a. Even if the ammonia charge is much reduced, direct ammonia evaporators CANNOT be used in process areas with high personnel density, such as boning rooms and packaging areas. A secondary glycol circuit will be required for these rooms.

b. Consider combining low charge ammonia with CO_2 cascade units for remote or even all freezer loads.

c. Large scale plate freezers will require a dedicated accumulator and pump-circulation of ammonia, but the dry suction can be integrated with the low charge ammonia plant serving the remainder of the facility.

SMART PACKAGED REFRIGERATION SYSTEMS

SUMMARY

As an alternative to conventional single-compressor freon refrigeration units, the new generation of smart packaged systems offer significant energy efficiency and other benefits.

CAVEAT

Most smart refrigeration units on the market are available for HFC refrigerants only. These refrigerants are high global warming gases and subject to phase-down. For sites seeking to reduce carbon footprint, such gases are best avoided and solutions such as CO_2 and ammonia investigated instead.

WHAT DATA/ INFORMATION IS NEEDED?

Smart refrigeration systems are like-for-like replacement for conventional small freon systems with single room evaporator as still used widely on some small meat processing sites. The usual design information for refrigeration equipment selection is required to select these systems, and often the equipment suppliers offer a selection service to support the installing contractor.

If replacement of existing freon units would require multiple smart units in close proximity, then consider a central rack solution (ideally using CO_2 refrigerant) instead. This is likely to be more cost effective and efficient even if smart units are used.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Equipment selection (outdoor unit and evaporator) is generally managed by the supplier, so that installation of the smart units is literally a plug-and-play exercise for the installing contractor. Some basic guidance (refer also to the Commercial Freon Systems Guidebook) can assist:

1. Ensure that the outdoor unit is located in a well-ventilated area to avoid recirculation of cooling air. Poor location will defeat the energy efficiency gains.
2. The smart units come complete with a pre-optimized controls package, so there is little the contractor can mess up as long as the instructions are followed. This reduces commissioning and installation defects that often plague small condensing unit installations.

AMPC

AMMONIA HEAT PUMPS

SUMMARY

Waste heat currently discharged via a cooling tower or evaporative condenser can be converted to hotter water for wash down or even sterilization using an ammonia heat pump.

WHAT DATA/ INFORMATION IS NEEDED?

Ammonia heat pumps need a source of warmish water from which they draw heat, and can then produce hot water up to 95 °C. Selecting a heat pump to replace an existing hot water boiler is not an entirely simple exercise and requires the following information:

1. Establish the current hot water demand (how MUCH water is used). There are a few ways to do this and it is best to assess the demand in several ways to cross check:
   - a. Fuel consumption: Where possible, meter the fuel used by the respective boilers, ideally over several months of operation. If hot water generation is the only fuel use on site, using fuel bills could provide this information.
   - b. Hot water consumption: Where possible, install water flow meters (cheap) to measure wash-water and sterilizer water consumption over several months of operation.
   - c. Existing boiler size and utilisation: Obtain current boiler capacities (noting these could be oversized) and if possible monitor boiler operation to understand utilisation (hrs/day). Important: Heat pumps are rarely sized to match the boilers they replace!
2. Understand usage profile (WHEN the hot water is used). There are a few ways to do this:
   - a. Observe current operation and interview staff. This will give some idea of when and for how long processes take place.
   - b. Monitor water use: Adding monitoring to the water meters (most water meters have a pulse output that can be attached to a monitoring system) will provide precise data on the daily consumption profile.

3. Understand the heat source. Generally this is cooling water from a refrigeration system or other source.

   a. Existing heat rejection capacities: Obtain current cooling tower and evaporative condenser heat rejection capacities. Ideally these will be much greater than the hot water demand.

   b. Understand the heat rejection utilisation and profile: Obtain trend logs from the refrigeration or other plants to determine the % load on the heat rejection across the day. The heat pump cannot draw more heat than is being rejected at any time.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once the above data is available a heat pump and hot water storage tanks are sized to match the daily hot water demand. This modelling process is best left to skilled engineers familiar with heat pump system design. The Australian Alliance for Energy Productivity (A2EP) is a useful starting point to obtain more information and find engineers to assist.

Some key guidance to site staff when selecting ammonia heat pumps:

1. Do not oversize heat pumps. Correctly selected heat pumps run more or less fully loaded all day, charging up storage tanks for intermittent use (wash water) or to supply into a ring main for steady use (sterilizer water). In this way the significant capital investment is best utilized.
2. Use stratified hot water storage tanks in combination with heat pumps, with cold town water feed into the bottom of the tank, and hot supply water fed from the top of the tank. This maximises the heat pump efficiency and makes it easier to control the heat pump.
3. Reconsider the design and control of any existing hot water ring main to minimize mixing of cold and hot water in the tank.
4. Retain any existing hot water boilers as backup unit for the heat pump, with the ability to revert to "old" operation if needed.

CO_2 HEAT PUMPS

SUMMARY

Using heat extracted from ambient air or waste heat, CO_2 heat pumps can generate hot water up to sterilizer duty (90 °C) at point of use.

WHAT DATA/ INFORMATION IS NEEDED?

CO_2 air-source heat pumps are available as standard units in range of sizes from as small as 4kW to a few 100kW. As these are cost-effective plug-and-play units, it is often best to multiplex these to achieve the desired duty, which give some backup and redundancy. The design strategy is therefore different to the large ammonia heat pumps as the hot water can be produced more or less on demand, with only small amounts of buffering needed to match fluctuating loads as happen during wash-down. Therefore the information needs are less and really only require an understanding of the current hot water demand (how MUCH water is used).

There as a few ways to do this and it is best to assess the demand in several ways to cross check:

1. Fuel consumption: Where possible, meter the fuel used by the respective hot water generators, ideally over several months of operation. This may be difficult or costly for smaller heating loads.
2. Hot water consumption: Where possible, install water flow meters (cheap) to measure wash-water and sterilizer water consumption over several months of operation.
3. Existing hot water generator size and utilisation: Obtain current hot water generator capacities if possible monitor or at least observe operation to understand utilisation (hrs/day).

39

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Once the above data is available a heat pump and hot water storage tanks are sized to match the daily hot water demand. For smaller loads and with multiplexed heat pumps, this is relatively straightforward and it is generally feasible to install enough capacity to meet peak hot water demand, this having some backup and redundancy during other times.

Some key guidance to site staff when selecting ammonia heat pumps:

1. Locate the heat pumps where they are well ventilated and ideally on the warmest side of the building. Ensure that service access is convenient.
2. Use stratified hot water storage tanks in combination with heat pumps, with cold town water feed into the bottom of the tank, and hot supply water fed from the top of the tank. This maximises the heat pump efficiency and makes it easier to control the heat pump and is especially important for CO_2 heat pumps.
3. Reconsider the design and control of any existing hot water ring main to minimize mixing of cold and hot water in the tank.
4. Retain any existing hot water boilers as backup unit for the heat pump, with the ability to revert to "old" operation if needed.

AMPC

40

CENTRAL GLYCOL SYSTEMS

SUMMARY

Using a centralized chiller plant to generate a supply of chilled glycol water for use across the site is a viable and robust alternative to direct ammonia or CO_2 central plant.

WHAT DATA/ INFORMATION IS NEEDED?

A propylene-glycol/water mixture chilled to -8degC or lower can be reticulated around the site and use in various medium temperature cooling loads, including

- Carcass chillers
- Chilled Storage Rooms
- Boning rooms andpackaging/processing areas
- Water chilling for spray cooling
- Air handling units for fresh air makeup to occupied spaces
- Even office air conditioning!

Low temperature (freezing) loads can be served by CO_2 cascade refrigeration units, connected to the glycol systems

Other plant combinations and arrangements are possible, such as

- a two-stage low charge ammonia plant that chills glycol for site reticulation on the high side, with a direct ammonia low stage for freezer loads, or
- a two stage low charge ammonia plant as above, but with the carcass chillers on direct ammonia high stage.

The usual information required for designing conventional ammonia systems are required for central glycol systems, including room dimensions and temperatures, product flow information, details of all equipment and processes in each room, etc.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Designing a central glycol refrigeration plant is an engineering exercise best left to experienced and trained refrigeration specialists, with specific expertise in this area. Central glycol plant is commonly used in other sectors (such as food processors, dairies, wineries and fruit and vegetable storage) and the technology is simple and reliable.

Some additional points of guidance include:

1. The fluid chiller used to chill the glycol can be a low cost freon-based unit or a high efficiency ammonia unit to suit the project budget. Upgrading the actual chiller plant can easily be done in future with minimal changes to the glycol system.
2. Consider combining the central glycol system with CO_2 cascade units for remote or even all freezer loads. This is an alternative to extending the ammonia chiller plant to do low stage duty.
3. Large scale plate freezers will require a dedicated accumulator and pump-circulation of ammonia with a dedicated ammonia plant.

AMPC

AMMONIA ABSORPTION REFRIGERATION

SUMMARY

Ammonia absorption refrigeration offer a niche solution for those processor sites with a surplus of high level heat on site, for example from consumption of biogas in gas engines or steam boilers, and who need further cooling capacity.

WHAT DATA/ INFORMATION IS NEEDED?

Surplus usable hot water at temperatures >90 °C can be used to generate chilled glycol for various cooling purposes, such as boning room cooling. y

Surplus hot water can be used to directly heat potable water for washdown or steriliser duty. If the available hot water supply exceeds these direct needs, an ammonia absorption system may be viable. To evaluate this option:

1. Determine the minimum consistent hot water flow rate and supply temperature that can be generated over a 24-hour weekday cycle. Absorption systems are best operated at steady duty and not cycled on and off regularly.
2. Determine if additional uses of chilled glycol are helpful on site. For example, if the site currently has direct ammonia chilling of the boning room (which is in breach of Australian safety regulations, but nonetheless common), then the glycol generated by the absorption unit could generate enough cooling to operate the boning room entirely of glycol.
3. Obtain design information on the cooling loads suitable to glycol cooling (size of space, product and equipment loads, etc) as are typically needed to size cooling equipment for these spaces or loads

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

With the above information know, modelling of absorption unit capacity and size of glycol storage tans is required to design the glycol system. This is best done by experienced engineers.

Some key guidance to site staff when selecting ammonia heat pumps:

1. Absorption units are heavy and bulky and are best accommodated in a plant room close to the source of surplus heat.
2. Absorption units reject low level heat via a cooling tower. This may require expansion of the current condenser or cooling tower deck.
3. Use stratified glycol storage tanks in combination with absorption refrigeration units to buffer cooling for later use chilled supply entering the tank at the bottom, and warmer glycol returning from the. This maximises the absorption unit efficiency and allows it to operate as steadily as possible.

REFRIGERATION AS A SERVICE

SUMMARY

Refrigeration as a Service (RaaS) is an outsourcing model placing the responsibility for the reliability and efficiency of the refrigeration systems onto an external provider.

WHAT DATA/ INFORMATION IS NEEDED?

Refer to the New Technology Handbook for more information on the benefits of RaaS to meat processor sites.

A RaaS contract works for both parties because the RaaS provider uses remote technology and expertise to operate and maintain the plant at a lower cost than the site is able to do conventionally, thus creating a margin that is shared, whilst reducing the hassle factor for the site.

The key information required to establish the cost modelling for RaaS, and to assess whether this is a good solution for a specific site, is the following:

1. Understanding the cooling and heating loads. This is critical, both to design any replacement or upgraded plant, but also to model the cooling and heating charges ($/kW) that will be charged for the service in future. Detailed monitoring either via the PLC and SCADA or a dedicated monitoring systems will be required prior to locking in a firm proposal.
2. Modelling the upgrade or replacement scope or cost. Understanding the required loads (point above) and a full assessment of current plant and condition will be required to establish these costs. This work is generally done by the RaaS provider, or an appointed consultant.
3. Production and energy use baseline data. o factor any benefits from carbon credits into the RaaS financial model, detailed and accurate energy and fuel consumption data for at least the past 24 months will be required to establish an energy baseline.

42

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

Entering into a RaaS contract with a supplier is a significant step and requires consideration of the following during contract setup:

1

Sale price and scope of the existing refrigeration system.

- The RaaS provide will invest capital into purchasing the existing plant from the processor if upgradeable, or to replace the plant with new if that offers greater benefits. This frees up processor capital for other functions and improves RoC.
- The sale price is linked to the buy-back price spelled out in the contract and hence the sale could either be at market price or for $1, depending on the processor's capital needs.

2

Monthly fixed costs.

- The RaaS provider will offer fixed (or annual escalating) monthly rates that include maintenance and breakdown costs. These rates are therefore known and guaranteed to the processor, irrespective of any breakdown events.
- The site should evaluate these relative to current maintenance, breakdown and insurance costs of the refrigeration plant and any hot water generation systems, as well as associate staff costs for managing and operating the plant, and the availability of management time for other functions.

3

Monthly variable costs

- The RaaS provide will charge the site for metered use of refrigeration and generated hot water at agreed fixed rates ($/kWhR or $/kWhH), adjusted annually with changes to utilisation and energy costs.
- These costs are therefore predictable and guaranteed to the processor.
- The site should evaluate this relative to the cost of fuel and energy currently consumed by the refrigeration plant and used to generate hot water.

4

Staff arrangements

- Some site may have on-site maintenance and plant operator staff that could be fully or partly dedicated to the refrigeration plant.
- This staff may be retained by the site with some agreed availability to the RaaS provider as part of the contract, or could switch to the RaaS provider payroll.

5

Availability and penalties

- The RaaS provider guarantees plant availability and maximum space temperatures under agreed operating conditions
- The contract details agree penalty clauses should the plant fail to meet the availability

6

Reporting

- The RaaS provider can provide a detailed dashboard to the site, with information on where energy is used to assist the site to reduce refrigeration costs. This can include regular energy use reporting by way of formatted electronic reports.

ORGANIC RANKIN CYCLE SYSTEMS

43

SUMMARY

Organic Rankine Cycle (ORC) systems offer another niche solution for those processors sites with a surplus of high level heat on site, for example from consumption of biogas in gas engines or steam boilers, and who are looking to generated electrical energy to offset grid power.

WHAT DATA/ INFORMATION IS NEEDED?

Surplus usable hot water at temperatures >180 °C can be used to generate electrical power using ORCs.

Surplus hot water can be used to directly heat potable water for washdown or steriliser duty. If the available hot water supply exceeds these direct needs and is hot enough, an ORC system may be viable. To evaluate this option:

1. Determine the minimum consistent hot water flow rate and supply temperature that can be generated over a 24-hour weekday cycle. ORCs can be small (<100 kW generation), but need at least 180 °C pressurized water in most cases.
2. ORC systems are best operated at steady high duty and not cycled on and off regularly as high utilisation rates improve the financial viability of the project. Unlike absorption systems, ORCs can rung intermittently, but this reduces the financial performance of the project.

IMPLEMENTATION / HARDWARE & CONTROL REQUIREMENTS

With the above information know, modelling of ORC unit capacity is required to design the system. This is best done by experienced engineers.

Some key guidance to site staff when selecting ammonia heat pumps:

1. ORC systems perform better with hotter water (>180 °C). If the waste heat is not reliably hot enough, consider using it for absorption cooling instead.
2. ORC units typically reject low level heat via an air-cooled condenser. These may benefit from adiabatic cooling (refer to EEO #4) to improve ORC performance.

AMPC

This Manual is one of five Guidebooks developed during the "Refrigeration Plant Energy Improvement" research project by the Australian Meat Processor Corporation (AMPC). The series aims to help plant personnel and stakeholders of meat processing facilities to identify energy efficiency opportunities within their refrigeration systems.

This "HOW-TO MANUAL" serves as an additional source of information to complement all other guidebooks and assess energy efficiency opportunities. It is therefore relevant to meat works of all sizes.

AMPC