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Refrigeration Energy-Efficiency Opportunities

FOR THE AUSTRALIAN MEAT PROCESSING INDUSTRY

INDUSTRIAL AMMONIA SYSTEMS
PART 1

REFRIGERATION ENERGY-EFFICIENCY OPPORTUNITIES

FOR THE AUSTRALIAN MEAT PROCESSING INDUSTRY

INDUSTRIAL AMMONIA SYSTEMS PART 1 – GUIDEBOOK

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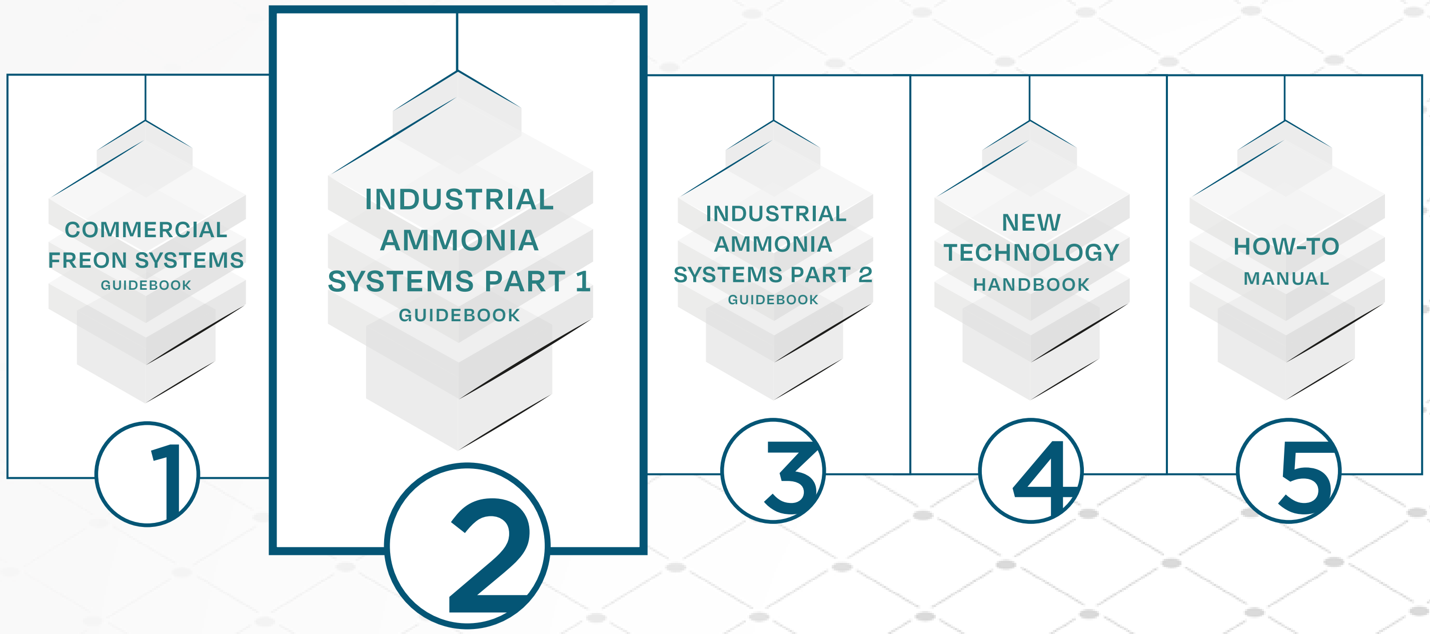
CONTENT OVERVIEW

PART 1

PART 2

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developments** is crucial when it comes to decision-making on major plant upgrades/restorations as investments into outdated technologies could result in a competitive disadvantage.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 Energy Efficiency Opportunity Calculation Tool where applicable.

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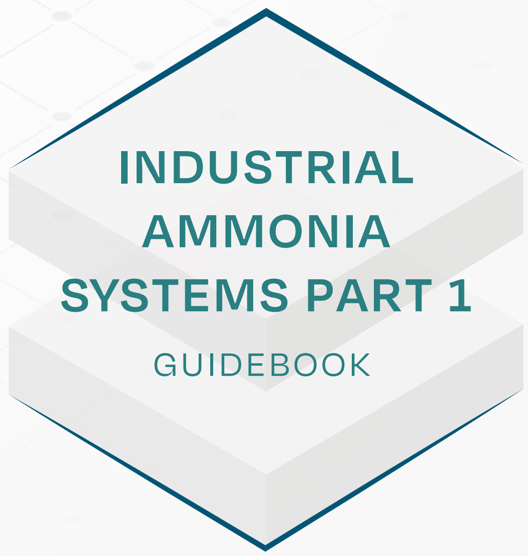
GUIDEBOOK: INDUSTRIAL AMMONIA SYSTEMS PART 1

Centralized ammonia plants are complex systems, custom-tailored to each site. This makes optimizing them more difficult than commercial systems. On the bright side, they allow for much more sophisticated measures to be implemented due to their scale and leave you more room for improvement. Because they are custom-tailored and production at meat works and the associated cooling and heating demands vary over a wide margin, what opportunities apply to one site might be totally different to the next. This is amplified by the drastically **differing states of respective refrigeration plants** regarding how they are controlled, and which energy efficiency opportunities already may have been implemented.

Some sites might be further ahead and tick off many of the opportunities presented. Others might still have more groundwork to do. Furthermore, some opportunities built on the foundation laid out by others. This is why a **staged approach** was chosen for the industrial ammonia systems guidebooks, with Part 1 & 2.

Part 1 gives a brief overview of ammonia refrigeration systems and then focusses on the very first important steps which must be taken care of. This first stage is referred to as the **"Essentials"** and aims to get the plant into a good running order while making use of some of the more fundamental energy efficiency opportunities. Then follow the **"Hard Yards"**, which aim to replace hardware that is holding back the plant's efficiency. Even if your plant is more advanced and has most of this covered, make sure each essential step has properly been taken care of. Be aware, with time and changes to the plant from when it was first commissioned faults might have crept in. Omissions in these first stages might significantly hinder savings achieved by more sophisticated measures discussed in Part 2.

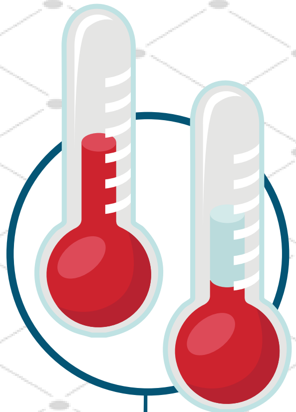
Part 2 will then delve into the **"Refinement"**, some more advanced features which mostly focus on control strategies and tease out the last bits of efficiency. Lastly, it will examine the **"Integration"** of refrigeration plants into providing hot water needs for the site as well.



TERMINOLOGY

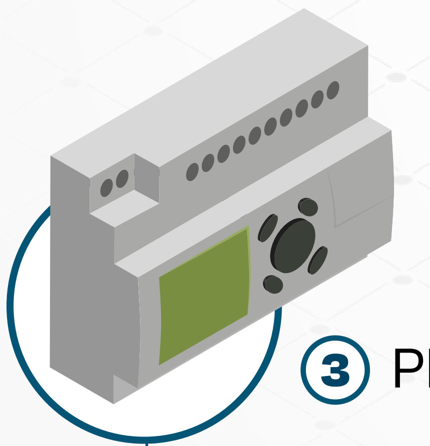
1 EEO

Opportunities to improve your plant's efficiency in these guidebooks are referred to as **E**nergy **E**fficiency **O**pportunities, or in short **EEO**s.



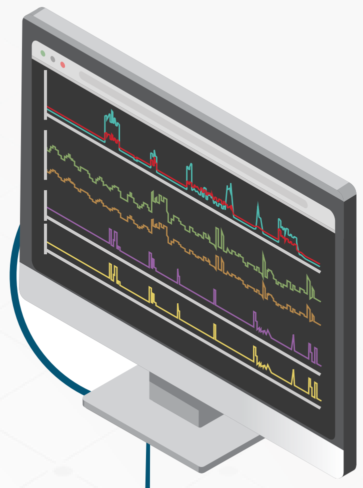
KELVIN [K] 2

Scientific unit for absolute temperature and temperature differences. E.g. the difference between 30 °C and 20 °C is **10 K.**



3 PLC

Programmable **L**ogic **C**ontrollers or **PLC**s are commonly used to control refrigeration systems. As the name suggests, they are programmed to follow specific control logics and can be re-programmed by knowledgeable persons.

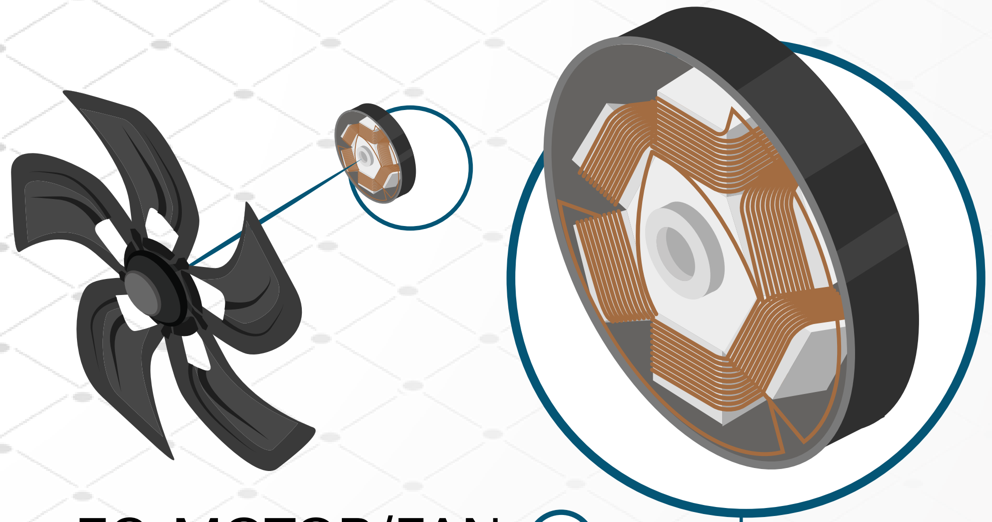


SCADA 4

Supervisory **C**ontrol **A**nd **D**ata **A**cquisition, or in short **SCADA**, is the broad term used for human-machine interfaces which allow personnel to visualize and understand operational system data and if necessary to interact with the system.

5 VSD

Varible **S**peed **D**rive (sometimes refered to as VFD, AFD and others) is the broad term used for power electronic controllers that allow you to run AC-motors as commonly used in refrigeration at varying speeds. This allows for **speed control** which brings many benefits.



EC-MOTOR/FAN 6

EC stands for **E**lectronically **C**ommutated. These motors possess a controller which commutates the electric current in such a way that it can **vary the speed** of the motor. As for VSDs this allows for **speed control** and its benefits.

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RECURRING THEMES

① DOES THIS WORK FOR ME?

With each EEO you will be asked some questions that aim to give you a **quick assessment** if this EEO might possibly be applicable to your plant.

▼

The Guidebooks keep the assessment very short with more detail for further assessment in the **How-To Manual.**

② SYNERGIES

You will often find the signpost as a symbol next to this theme which indicates the path you should take on this staged approach towards energy efficiency. It might show you where you came from and where you can go from here.

▼

Some EEOs require prior implementation of other EEOs as a necessity. Others benefit from or make more sense as an investment when done in conjunction with another EEO.It might show you the steps you have taken so far to get here and where you can go from here.

▼

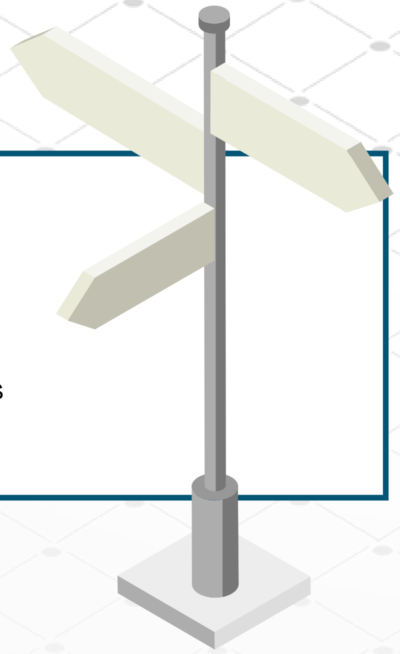
These EEOs are listed in 2 categories:

Follows:

Prior implementation of EEOs ... is essential for this EEO or will help it reach its full potential.

Enables:

After this EEO has been implemented it will enable you to make full use of EEOs ...



③ GOOD TO KNOW

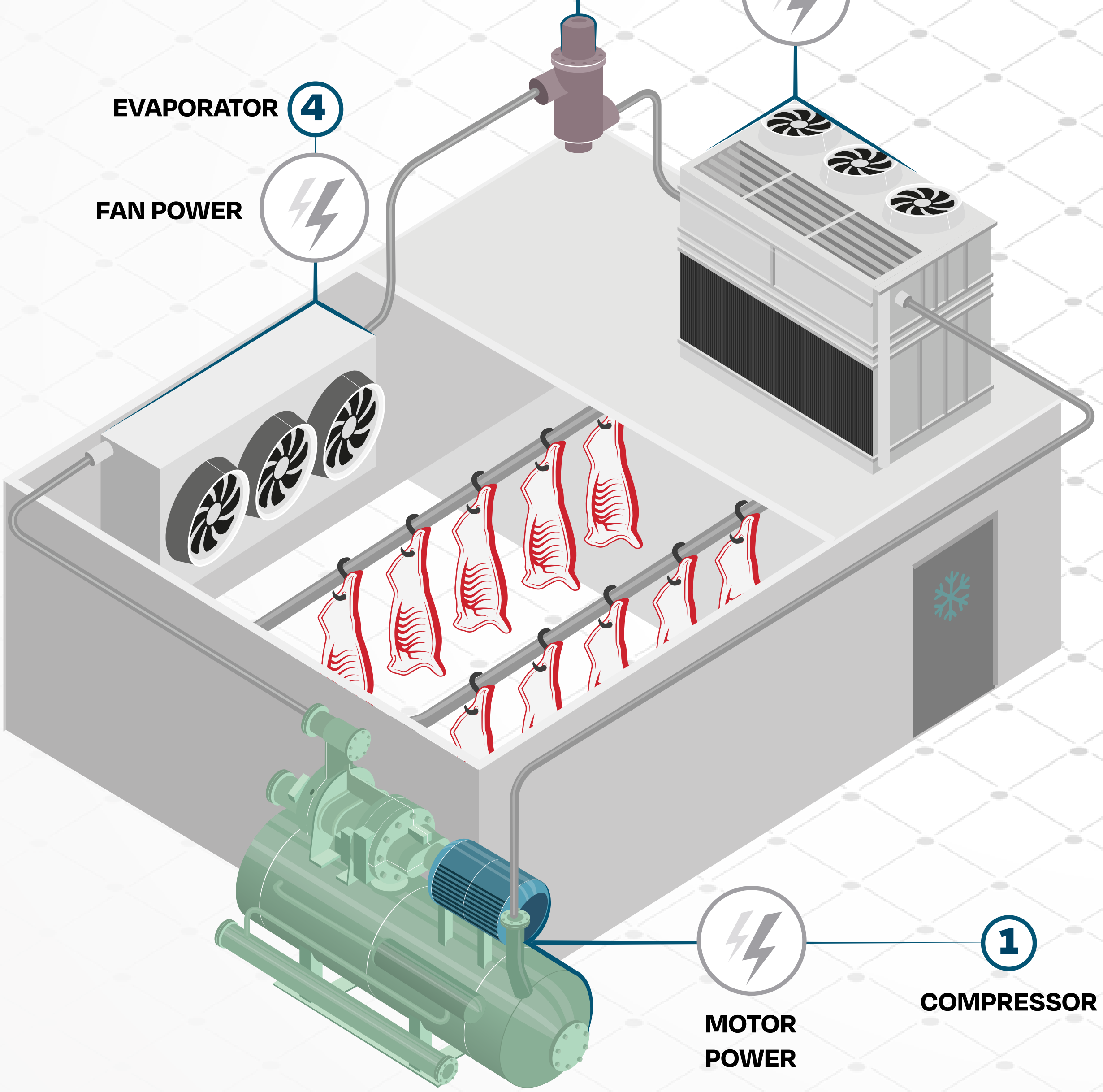
- As the name might suggest, this category will give you some **extra** information.
- This information is "good to know" as an addition to the more fundamental information which was given to you as part of each EEO.

POSSIBLE POTHOLES ④

These Guidebooks are not trying to sell you anything, but are meant to give you good advice on how to save energy on refrigeration. This also means making you aware of possible issues that might arise when trying to implement an EEO. But knowing about these "potholes" beforehand can help you avoid them, making sure you are in for a smooth ride.

REFRIGERATION BASICS

The refrigeration systems we encounter in most meat works are **vapour compression systems.** They consist of **4 basic components** + miscellaneous equipment (filters, valves, accumulators, etc.). This graphic gives you a short explanation of their functions and highlights where electric power is consumed within the system*****. All EEOs will evolve around optimising operation of these components and reducing their power draw.



*There are other power consumers like pumps, electronics, controls, etc. But these are of less concern.

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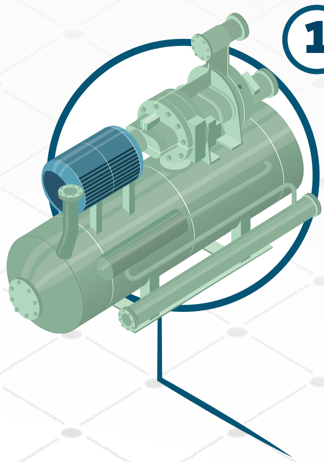


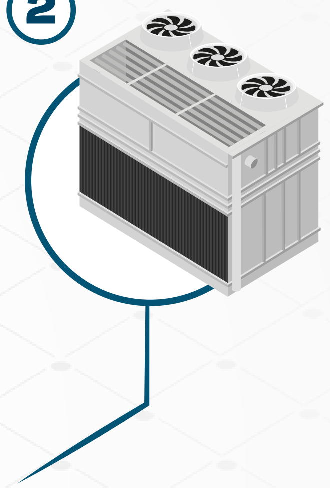
① COMPRESSOR

Takes in cold vapour coming from the evaporator and expansion valve at **suction pressure.** Compresses it to hot gas at **discharge pressure** using electric power.

▼

Biggest power demand in the system. The higher the pressure difference between suction & discharge, the more power is needed. E.g. it takes more energy to compress vapour from a **colder** evaporator (pressure is **lower**) or to discharge into a **warmer** condenser (pressure is **higher**).

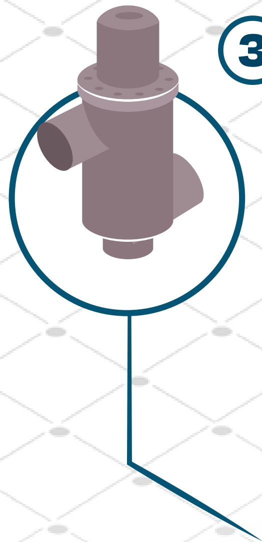
CONDENSER ②



Refrigerant **rejects heat** to ambient. Most of the heat is rejected by turning from vapour to liquid at **condensing pressure**. For practical purposes condensing and compressor discharge pressure are the same. This is also commonly referred to as head pressure. Capacity depends on temperature difference to ambient, air flow and heat exchanging surface.

▼

If **ambient temperature rises** and the condenser is already at full capacity, the condensing pressure rises and with it **compressor power**.



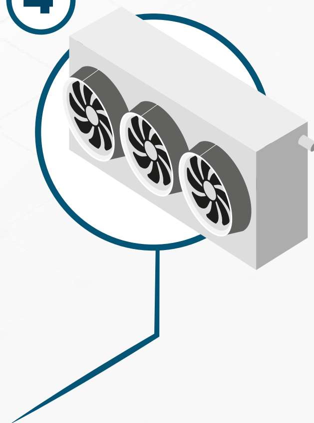
③ EXPANSION VALVE

Creates a **large pressure drop** between high and low pressure side by restricting refrigerant flow. After the valve, part of the refrigerant flashes into vapour cooling the remaining liquid to lower temperature.

▼

The valve itself does not consume power, but **flash gas generation** from the valve requires **compressor power** for subsequent re-compression.

EVAPORATOR ④



Refrigerant **absorbs heat** by evaporating from liquid to vapour at **evaporation pressure**. For practical purposes evaporation pressure and suction pressure are the same.

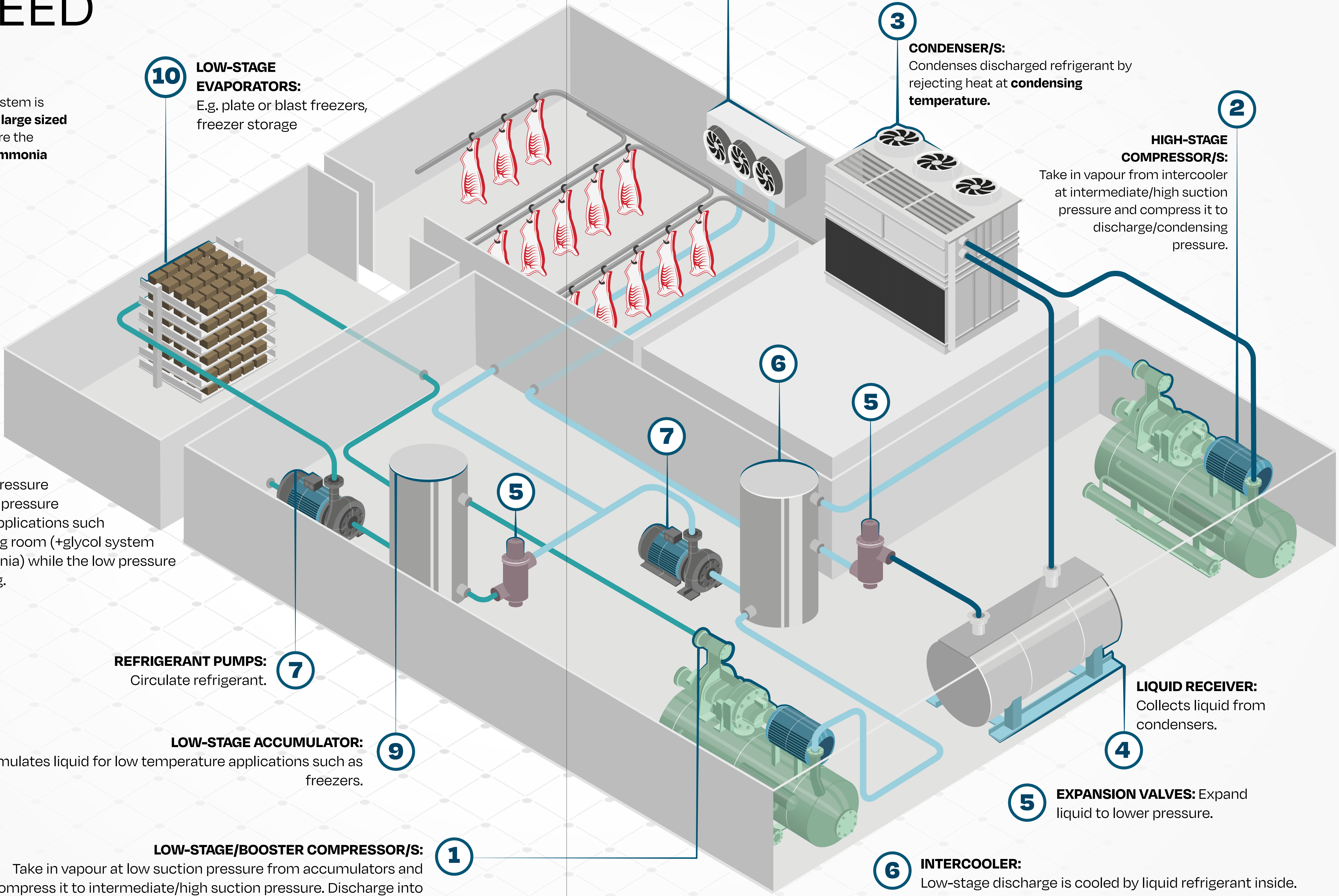
▼

To reach **colder temperatures** evaporation pressure must be lowered, in turn **compressor power** rises.

2-STAGE LIQUID OVERFEED

AMMONIA PLANT

This type of refrigeration system is found in most **medium and large sized abattoirs** in Australia, and are the subject of the **"Industrial Ammonia Systems"** guidebooks.



The 2-stage system supplies cooling at two different temperature/pressure levels. The intermediate pressure stage supplies chilling applications such as chillers and the boning room (+glycol system due to toxicity of ammonia) while the low pressure stage serves for freezing.

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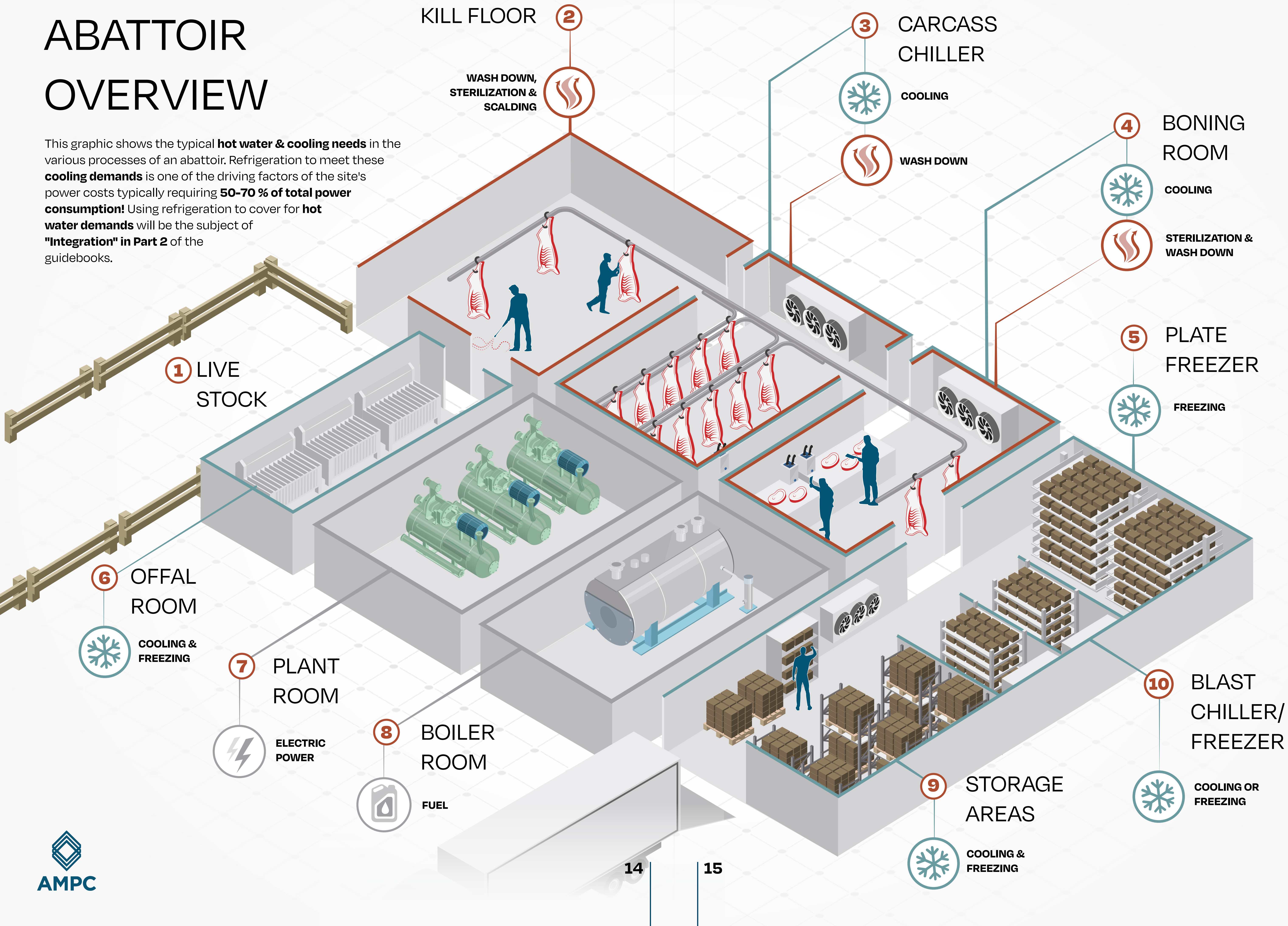
ABATTOIR OVERVIEW

This graphic shows the typical **hot water & cooling needs** in the various processes of an abattoir. Refrigeration to meet these **cooling demands** is one of the driving factors of the site's power costs typically requiring **50-70 % of total power consumption!** Using refrigeration to cover for **hot water demands** will be the subject of **"Integration" in Part 2** of the guidebooks.



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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.

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CONTROLS & MONITORING UPGRADE

& SENSOR CALIBRATION

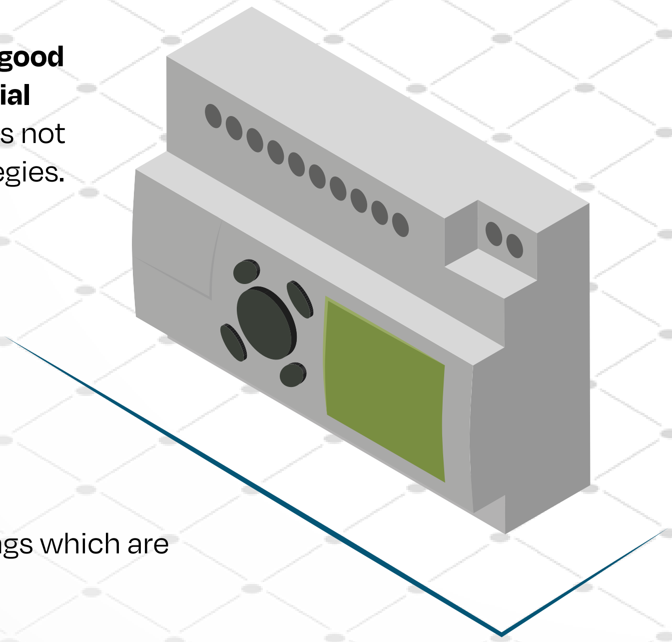
1 PLC UPGRADE

Until recently, technologies like VSDs were not as prevalent and controls might have been simpler than what is required for many of the EEOs presented in this Guidebook.

If your **PLC is outdated**, you **might not be able to program** more sophisticated control strategies as desired. It may also **lack the ability to take certain inputs** from new up-to-date technology like speed drives.

Check what your PLC is capable of. You might have to **upgrade your PLC** first before you can start implementing other EEOs.

Finally, make sure your **controls are good** and actually make **full use of potential savings** from your hardware. If that is not the case upgrade your control strategies.



2 MONITORING UPGRADE

You **cannot diagnose or control** things which are **hidden from you**.

To be able to **diagnose undesired plant behaviour** you first need to be able to measure (sensors) and then visualise it (SCADA, trending).

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More **sophisticated control** strategies, such as variable head pressure control, need **more data/inputs** from sensors, such as plant load and ambient humidity/temperature sensors.

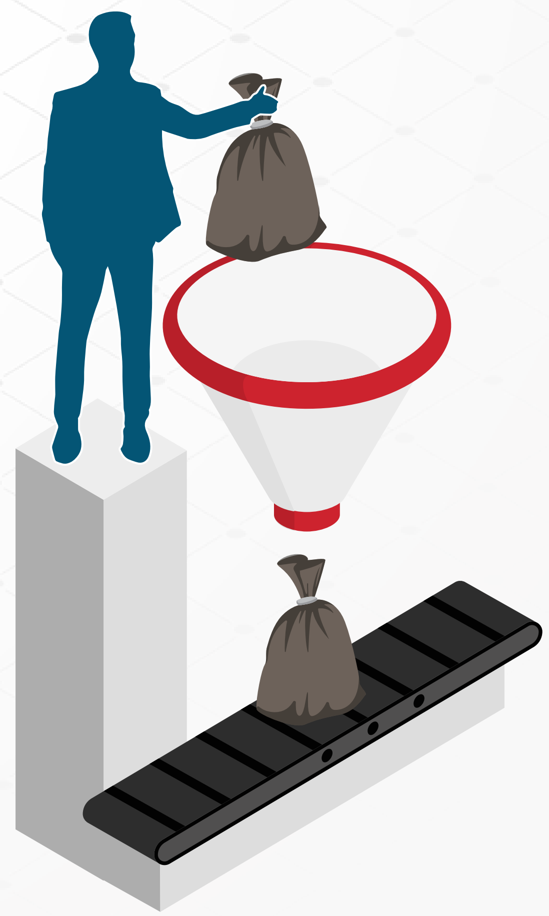
Lastly and maybe most importantly, measurements and their visualization will enable you to **verify/quantify savings** from implementing energy efficiency measures.

"Make sure you have all essential sensors covered and that they are actually implemented in your monitoring system, so you can visualise and analyse them."

Refer to the **How-To Manual** on information which sensors are essential and should be installed at your plant.

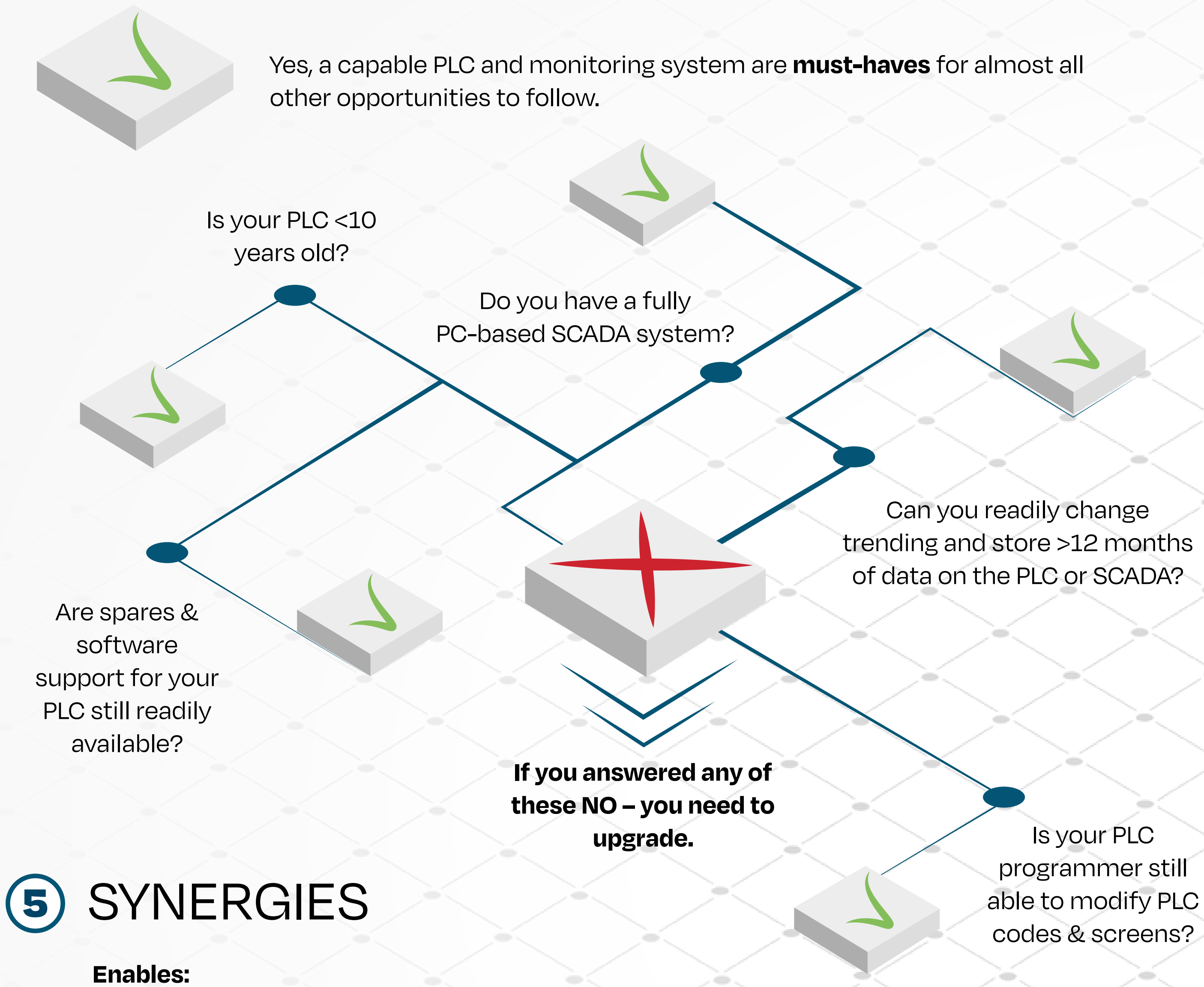
3 SENSOR CALIBRATION

- All these sensors are of little use, if what they measure is wrong. This might be the case, if sensors are not calibrated correctly or re-calibrated as specified.
- In accordance with the motto **"junk in junk out"**, if you feed incorrect informationon in on one end, incorrect results will come out of the other.



4 DOES THIS WORK FOR ME?

Yes, a capable PLC and monitoring system are **must-haves** for almost all other opportunities to follow.



5 SYNERGIES

Enables:

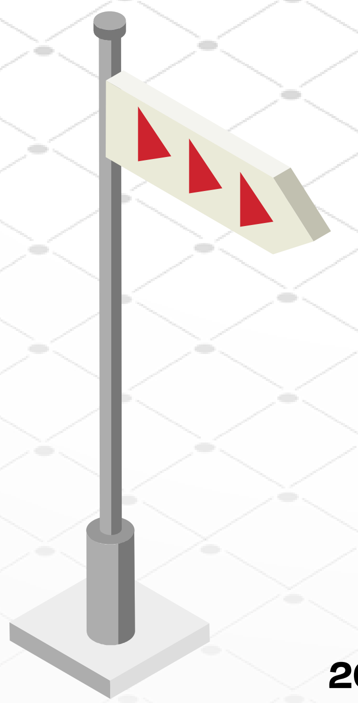
Capable PLC and SCADA are **the first and most important enablers** for all EEOs to come.

By being able to precisely control and monitor your plant you will be able to:

a **Get the most out of** equipment and each EEO or, to be more blunt, **your money**, by optimising control strategies. You are groping in the dark without proper monitoring.

b Detect faults or faulty operation.

c **Verify energy savings** from EEOs and justify them towards decision makers.



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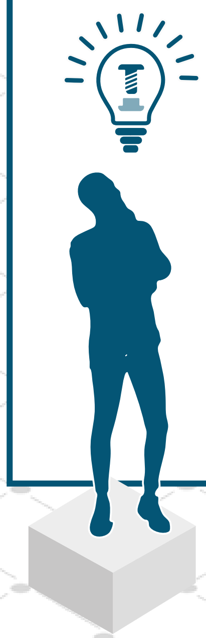
6 GOOD TO KNOW



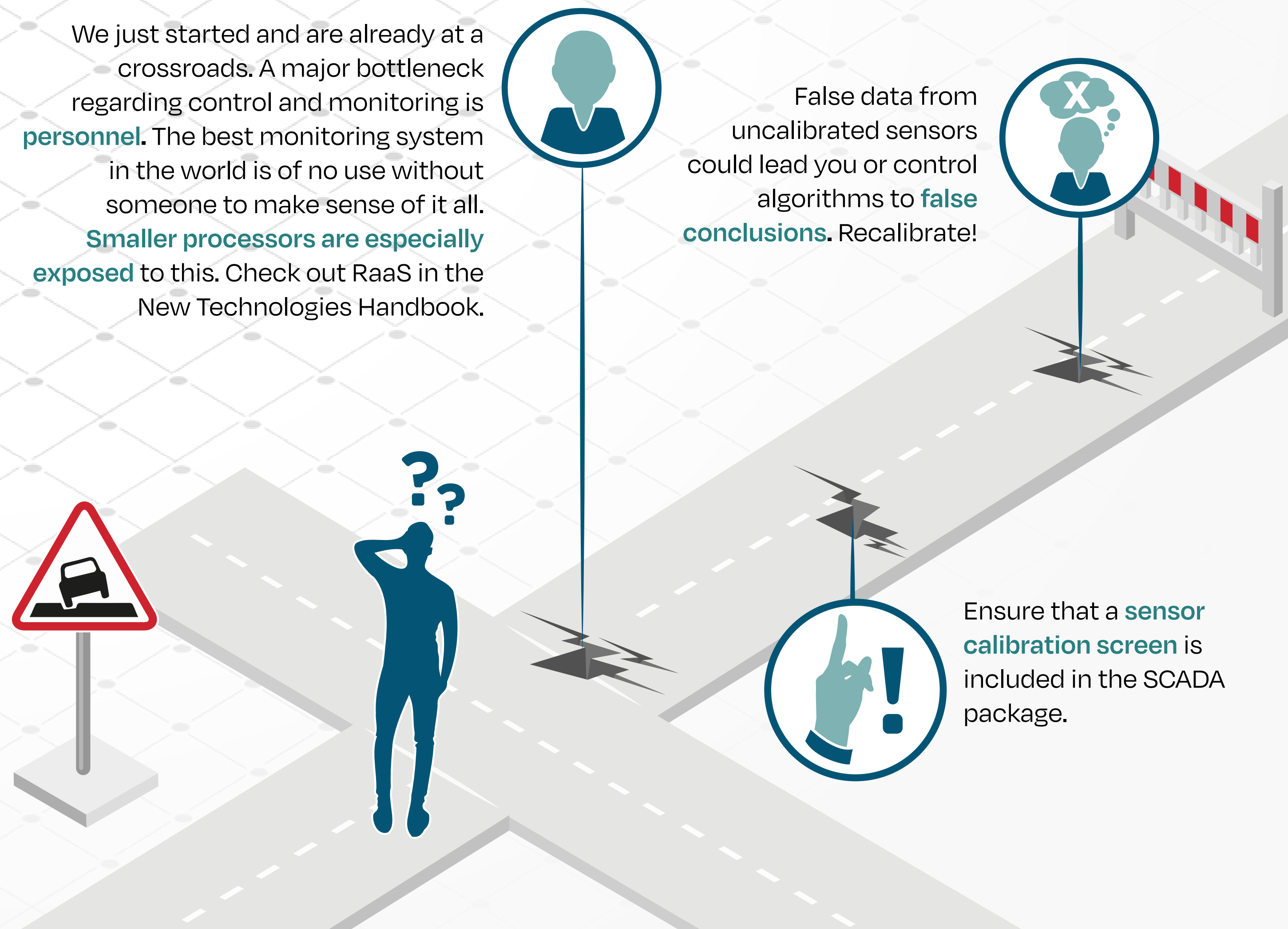
- A PLC itself **does not save energy**. But it will enable EEOs that do. **Better/upgraded control strategies** save energy, and very much so! Maybe it does not even have to be a new PLC but just a **reprogramming** of it. This might be **your cheapest and quickest way** of reducing energy demand with **immediate returns!**
- Hence, it might be a good starting point to **revisit control strategies** and optimising them if necessary.
- Use a modern **universal SCADA** system rather than a PLC specific package. Get professional advice in relation to SCADA and PLC integration with other systems on the site.
- You might be able to cross off most of what was mentioned here, but make sure there are **no omissions**. This is especially true when it comes **to implementation of sensor data in your SCADA.** Often useful signals, like speed/frequency from VSDs, which could be available are not, because they have not been put into the SCADA system.

POSSIBLE POTHOLES 7

We just started and are already at a crossroads. A major bottleneck regarding control and monitoring is personnel. The best monitoring system in the world is of no use without someone to make sense of it all. Smaller processors are especially exposed to this. Check out RaaS in the New Technologies Handbook.

False data from uncalibrated sensors could lead you or control algorithms to false conclusions. Recalibrate!

Ensure that a sensor calibration screen is included in the SCADA package.



PLANT STABILISATION

THE FOUNDATION OF AN EFFICIENT PLANT

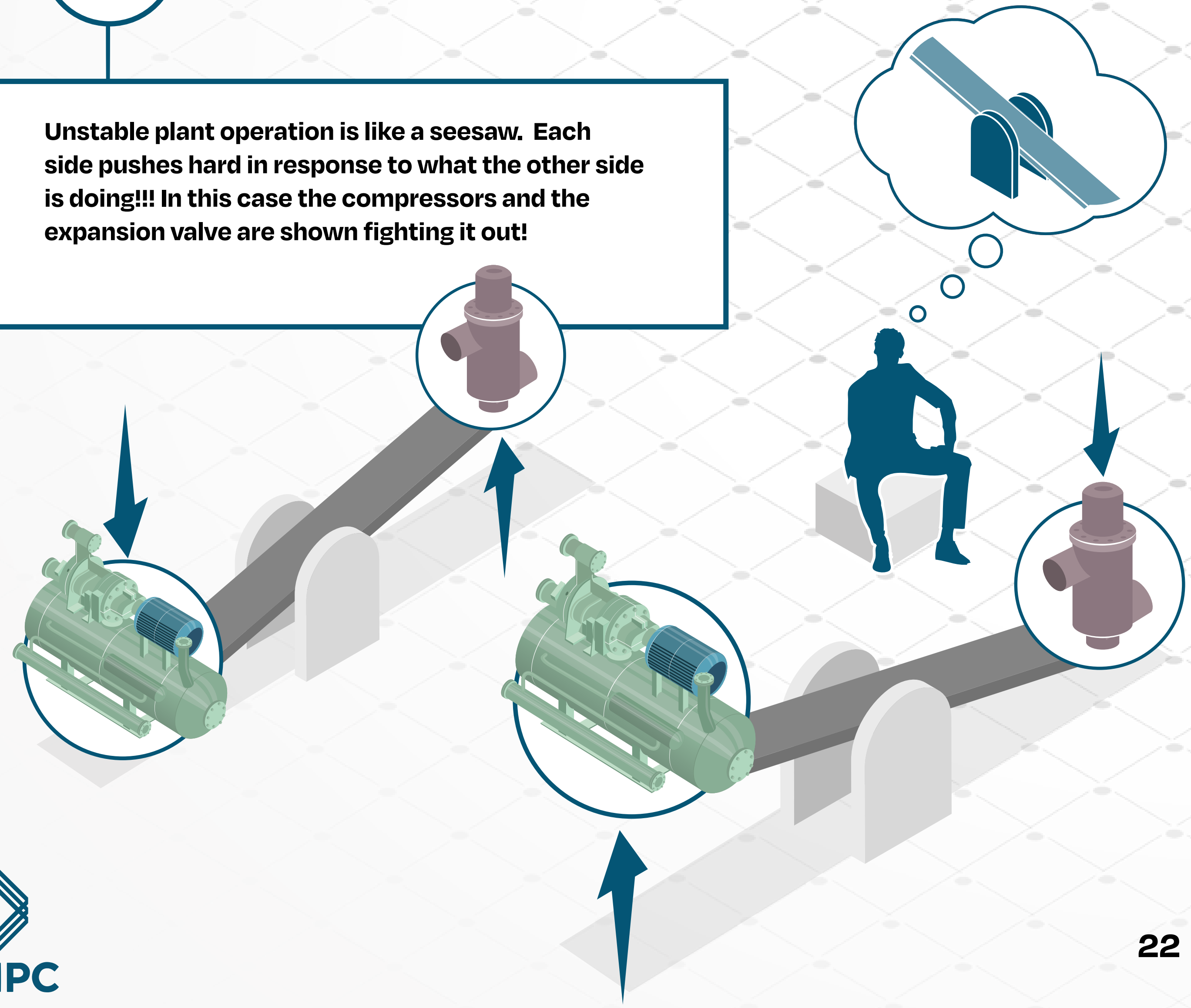
1 UNSTABLE PLANT OPERATION

Compressor and condenser fans should run steadily and only react to load and temperature changes to **minimize energy use.**

Instabilities from poor or sluggish plant control lead to **pressure fluctuations** in the system.

Controls in other parts of the plant react to these fluctuations by ramping up or down or turning on and off. If these controls are also poor, they might **overcompensate.**

Unstable plant operation is like a seesaw. Each side pushes hard in response to what the other side is doing!!! In this case the compressors and the expansion valve are shown fighting it out!



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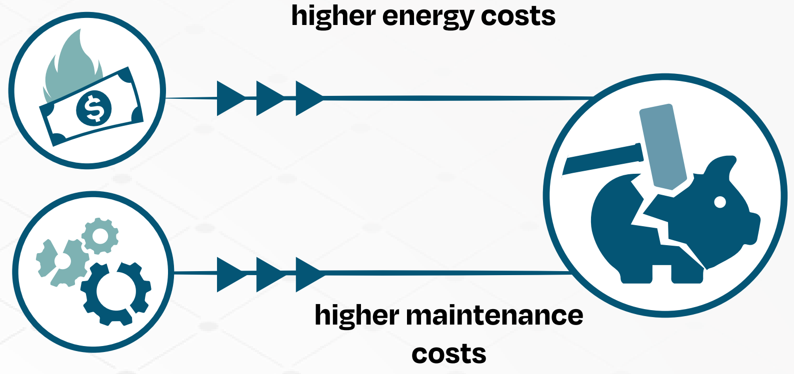
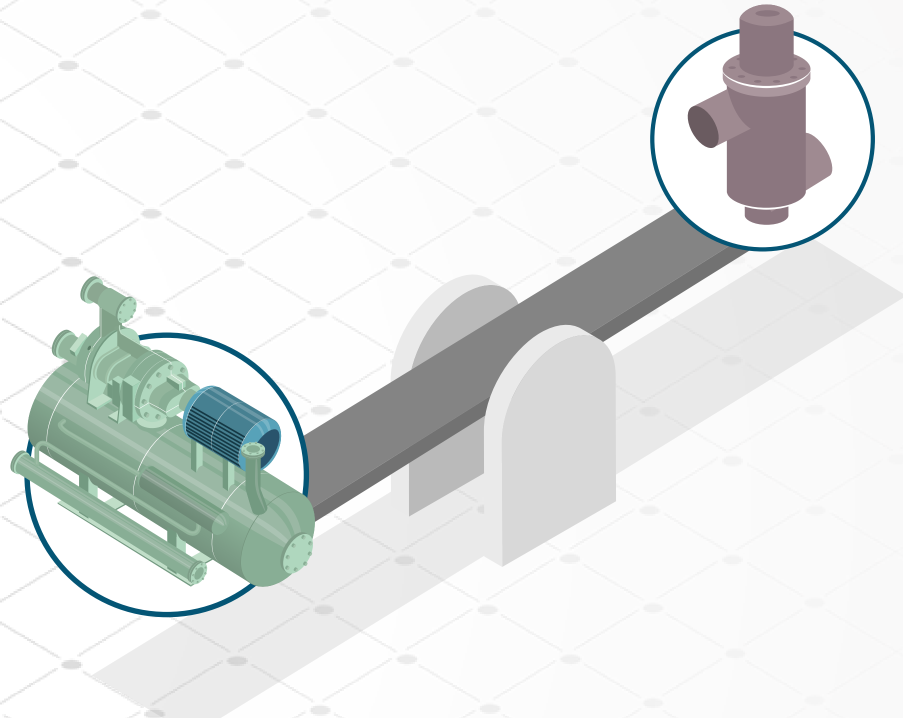
Constant ramping of compressors and fans is **inefficient** & additional compressors turning on draw high starting currents.

Compressor **short-cycling** and constantly running the compressor slide-valve up and down when mechanically loading/unloading increases **wear and tear**, further **reducing efficiency and shortening lifespan.**



2 PLANT STABILISATION

Ideally the seesaw should be in equilibrium or just move gently. Each side just doing enough push to keep the balance, but not overreact.



To achieve stable plant operation:

Firstly, **identify underlying issues** and **fix** them. More often than not they can be **traced back to** step or on/off control of expansion valves, fans or compressors.

Secondly, improve PLC control logic to **smooth the response** to any changes by responding gently and proportionately.

Refined PLC controls may help to dampen fluctuations and can be a cheap fix for hardware deficiencies, such as step control of vessel level. But it is better to **first identify and fix these deficiencies** and then optimise PLC controls.

③ DOES THIS WORK FOR ME?

Yes, a stable plant is the foundation for further energy efficiency measures. Unstable plant operation increases energy use and hamstrings other efficiency efforts.

Look for these telltale signs of an unstable plant:

- Do compressors turn on and off frequently for short periods?
- Do liquid levels in your vessels fluctuate continuously?
- Are system pressures going up and down?

④ SYNERGIES

Follows:

- **Control & Monitoring Upgrade** - allows you to implement better, quicker controls with stabilising effect. A well set out monitoring system makes it possible to **identify and then pinpoint** sources of plant instability.
- **Vessel Liquid Level Control** - if done well stabilises **suction pressure** and with it compressor operation.
- **Water Removal** - high water contents can throw off liquid level readings due to foaming and destabilise the plant.
- **Compressor Speed Control and Staging** - help to flatten remaining suction pressure fluctuations by means of better control responsiveness and accuracy.
- **Condenser Fan Speed Control** - soothes head pressure by means of better control responsiveness and accuracy.
- **Dedicated Hot Gas Compressor** - head pressure on remaining compressors does not need to be varied to accommodate defrosts/reheats.
- **Hot Gas Float Valves** - hot gas bypass from blow through due to carcass reheats can result in substantial load spikes on the high stage.
- **Bottle Neck Removal** - some bottle necks can have destabilising effects.
- **Defrost Drain To High Stage Suction** - smaller overall load spike from defrosting low stage evaporators, total avoidance of load spike on low stage.

Enables:

Energy savings from **Condenser Fan Speed Control and Evaporator Fan Speed Control** are enhanced by stable plant operation. Implementation of **Variable Head Pressure Control, Suction Pressure Optimisation and High Stage Economiser** should only be taken up on stable plants.

⑤ GOOD TO KNOW

- A variety of measures can be implemented to improve plant stability. Plant Stability is not a single EEO, but the result of **multiple refinements** and proper control throughout the plant.
- Unstable systems almost always use more energy and wear out quicker. Plant instability is almost always caused by plant control or design, and **rarely by external or process influences.**
- When it comes to controls, the plant must be considered **as a whole.** For example, poor liquid level control can lead to pressure fluctuations. If compressor control does not account for this and has been set-up rudimentary, an oversensitive staging will result in short-cycling and make things even worse.
- A well set out monitoring system (see pg. 18 - 21) helps you to first identify instabilities and later to **verify** improvements.
- Admittedly, figuring out underlying issues is not always an easy task. Get expert advice.
- Savings calculated with help of the **"Calculation Spreadsheet Tool"** assume stable plant operation, because otherwise they might not be realised. It is the very foundation on which we can build an efficient plant.

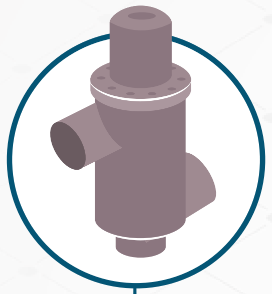
⑥ POSSIBLE POTHOLES

If large drive motors in the system run **fixed speed** only, It is often hard to achieve stable plant operation.

VESSEL LIQUID LEVEL CONTROL

TO STABILISE PLANT OPERATION

1 PROBLEMATIC LIQUID LEVEL CONTROL



An unstable plant can often be traced back to the **liquid make up in vessels** (intercooler, accumulator) and how **expansion valves** on these vessels are controlled.

In the past, liquid level was often controlled by **float switches.**

One switch located at the **minimum level**, which would **open the expansion valve** once the liquid level dropped below it, and another located at the **maximum level**, which would then **shut** the valve.

Consequently, the liquid level **fluctuates** between maximum and minimum and the **expansion valve is either wide open or completely shut**

The valve therefore operates in steps or pulses and not proportionately in response to the continuous cooling loads.

It does not always have to be float switches which cause this behaviour! Sometimes more sophisticated sensors such as **pressure level sensors** are present, but controls have been **set up poorly.** For example, a control strategy that opens the expansion valve at a set minimum level and closes it after reaching a set maximum **behaves just like float switches!**

2 FLASH GAS

This leads to uneven flash gas generation.
A brief explanation:

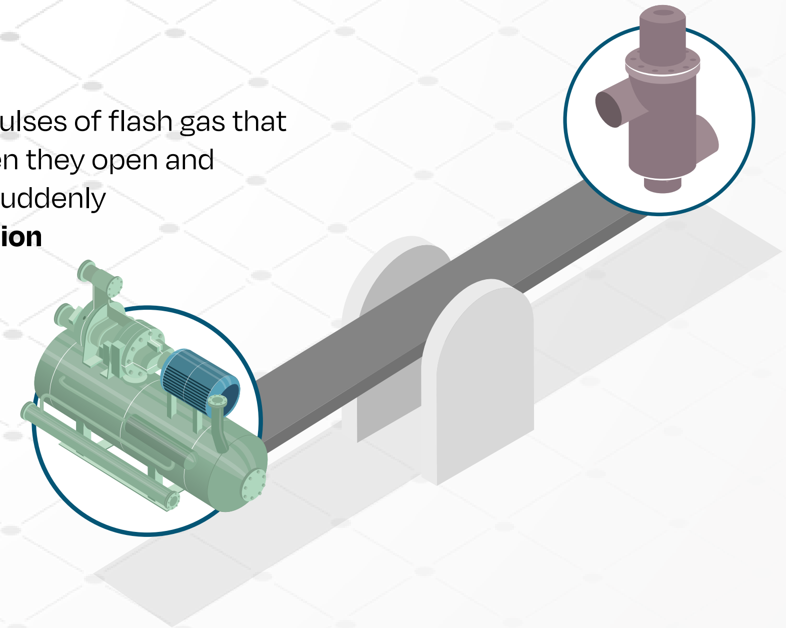
Flash gas forms when liquid refrigerant passes through the **expansion valve.** Some of the refrigerant flash evaporates and consumes heat by doing so. This cools the remaining liquid down. By turning from liquid to gas it **expands** in volume, hence the name "expansion valve". This gas generation acts as a load on compressors just like gas coming from evaporators due to cooling load.

Compressors must react to flash gas generation by **ramping up and down** and worst case turning **on and off.**

This fluctuation **propagates** from low to high stage compressors and all the way to the condensers making the plant run in an unstable manner.

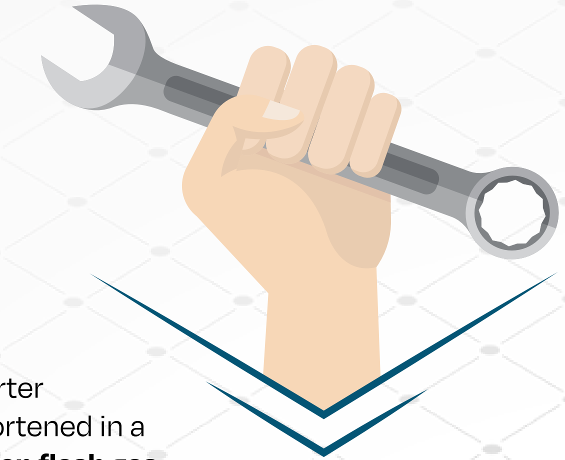
3 STEADY LIQUID LEVEL CONTROL

Instead of creating intermittent pulses of flash gas that overwhelm the compressors when they open and then do the opposite when they suddenly close, we can **operate the expansion valve continuously.** In this way flash gas forms steadily and can be sucked up by the compressors just as steadily. This can be done via a motor valve regulated by a pressure level sensor for example.



The following fix can be applied to make flash gas generation effectively continuous, even with float switch control:

④ A POSSIBLE FIX



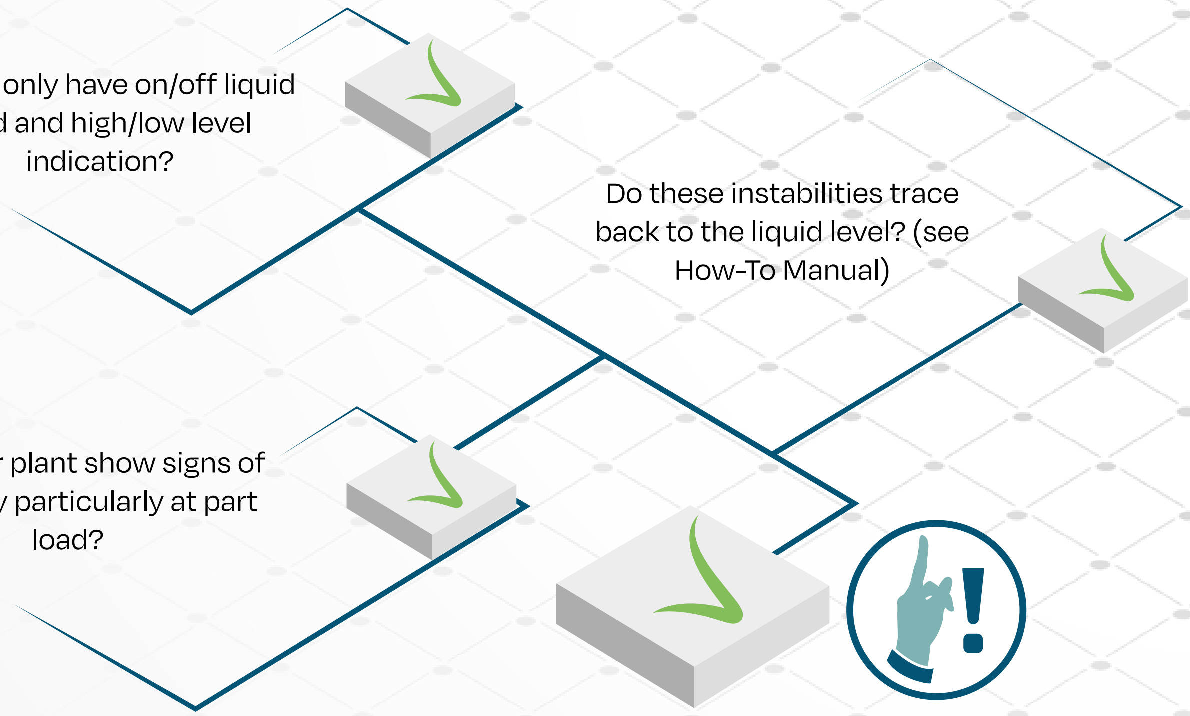
If a vessel is controlled via float switches, there is a possible fix that **does not require any hardware.**

Variable bandwidth control only needs a **competent PLC programmer** and uses much shorter pulses which are extended or shortened in a clever way to **effectively smoothen flash gas generation** and pressure fluctuations.

HOW-TO MANUAL

For detail on how this works and can be implemented look into the **How-To Manual** under this EEO.

⑤ DOES THIS WORK FOR ME?



You need to fix this issue! You can either upgrade to pressure level sensors and a motor-expansion valve that lets you regulate refrigerant flow and liquid level precisely or you have to implement variable bandwidth control as a quick but proper fix.

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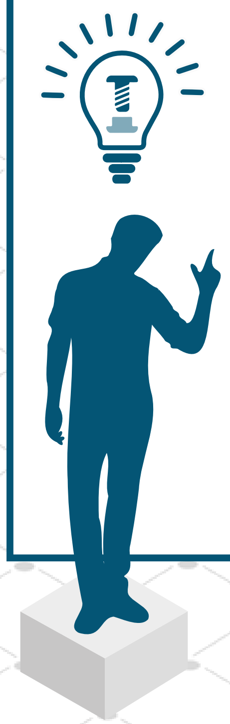
⑥ SYNERGIES

Enables:

Liquid level control might be one of the **major underlying issues** of an unstable plant. Solving it could drastically improve and **enable "Plant Stabilisation" and all associated followers.**

⑦ GOOD TO KNOW

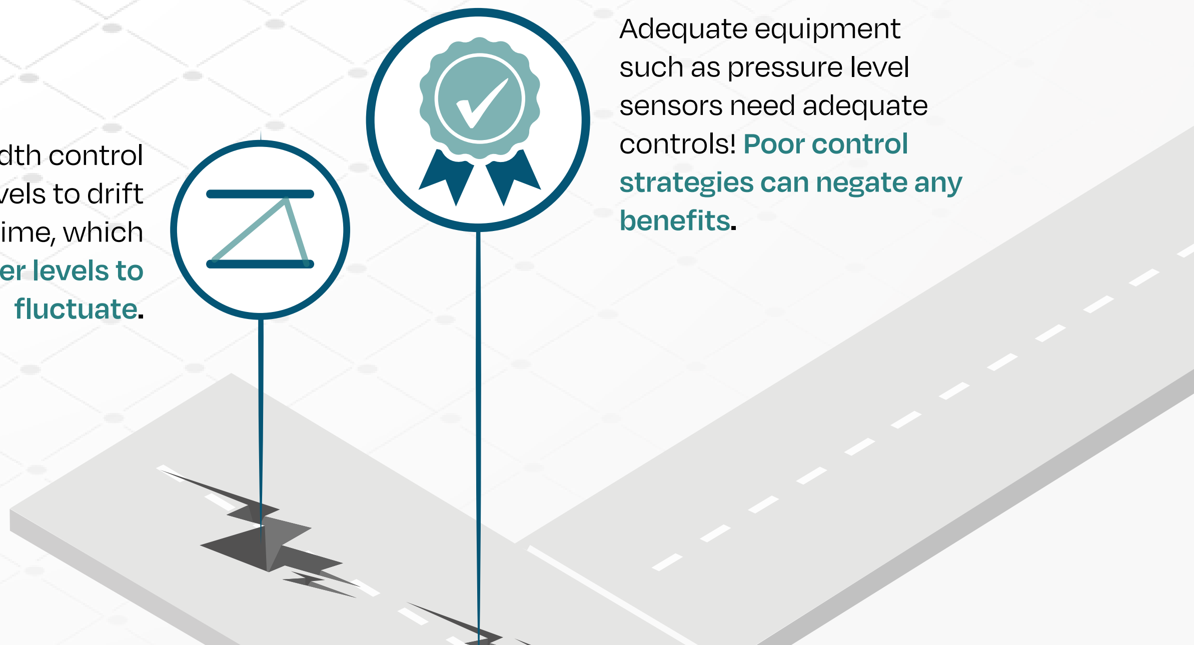


- This is another example of a **part load problem**. When there is **much vapour coming from evaporators** due to cooling demand, **flash gas has little impact**. At part load however, with **little vapour load** from evaporators, the effect of flash gas generation has a **major impact** on compressor load.
- In its essence this can be as simple as a control upgrade but will have major ramifications on plant efficiency. Having a **good PLC** (see pg. 18 - 21) and a **competent PLC programmer** at hand makes this much easier to implement.
- **Variable bandwidth control** is an effective interim or even permanent control strategy as long as fixed level control is not critical.
- If you have a multitude of vessels and all are controlled well, **except for that one old vessel** which is still on float switches, this might be **enough to throw off your plant's stability.** Make sure this has been taken care of across the board.

POSSIBLE POTHOLES ⑧

Variable bandwidth control will cause liquid levels to drift up and down over time, which may cause receiver levels to fluctuate.

Adequate equipment such as pressure level sensors need adequate controls! Poor control strategies can negate any benefits.



CONDENSER FAN SPEED CONTROL

1 HEAD PRESSURE CONTROL

After the vapour has been compressed to hot gas, it is discharged by the compressors. The **discharge pressure** often is referred to as **head pressure.**

▼

Head pressure relies on **condensing temperature**, which in turn depends on ambient conditions and condenser capacity.

▼

We cannot influence the ambient, but we can **regulate capacity using condenser fans.**

▼

Fans are designed to meet peak cooling demands at peak design temperature.

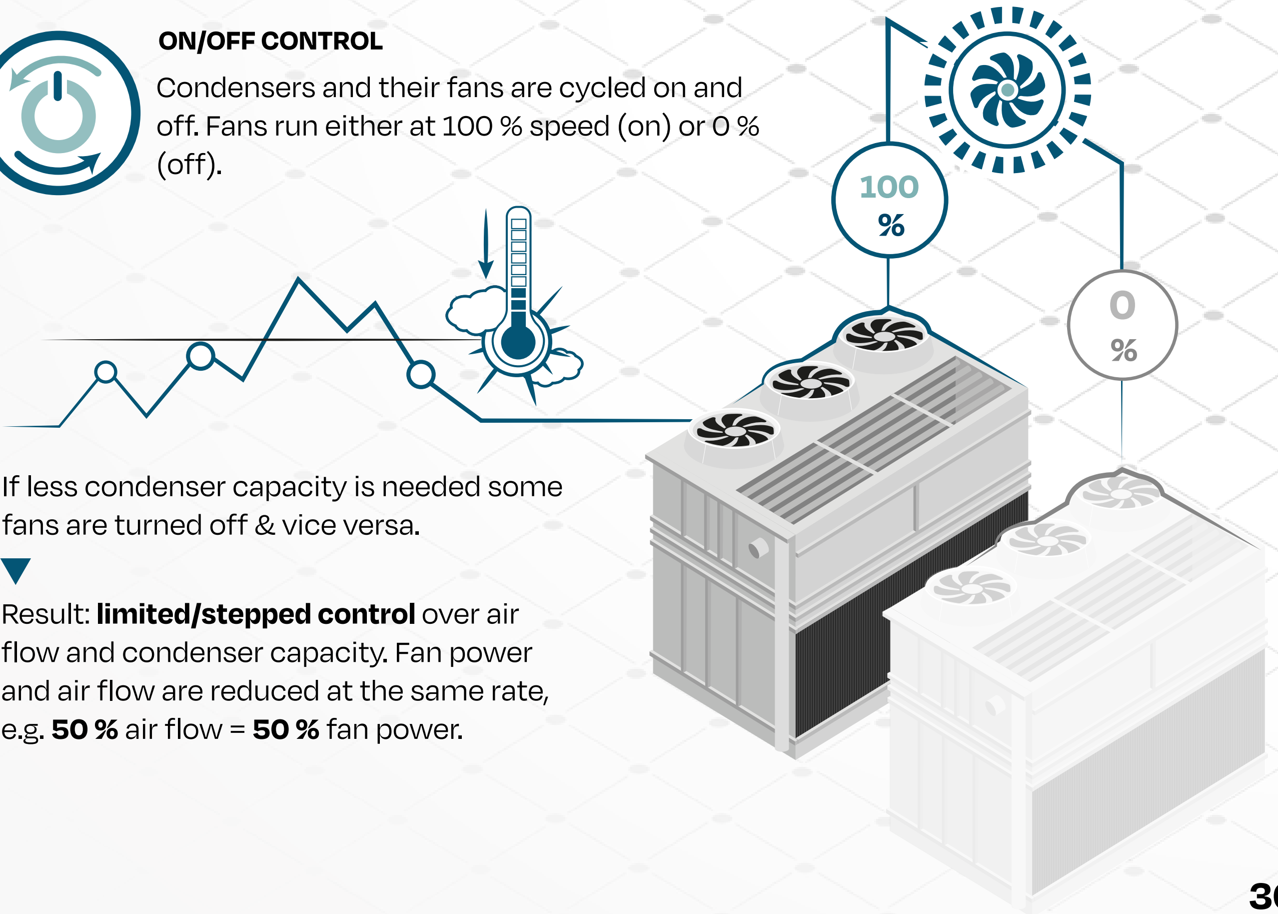
▼

If ambient is cooler than the design temperature and/or the cooling load is not at peak design load, full fan power is **not needed.**

2 COMMON PRACTICE

ON/OFF CONTROL

Condensers and their fans are cycled on and off. Fans run either at 100 % speed (on) or 0 % (off).



If less condenser capacity is needed some fans are turned off & vice versa.

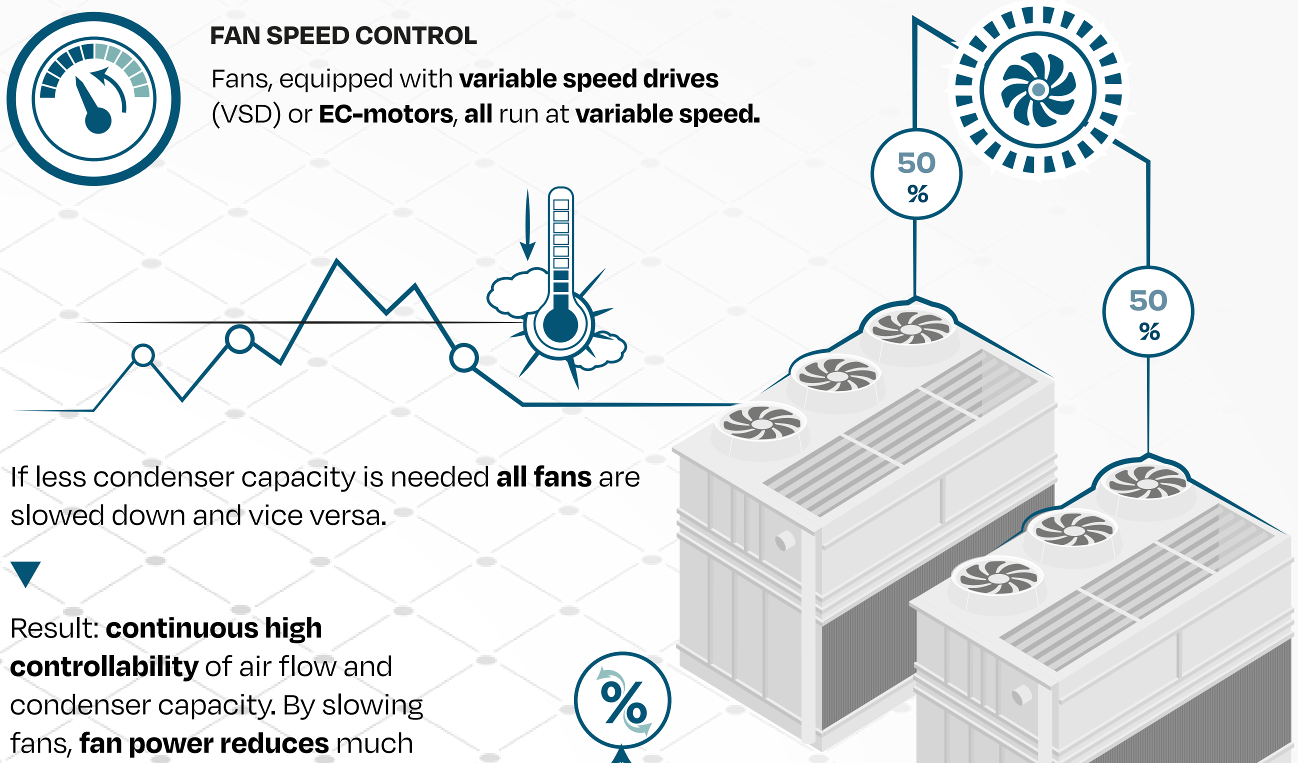
▼

Result: **limited/stepped control** over air flow and condenser capacity. Fan power and air flow are reduced at the same rate, e.g. **50 %** air flow = **50 %** fan power.

3 BETTER PRACTICE

FAN SPEED CONTROL

Fans, equipped with **variable speed drives** (VSD) or **EC-motors**, **all** run at **variable speed.**

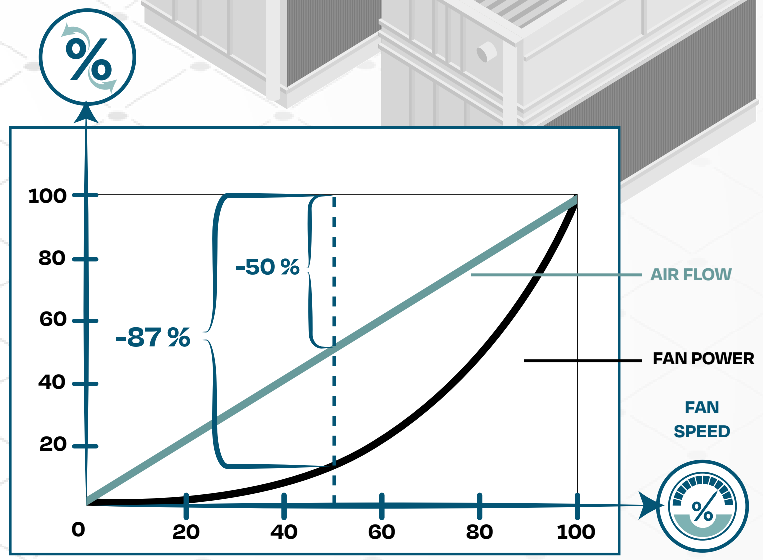


If less condenser capacity is needed **all fans** are slowed down and vice versa.

▼

Result: **continuous high controllability** of air flow and condenser capacity. By slowing fans, **fan power reduces** much quicker than air flow, see graph. **Highly reduced** fan power at part load,

50 % air flow≈**13 %** fan power.



4 BENEFITS

vs.

ON/OFF CONTROL	FAN SPEED CONTROL
High energy use at part load	Significantly **less energy** use at part load
Stepped, bad controllability	**Continously, highly** control-lable
Higher **wear & tear due to startups**	**Smoother** plant operation and significant maintenance savings for fan belts
Noisy restarts & screeching belts	**Low** noise operation

SAVINGS (energy & maintenance)

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5 DOES THIS WORK FOR ME?

CHECKLIST

Are your condenser fans speed controlled?

Install VSDs on all condenser fans. Consider a **Condenser Upgrade** (see pg. 74 - 79) before investing in old condensers. **Implement proper fan control logic.**

Perfect!

Try implementing **fan speed** into your **monitoring system** to check if control strategy is good, that the plant runs steadily (stable) and fans are running smoothly.

SYNERGIES 6

Condenser Fan Speed Control is a Follower and Enabler of Plant Stabilisation.

Follows:

- The full potential of condenser fan savings is achieved with **Plant Stabilisation** after suction pressure/compressor operation has been stabilised. If fans must constantly ramp up and down due to pressure fluctuations coming from the compressors, intended savings from running fans at part speed will only partly be achieved.
- Condenser capacity gained from **Air Removal, Bottle Neck Removal (Undersized Condenser)** and **Condenser Upgrade** helps to slow fans down and save energy.

Enables:

- Helps **Plant Stabilisation** by stabilising head pressure with quick and precise control response to disturbances.
- **Variable Head Pressure Control** requires prior implementation of **Condenser Fan Speed Control** to regulate head pressure effectively.

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7 GOOD TO KNOW

- You need to equip **all** condensers with VSDs, not just single ones.
- If some condensers are more efficient than others (see Hard Yards), this can be compensated for once all condensers have **fan VSDs.**
- Noise generated and power used by fans are directly **proportionate** - if your condensers are less noisy you are also saving fan power.
- By running all the condensers fans together there is less outlet pressure variation between condensers - makes it easier to **design the drains lines** to the receiver!

POSSIBLE POTHOLES 8

VSDs need to be in a cool, clean environment or they could trip out on **hot days.**

Only retrofit newer condensers with enough lifetime left on them.

▼

Short remaining lifetime makes it **harder** for investments into VSDs to pay off.

Cheap VSDs may cause **harmonic problems** on site that can damage electronics.

Make sure you have the **right control system** (suitable PLC) that can be programmed for this control.

VSDs need to be **kept clean.**

COMPRESSOR SPEED CONTROL & STAGING

1 SUCTION PRESSURE CONTROL

Suction pressure is the pressure at which the compressors suck in the vapour from the accumulators/intercooler.

Suction pressure is **controlled by compressor operation.**

Vapour is fed into these vessels from the various **evaporators,** where it **absorbed heat for refrigeration purposes**, and from the **expansion valves**, due to **flash gas generation.**

The **more cooling load** is on the system, the **more vapour** ends up inside these vessels where it would lead to a **pressure increase**, if it is not removed.

So, the compressors must suck out as much vapour as is coming in by matching their capacity, or in other words their gas throughput, to the vapour/refrigeration load. FYI, this is why unsteady flash gas generation from vessel liquid feed can be problematic, see pg. 26 - 29.

This means, if more vapour is coming into the vessel and **pressure rises**, compressors must **ramp up** their capacity to take in more vapour. On the other hand, if pressure drops, so should compressor capacity.

How compressor capacity is managed depends on the **control mechanisms at hand and strategies implemented into the PLC/controls.** The former is **hardware** related; the latter is not, provided adequate control systems are available (see pg. 18 - 21). Let's have a look at the two relevant control mechanisms for industrial-type screw compressors and how we can finetune control strategies to achieve maximum energy efficiency and savings.

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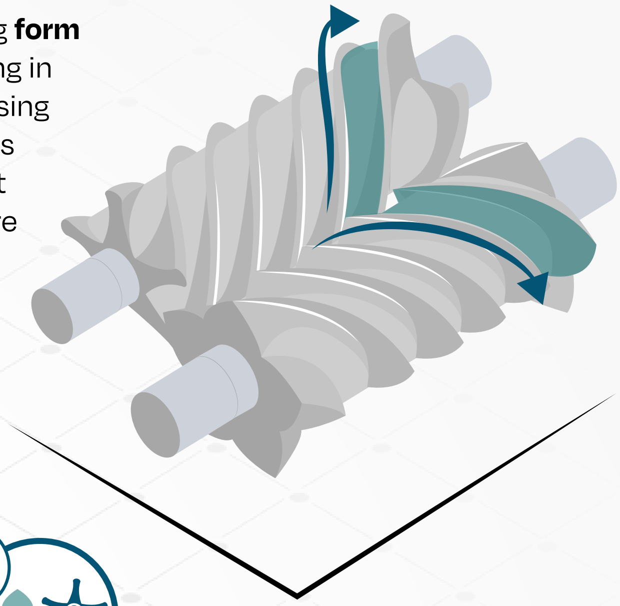
2 CONTROL MECHANISMS

The rotating screws and the surrounding housing **form compression chambers** that widen, when sucking in vapour, **shut**, and then **narrow** in, when compressing it. The volume of these chambers is referred to as the **swept volume** (for reference, this means just the same as in a piston engine you might be more familiar with) and determines how much vapour is taken in per compression cycle.



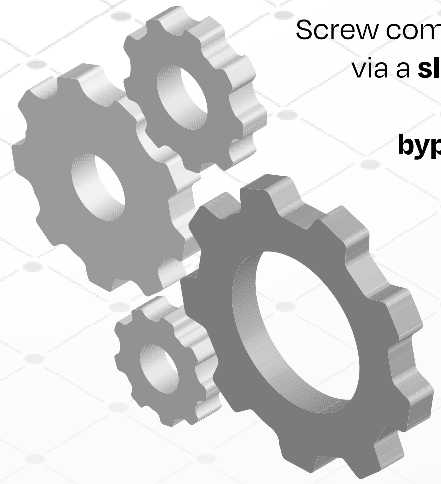
▶ **To regulate vapour throughput, you have two options:**

1. **Modify swept volume**, therefore taking in more or less vapour per compression cycle → **mechanical unloading**

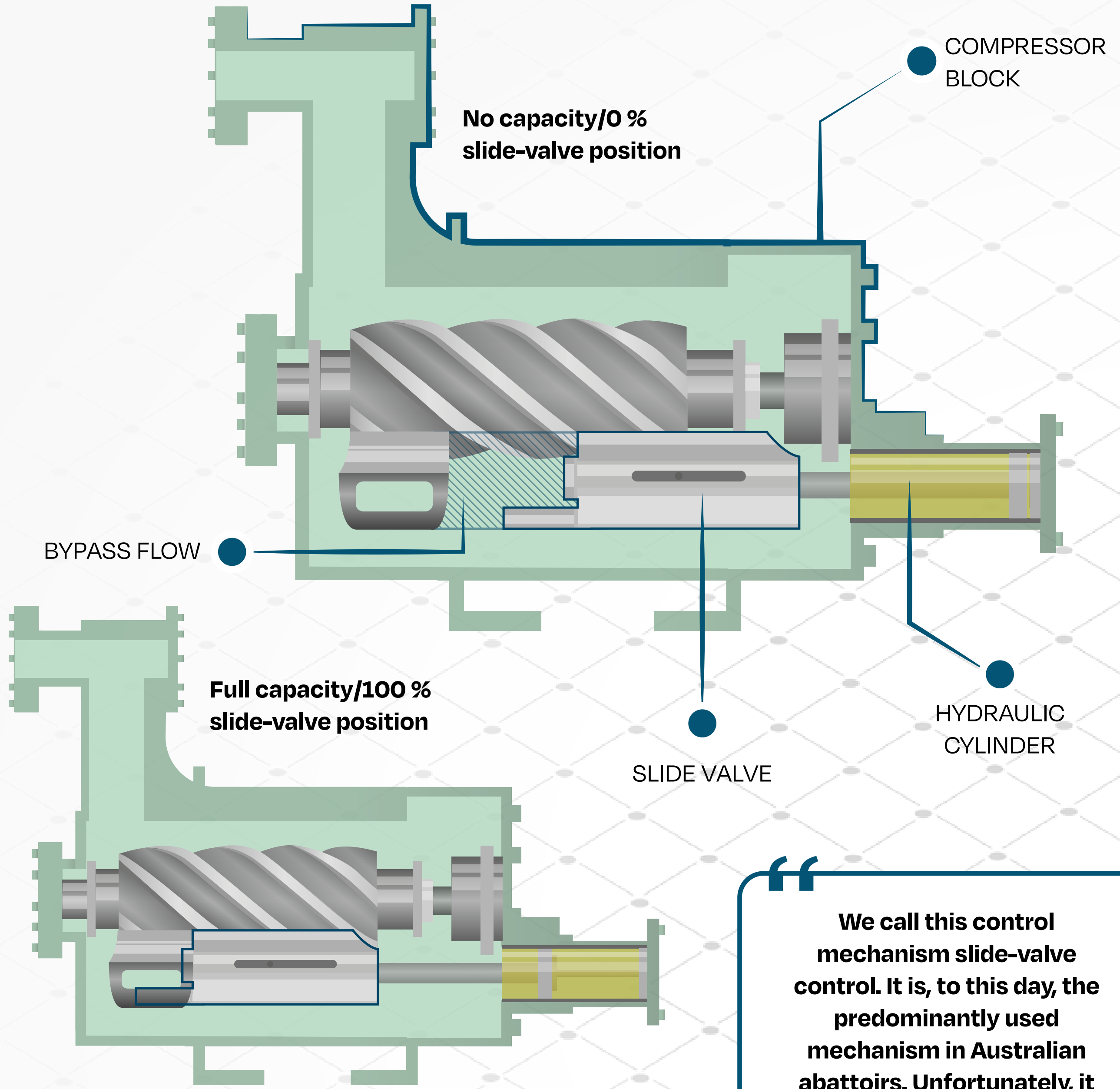
2. **Modify speed** of the screws' rotation to increase or slow the rate of compression cycles per time → **speed control**

SLIDE VALVE / MECHANICAL UNLOADING 3

Most compressors run at **fixed speed.** So, if we cannot modify speed, that leaves us only with **varying the swept volume:**



Screw compressors can regulate their swept volume via a **slide-valve** that exposes part of the screws, preventing this part from sealing off and **bypassing** it. This effectively **removes part of the swept volume** of the compression chambers formed by the rotating screws.

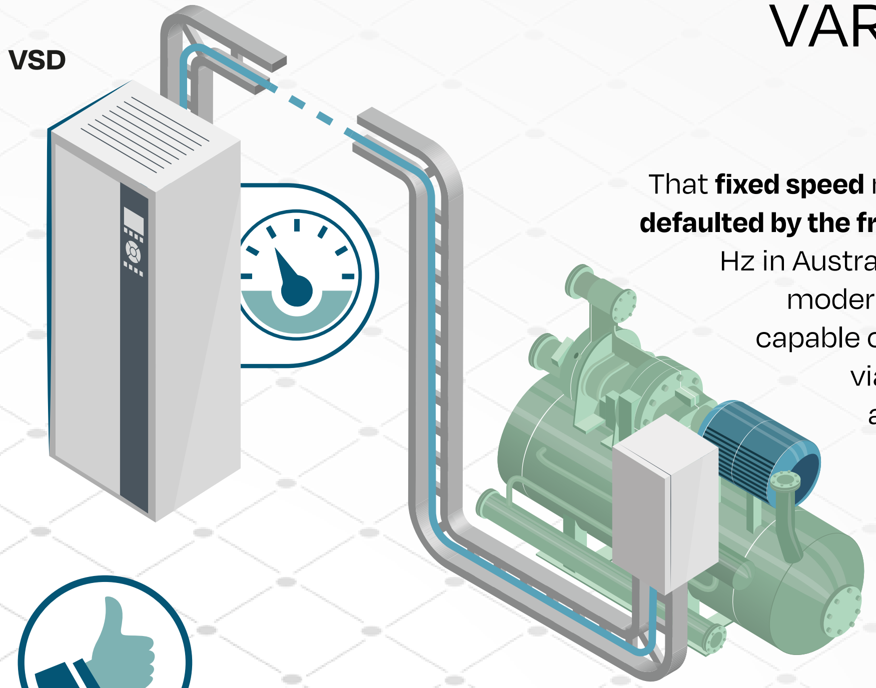


"We call this control mechanism slide-valve control. It is, to this day, the predominantly used mechanism in Australian abattoirs. Unfortunately, it has a few draw backs."

- **Bypass** gas flows result in **considerable energy losses.**
- The position of the valve is controlled by a hydraulic oil cylinder. Changing the slide position is a **sluggish** process, not well suited to quickly react and straighten out suction pressure fluctuations.
- Heavy use with constant swaying of the slide valve can lead to **exacerbated compressor wear.** Slide valve mounts and bearings can wear out resulting in the slide valve banging against the sensitive sealing tips of the screws, which are crucial for energy efficiency of the compressors, see pg. 54 - 57.

VARIABLE SPEED CONTROL ④

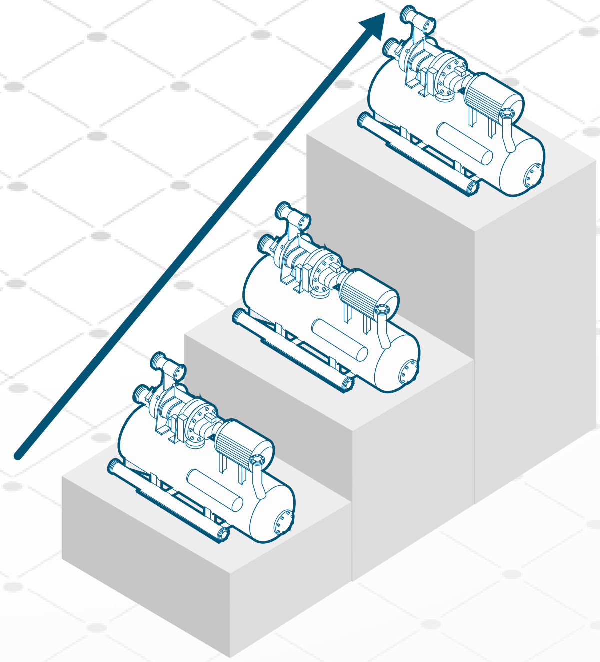
That **fixed speed** most compressors run with is **defaulted by the frequency of the power grid** (50 Hz in Australia). Thanks to the wonders of modern-day technology, we are now capable of transforming the frequency via a **variable speed drive or VSD** allowing for **compressor speed control.**



- By varying the speed, controls can regulate the number of compression cycles per time rather than changing the swept volume via slide-valve. Instead, compressors run fully loaded (100 % slide-valve position) **without associated energy losses.**
- Very **fast responding** times for capacity control **improve plant controllability and enhance plant operation/stability.**
- **Reduced wear and tear** on compressors associated with slide-valve operation.

COMPRESSOR STAGING ⑤

A staging strategy typically manages the following:



Prioritising operation of certain compressors over others – newer, less worn, **efficient compressors should have priority** over older compressors.

Lead-duty – lead compressors modulate their load either via speed or slide-valve position to match cooling demand. Compressors with speed drives should take the lead allowing all other compressors to run fully loaded.

→ minimize mechanical unloading

Rotate compressor duties – makes sure compressors are not short-cycled & rotates compressor duty where possible to spread wear evenly.

HOW-TO MANUAL

For more information check out Compressor Speed Control & Staging in the How-To Manual.

DOES THIS WORK FOR ME? 6

CHECKLIST

Do you have a **good*** staging strategy with **variable speed** control?

No **modification** needed

*See How-To-Manual for examples of good practice staging and make sure your controls account for them.

Are your compressors in **good condition** & only a few years old?

Retrofit at least one VSD to **the biggest compressor** (or more) and implement control logic.

Consider **replacing** worn down/old compressors. Make sure at least one of them is equipped with a VSD. **Do not** invest in a VSD on an old worn out compressor.

SYNERGIES 7

Follows:

Staging greatly benefits from accurate compressor efficiency measurements with **Suction Flow Meters.** Efficient compressors can be given the highest priority with worn compressors put at the end of the sequence.

Enables:

- Speed control and good staging are a part of **Plant Stablisation**, as it can react much more quickly to disturbances preventing them from building up.
- Part loading compressors more efficient with the help of a VSD enables savings from reduced heat load due to **Evaporator Fan Speed Control.**
- Slide-valve unloading opens the economiser port to suction. Hence, effective use of a **High Stage Economiser** requires compressors to run at 100 % slide position/speed controlled.
- Staging determines which compressors will run the most. These should be fitted with **Efficient Compressor Motors.**

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8 GOOD TO KNOW

- Equip at least the compressor with the **largest capacity** with a VSD. This way it operates as the lead compressor while all others run at 100 % or 0 % but on/off cycling is reduced to a minimum.
- VSDs can operate your compressors at **higher speeds** (60 Hz) and with it **increase their capacity.**
- A good staging control makes sure recently turned off motors stay off for a minimum time frame. This lets them cool down and avoids overheating to **reduce stress**.
- **Good band-aid**: if your compressor is excessively large, you can fix that problem. instead of replacing it you can run it at lower speed and generate the same outcome.
- We are starting to see the bigger picture. Understanding how compressors react to vapour load fluctuations, we can see why it is important **to look at the plant as a whole** and take care of things like vessel liquid feed, see pg. 26 - 29.
- Old worn compressors must **not necessarily** be replaced. If they are put at the end of the compressor sequence and are rarely used, their inefficiency does not weigh heavy on the plant's total energy use, given compressors further up the sequence are efficient.
- Compressor duty and sequencing are sometimes managed manually. Humans are **prone to mistakes**. The wrong compressor could end up running over an entire weekend or even months. **Automated staging** solves this problem.

POSSIBLE POTHOLES 9

Only retrofit newer compressors with enough lifetime left on them.

▼

short remaining lifetime makes it harder for investments into vsds to pay off.

Make sure you have the right control system (suitable PLC) that can be programmed for this control.

VSDs need to be kept clean.

VSDs need to be in a cool, clean environment or they could trip out on hot days.

Cheap VSDs may cause harmonic problems on site that can damage electronics.

AIR & WATER REMOVAL

1 AIR CONTAMINATION

Low-temperature ammonia systems run at **vacuum.**

Outside **air and water** vapour can enter system through leakages.

Water and air **accumulate** over time and reduce system efficiency.

Water accumulates in the cold parts of system (medium & low stage vessels).

Water forms solution with liquid ammonia.

Ammonia-water-solution evaporates at lower pressure than pure ammonia.

Suction pressure must be reduced to achieve same evaporation temperature.

Air accumulates in warm parts of system (condensers).

Heat exchanging surface is reduced and with it capacity of condenser leading to higher energy use. (See also: bottle neck removal – undersized condenser).

Pressure difference on compressors rises & with it energy consumption.

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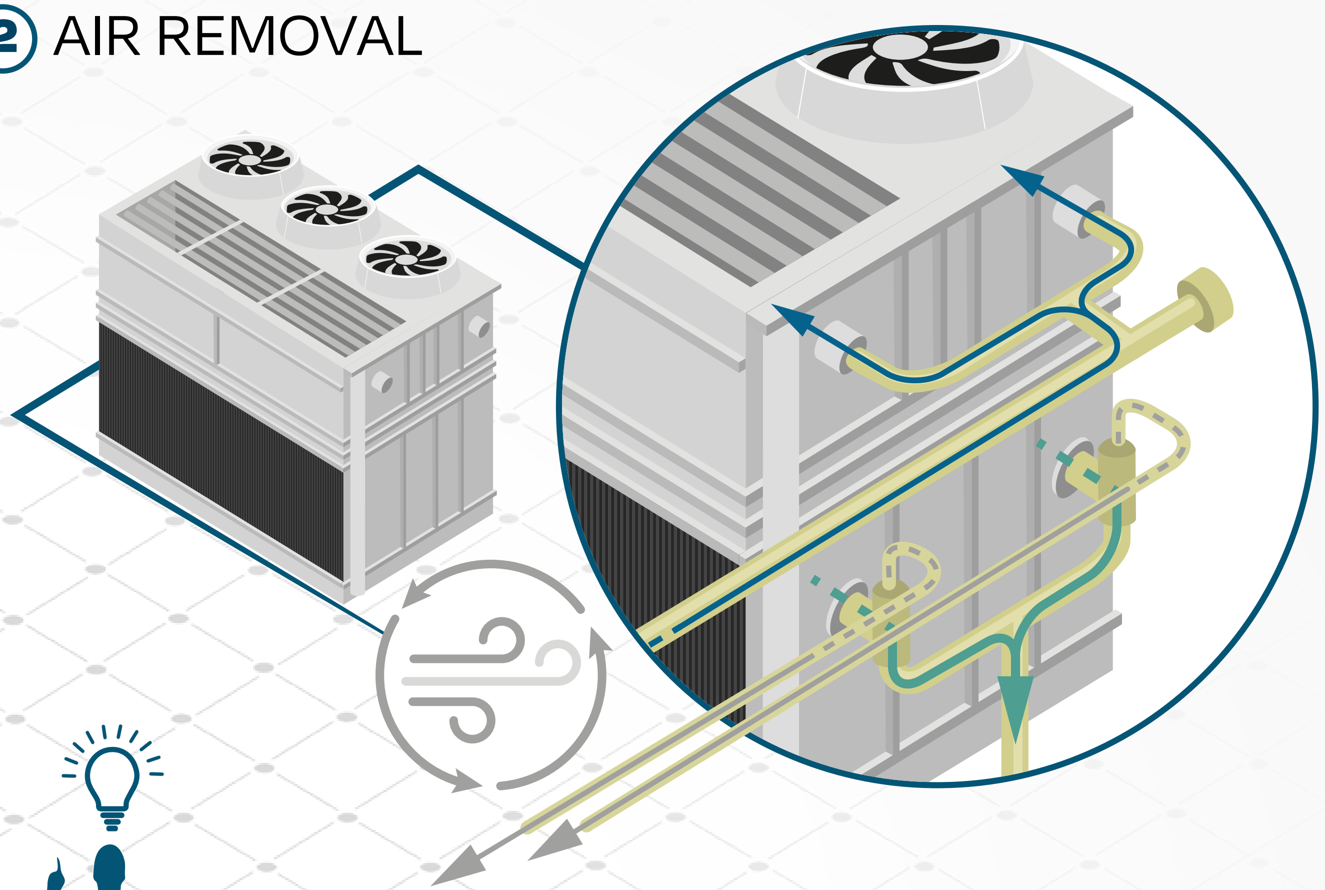
2 AIR REMOVAL



- **Most ammonia systems require air purging.**
- **Systems running at low pressure require continuous air purging**

- If you have not done so already, install **air purging systems** on your condensers
- If air is purged manually, make sure this is done **regularly**!

WATER REMOVAL 3

Most ammonia systems have air purging systems, but often that is not the case for water removal.

There are different possibilities to remove water:

WATER-PURGER

REPLACE REFRIGERANT

WATER-PURGER

- Install an auto-purger that constantly removes small amounts of water from your system
- Or: rent a water-purger from time to time

REPLACE REFRIGERANT

- Ammonia is a relatively cheap natural refrigerant.
- By replacing refrigerant you also get rid of the water within.

source: Hansen Technologies

DOES THIS WORK FOR ME? (4)

Are you getting **a bit of water** with the oil when you drain?

Sure sign of too much water in the ammonia!

Are condenser fans running disproportionately hard on **cold days** when the plant is at part load?

Accumulated air on the inside might be the problem.

Do you run suction temperatures **below -33 °C?**

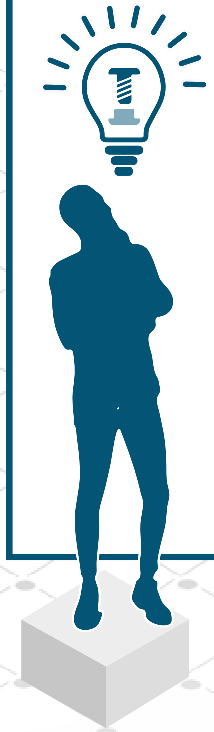
Below that temperature threshold you operate at a vacuum and run at higher risk of air contamination.

(5) SYNERGIES

Enables:

- **Fan Speed Control + Variable Head Pressure Control** - both benefit from condenser capacity, which would be lost to **air** accumulation if not removed properly.
- **Plant Stabilisation** - High water contents can result in inaccurate, fluctuating vessel liquid level readings due to foaming. This in turn throws off vessel liquid control and destabilises the plant.
- **Suction Pressure Optimisation** - Removing water enables you to increase suction pressure.

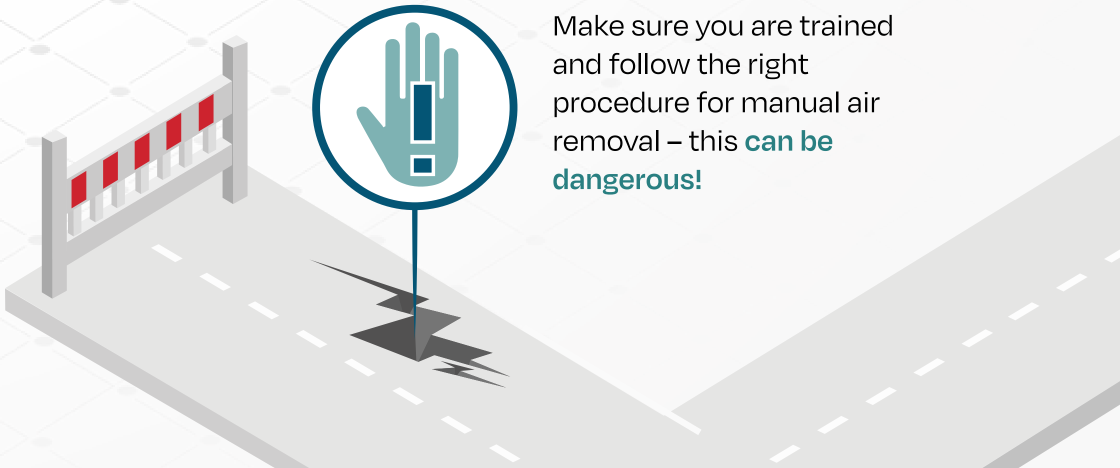
(6) GOOD TO KNOW



- If your system uses high side float valves, make sure you **purge air** from them too!
- As long as you run the lowest pressure in the ammonia system above atmospheric pressure you should have less air and water in the system. Run the suction **above -33.3 °C** saturated suction temperature.
- Make it a **regular habit** to feel the temperature of condenser exit lines especially if these have purge pots – cold lines often indicates air accumulation.
- Water accumulation is **more rapid** in summer and in humid climates due to the high moisture levels in the air that the plant sucks in!
- Dedicated air collection points and multi-point automatic purging generally required.
- Manifolded air collection lines used with single-point purging just circulate air around system.

POSSIBLE POTHOLES (7)

Make sure you are trained and follow the right procedure for manual air removal – this can be dangerous!



OIL INJECTION OPTIMISATION

FOR SCREW COMPRESSORS

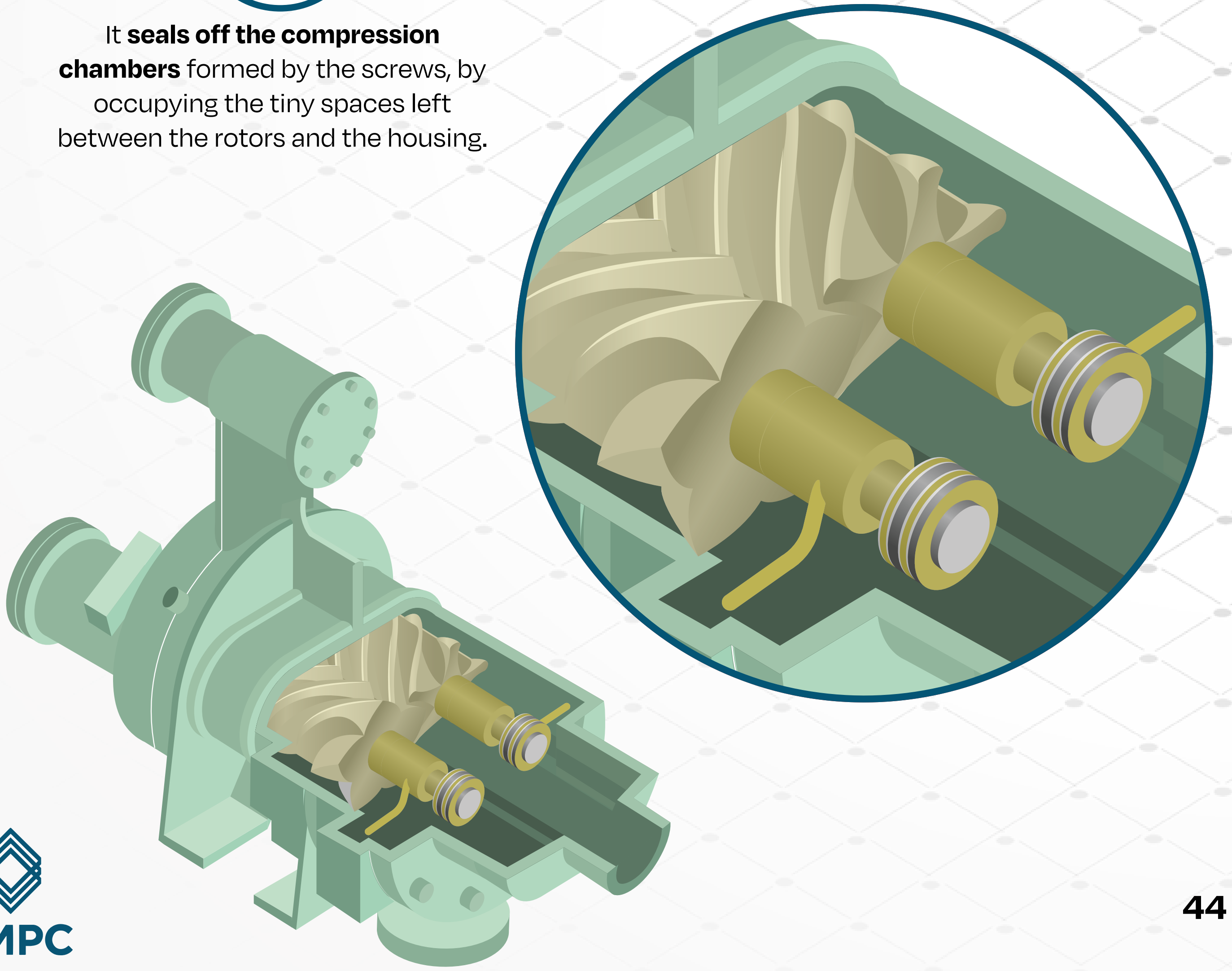
① OIL FUNCTIONS

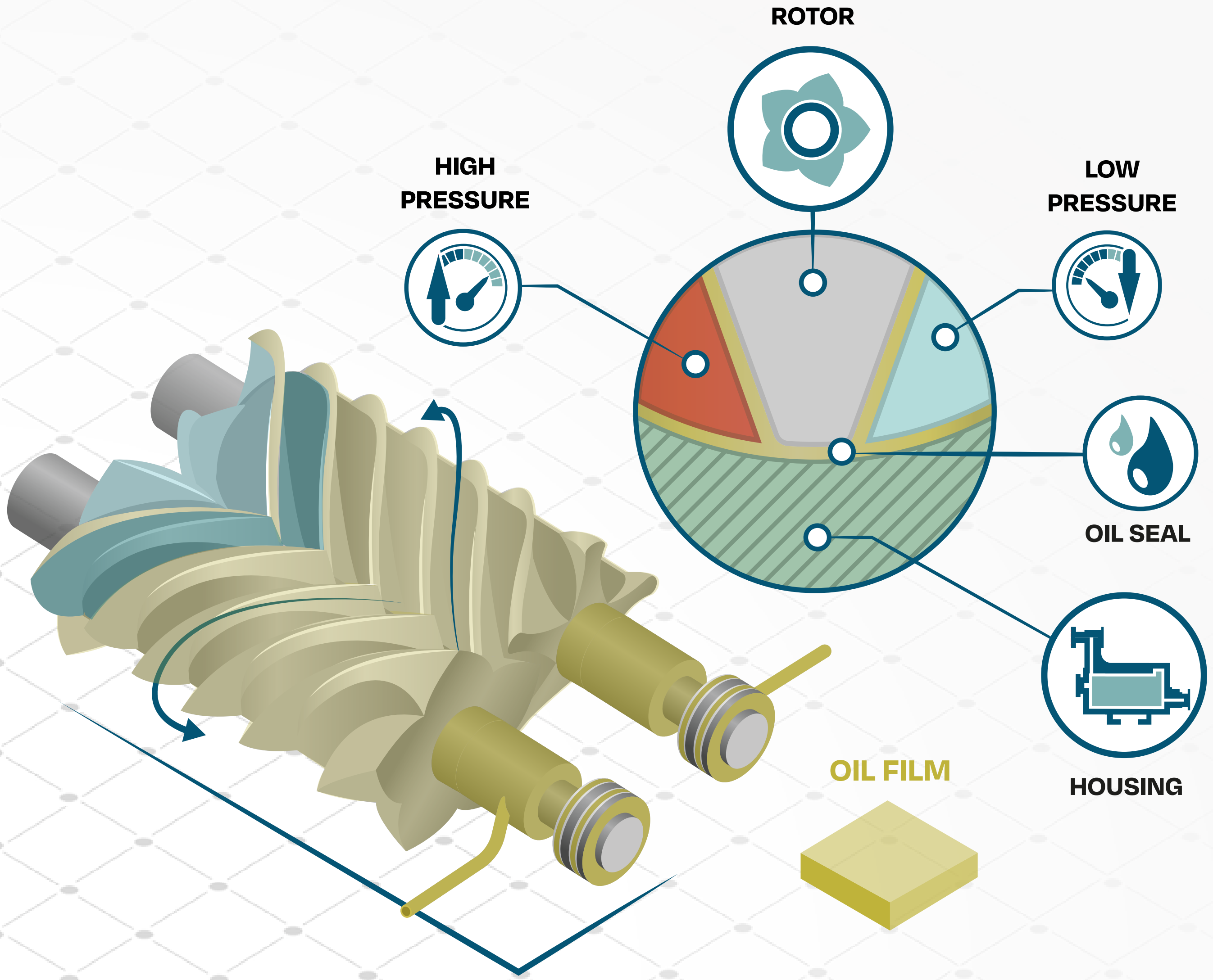
Oil is injected on the inside of each screw compressor where it serves **multiple functions:**

The most obvious is **lubrication of bearings and moving parts.**

It also absorbs some of the compression heat and **cools the compressor.**

It **seals off the compression chambers** formed by the screws, by occupying the tiny spaces left between the rotors and the housing.





② INJECTION OPTIMISATION

For each compressor there is an **optimum amount of oil** that should be injected. Deviations from this optimum will result in efficiency loss and other less desirable consequences. Especially oil **overfeed** can lead to **over compression** and associated energy penalties.

Easy **indicators** to identify compressors with less ideal oil injection are compressor **discharge temperatures** during operation. Discharge temperatures that **deviate from the mean** could potentially stem from **oil over- or underfeed.**

Lower discharge temperature due to surplus cooling from the oil indicate **overfeed**, while **higher** temperatures point towards **underfeed.**

"Compressors with **roller bearings** can operate at very low speeds. It might be recommended to adjust oil injection rates at these lower speeds. **Check with the manufacturer!"**

3 DOES THIS WORK FOR ME?

CHECKLIST

Do discharge temperatures of your compressors vary across each stage?

Discharge temperature variations between the compressors of a corresponding stage could be an indication that this is not managed properly.

Do some of the compressor operate at variable speed?

You might have to adjust oil injection at very low speeds.

YES!

If you answered **yes** to any of these questions, it is recommended to **check and fine-tune** oil injection rates for all compressors.

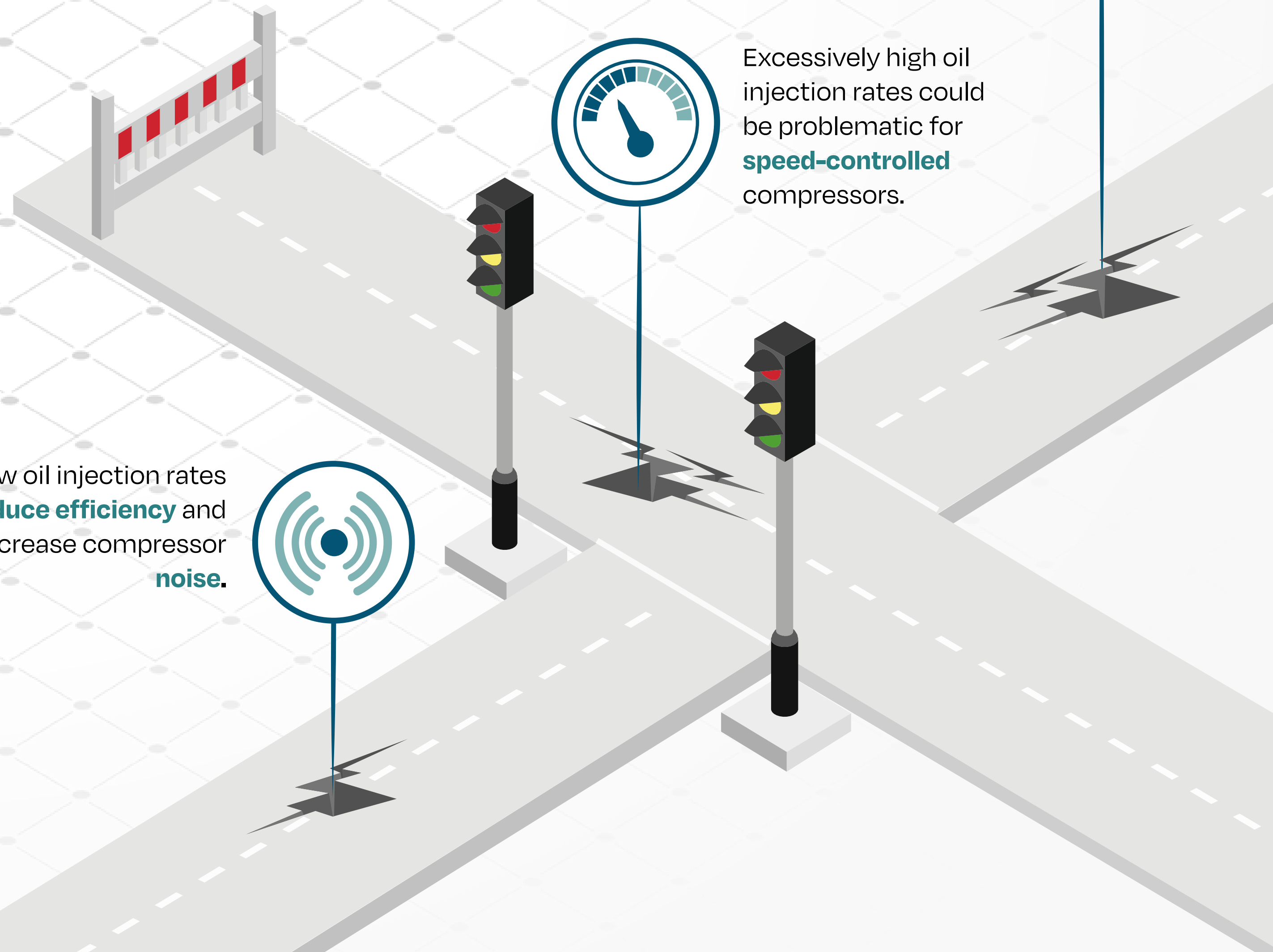
SYNERGIES 4

A well set out monitoring system from a **Controls & Monitoring Upgrade** that shows you all discharge temperatures will help you to quickly identify deviations from the mean and identify unoptimized oil injection.

5 GOOD TO KNOW

- This is a **"low hanging fruit"**. If it has not been properly fine-tuned already, this can give you quick savings with relatively small effort.
- All compressors should have oil feed **adjusted to optimum** amount, if compressors have been commissioned correctly. It is still worth the effort to verify.

6 POSSIBLE POTHOLES



Unless the compressor is fitted with an internal orifice to limit oil injection, excessive oil injection could cause **compressor damage**.

Excessively high oil injection rates could be problematic for **speed-controlled** compressors.

Low oil injection rates **reduce efficiency** and increase compressor **noise**.

HARD YARDS

BIG INVESTMENTS,
BIG RETURNS

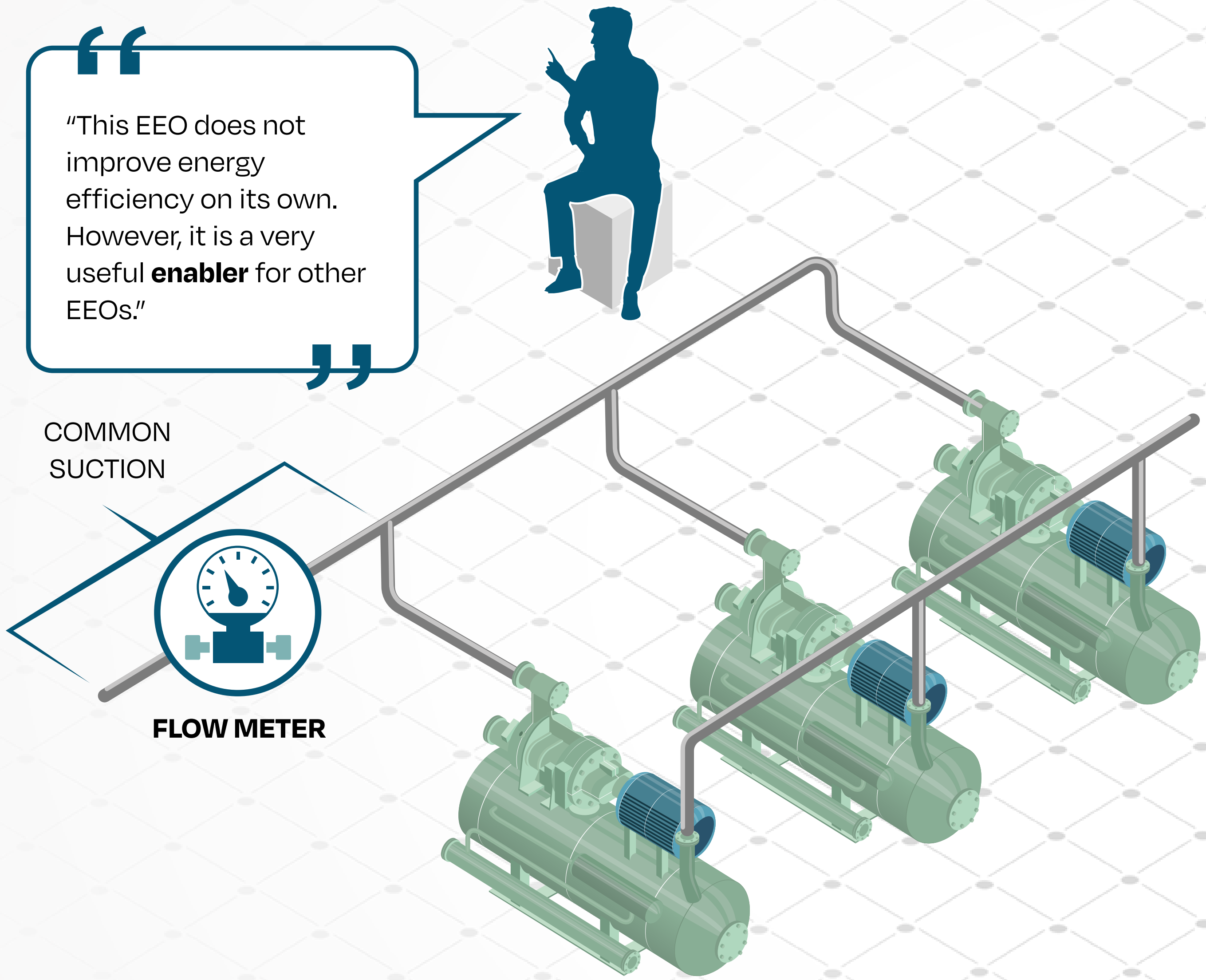
The Hard Yards cover a range of EEOs that mostly focus on replacinginefficient hardware and processes with better more efficient ones. Lost efficiency on old worn equipment is retrieved and bottle necks of an aging plant which are holding it back are stamped out. These are bigger investments that require 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

TO DETERMINE COMPRESSOR EFFICIENCY

1 FLOW MEASUREMENT

"This EEO does not improve energy efficiency on its own. However, it is a very useful **enabler** for other EEOs."



Installing a gas **flow meter** in the **common** suction allows you to measure the amount of refrigerant vapour taken in by **all compressors** that run at that moment.

This lets you accurately calculate how much cooling is **actually** done by the compressors.

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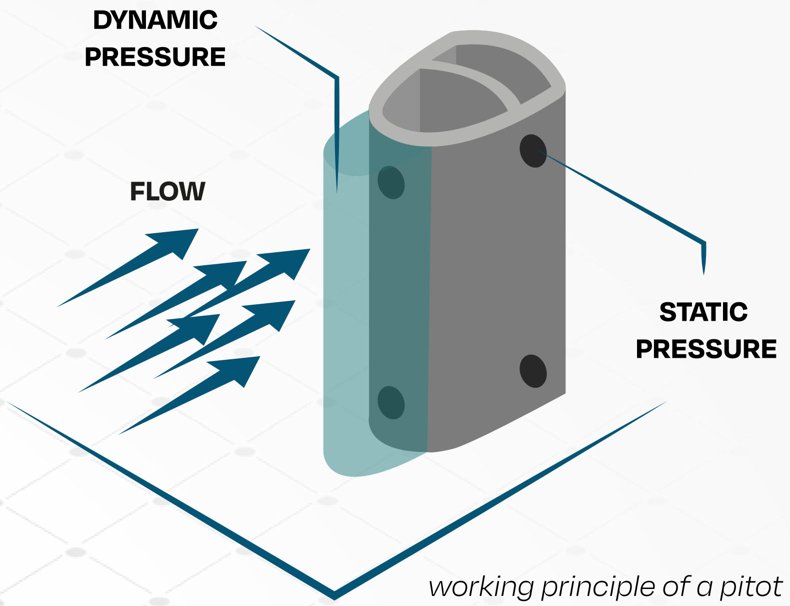
Make sure to use a flow meter that creates **little to no pressure drop** as this would otherwise make your plant less efficient, the exact opposite of what we are trying to achieve. Flow meters that work on the **pitot tube principle** are suited for this.



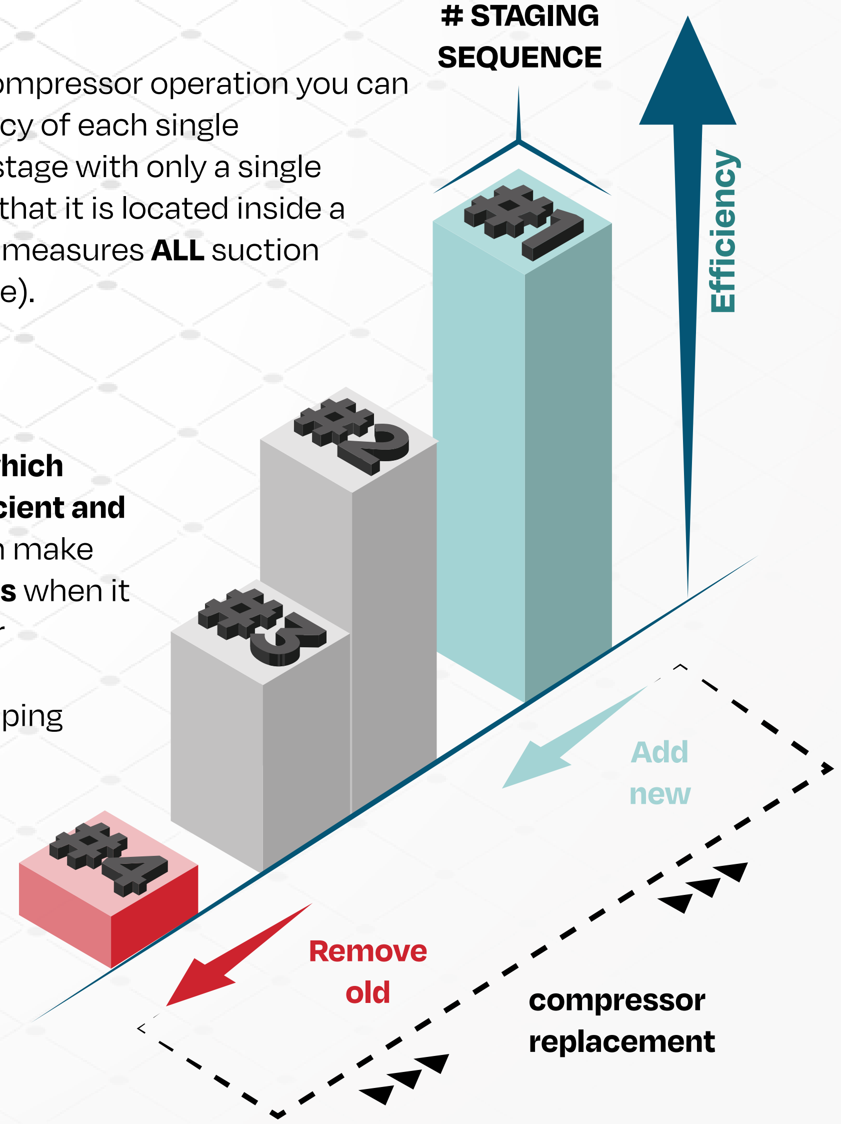
working principle of a pitot tube type flow meter

2 DETERMINE COMPRESSOR EFFICIENCY

With a flow measurement you can now **contrast cooling capacity with power used** by the compressors, in other words **compressor efficiency.**

By cleverly rotating compressor operation you can figure out the efficiency of each single compressor within a stage with only a single flow meter (provided that it is located inside a **common** suction and measures **ALL** suction of the respective stage).

Knowing for certain **which compressors are efficient and which are not** you can make much **better decisions** when it comes to compressor staging, replacing compressors or equipping them with new hardware, so investments achieve maximum return.



③ DOES THIS WORK FOR ME?

CHECKLIST

Do you use multiple screw compressors (as opposed to reciprocating) per stage?

Are you unsure of effectiveness of compressor overhauls?

If **yes**, then knowledge of the actual gas flow will benefit you.

④ SYNERGIES

Follows:

- In a way, suction flow meters are an expansion of **Control & Monitoring Upgrade** and need to be implemented into the SCADA to do analytics.

Enables:

- Major enabler for **Compressor Block Replacement**, as you are no longer groping in the dark when it comes to compressor efficiency. Lets you exchange uncertainty for certainty and enables you to sniff out incidents that might otherwise have gone unnoticed.
- **Compressor Speed Control & Staging:** Get the absolute most out of your staging strategy by always running your most efficient compressors and put less efficient ones at the back of your sequence.
- Justify investments into VSDs for **Speed Control** and into **Efficient Compressor Motors** on compressors with much lifespan left on them.

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⑤ GOOD TO KNOW

- Flow meters can provide a before and after snapshot when doing compressor overhauls. Have efficiency levels been restored? Make an educated **decision between compressor overhaul vs. replacement.**
- Flow meters (with some on-line analytics) can provide live warning of **sudden or gradual** compressor damage/wear.

POSSIBLE POTHOLES ⑥

Flow data alone may not be useful. Analytics, trending and qualified personnel to analyse changes over time are required to gain benefit.

Flow meters should NOT contribute to pressure drop as this causes energy losses. Do not use orifice plates for this reason.

Flow meters require certain lengths of straight pipe upstream and downstream to be accurate.

Flow meters are not cheap and by themselves they do not save any energy.

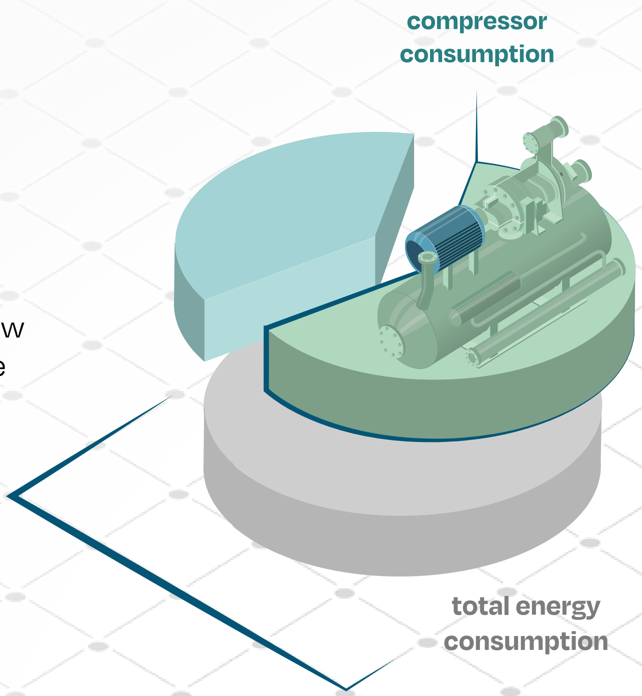
Piping layout might not have a long section of common suction and require multiple suction meters

Do NOT install flow meters on single suction branches without fitting ALL branches with flow meters. You must be able to measure total suction otherwise the measurement is useless.

COMPRESSOR BLOCK REPLACEMENT

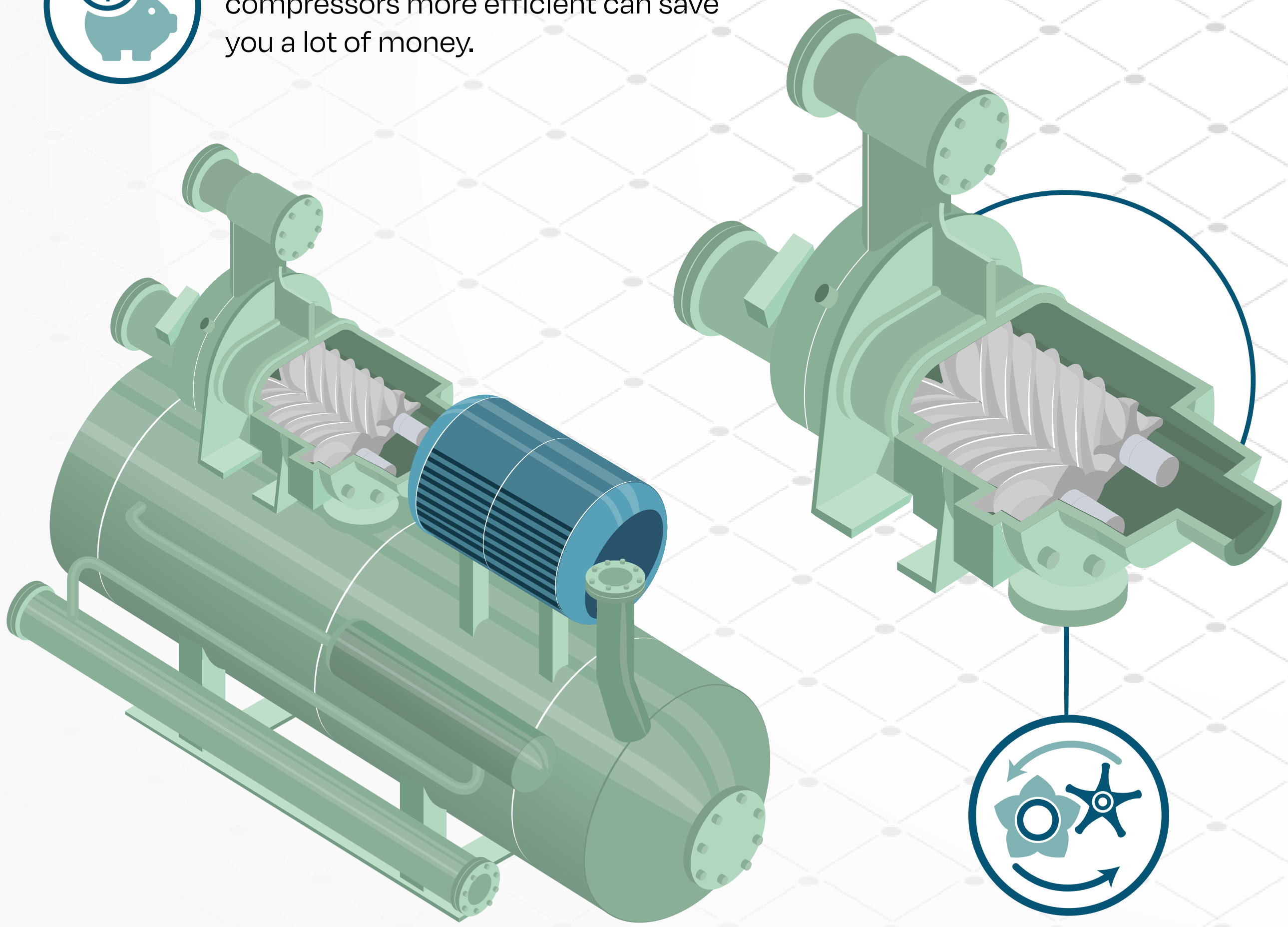
1 OPEN SCREW COMPRESSORS

Industrial refrigeration mostly utilises open screw compressor blocks that are driven by an outside motor.



Compressors do the **"heavy lifting"** in a refrigeration plant by compressing the vapour. Hence, they use **most of the energy.**

Consequently, making your compressors more efficient can save you a lot of money.



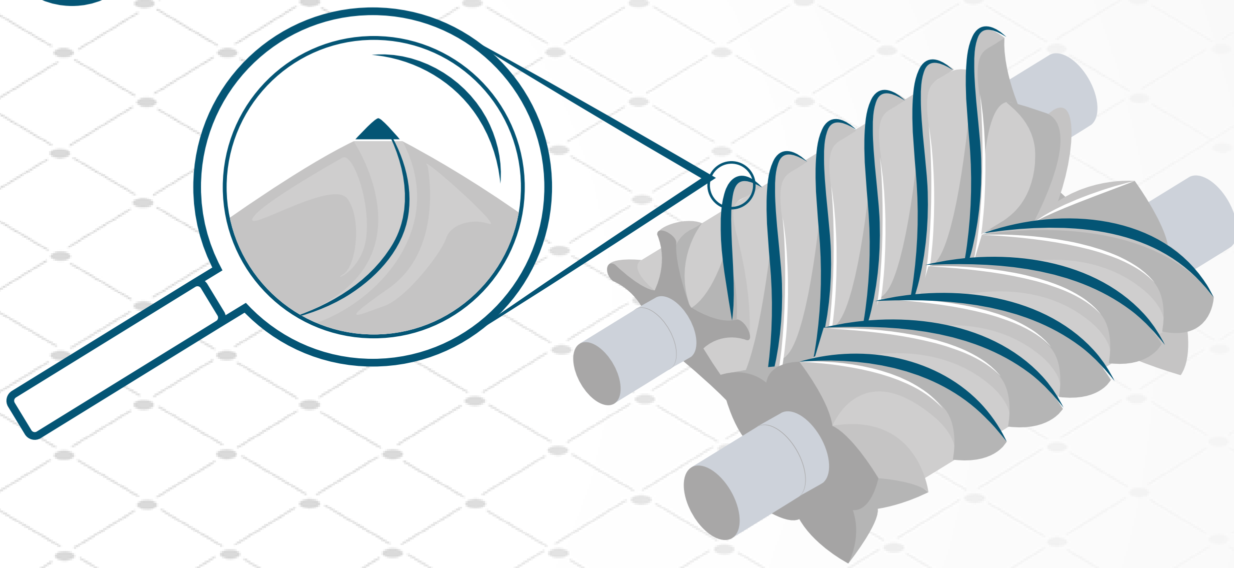
Replace worn compressor block

2 BLOCK REPLACEMENT

Screw compressors feature a **fine tip** along the top of each rotor lobe. This tip **seals the compression chambers** that are formed by the rotating screws.

If the **tip is damaged or worn out, it does not seal correctly** and the efficiency of the compressor declines.

This leads to **higher energy consumption** by the compressors.



Replace damaged or old worn out compressor blocks!

It is **hard to quantify compressor wear** without conducting a flow measurement. But hours of operation and age can be a good telltale. Screw compressors lose about **1-2% of their efficiency per year**.

Caution! New compressors might have been **damaged during an incident** and lost a big chunk of their efficiency at once. Consider **compressor history.**

3 BE AWARE OF THE EASY FIX

- Instead of replacing blocks, operators often decide to **refurbish** old ones, thinking they are saving a bit of money.
- What is actually done to "overhaul" these compressors and restore efficiency? Changing bearings does nothing to reinstate sealing. **How confident are you that efficiency has been reinstated?**
- Refurbishments are still **expensive procedures.** If, in comparison to a block replacement, operational costs from higher energy use are taken into account, this might be **a bad investment!**

Consider **operational costs** when deciding on **replacement vs. overhaul.**

4 DOES THIS WORK FOR ME?

Hard to determine without flow measurement, but ask yourself these questions:

COMPRESSOR REPLACEMENT

What did the compressor's inside look like when it was last maintained? Were sealing tips still ok?	Worn down tips & scratched housing are a bad sign.
Did the compressor have an incident? Did it need repair?	→ Probably took damage and now runs less efficiently.
How many hours of running time are on the compressor?	→ Rule of thumb: replace after 100,000 h → 1-2 % efficiency loss per year with normal running hours

5 SYNERGIES

Follows:

Compressor replacement greatly benefits from prior installation of **"Suction Flow Meters"**. These help to **accurately determine** compressor wear, so you do not have to assume wear and tear and can circumnavigate "possible potholes".

Enables:

"Compressor Staging & Speed Control" benefits from putting new compressors **first in the staging sequence** and thanks to a full life-time ahead **investments into VSDs certainly pay off.** Spending a bit extra on **variable volume ratio** compressors when replacing enables additional savings from **"Variable Head Pressure Control".**

6 GOOD TO KNOW

- Compressors which run mechanially unloaded are at greater risk of degradation due to wear between the slide valve & rotor. **Speed controlled compressors** last longer!
- Degradation has a greater effect on single-stage or high-stage compressors and these tend to wear faster, hence focus on these first.
- Run the new compressors as lead machines, and the older ones as lag, not the other way round. **Best energy outcome** that way.
- Try to upgrade single stage & high stage to **variable volume ratio** compressors when these are replaced – the additional investment almost always pays for itself, especially in combination with **variable head pressure control (VHPC)**

7 POSSIBLE POTHOLES

Age indication: bad compressors might be replaced too late, good ones too early

Estimating degradation without suction flow measurement or accurate run hour records is difficult. Age is an indication only.

DEDICATED HOT GAS COMPRESSOR

1 HOT GAS

Hot gas refers to the hot high-pressure refrigerant gas discharged by the compressors of the high stage.

Instead of routing all discharge towards the condensers, you can tap into and channel it to the **evaporators** (where it condenses instead) for heating.

Most abattoirs use hot gas to **defrost** their evaporators.

Some abattoirs, mostly those that process **fatty grain fed cattle**, also use their hot gas defrosts over a prolonged period to **reheat carcasses** and soften the fat layer.

Whether defrost or reheat, high temperatures for a **quick intensive heating** are preferred to **avoid unnecessary heat** introduced into the cooling space or deeper into the carcasses respectively.

Hence, **high discharge pressure** is needed. That is why many abattoirs constantly, or when hot gas is needed, run higher discharge pressures by slowing down condenser fans.

Conversely this means, **all** compressors must run at a higher discharge pressure and need to overcome a **bigger pressure difference** expending **more power.**

"For example, running your compressors at a discharge of 1050 kPa (g) instead of 900 kPa (g) uses roughly **11 % more high stage compressor power!**"

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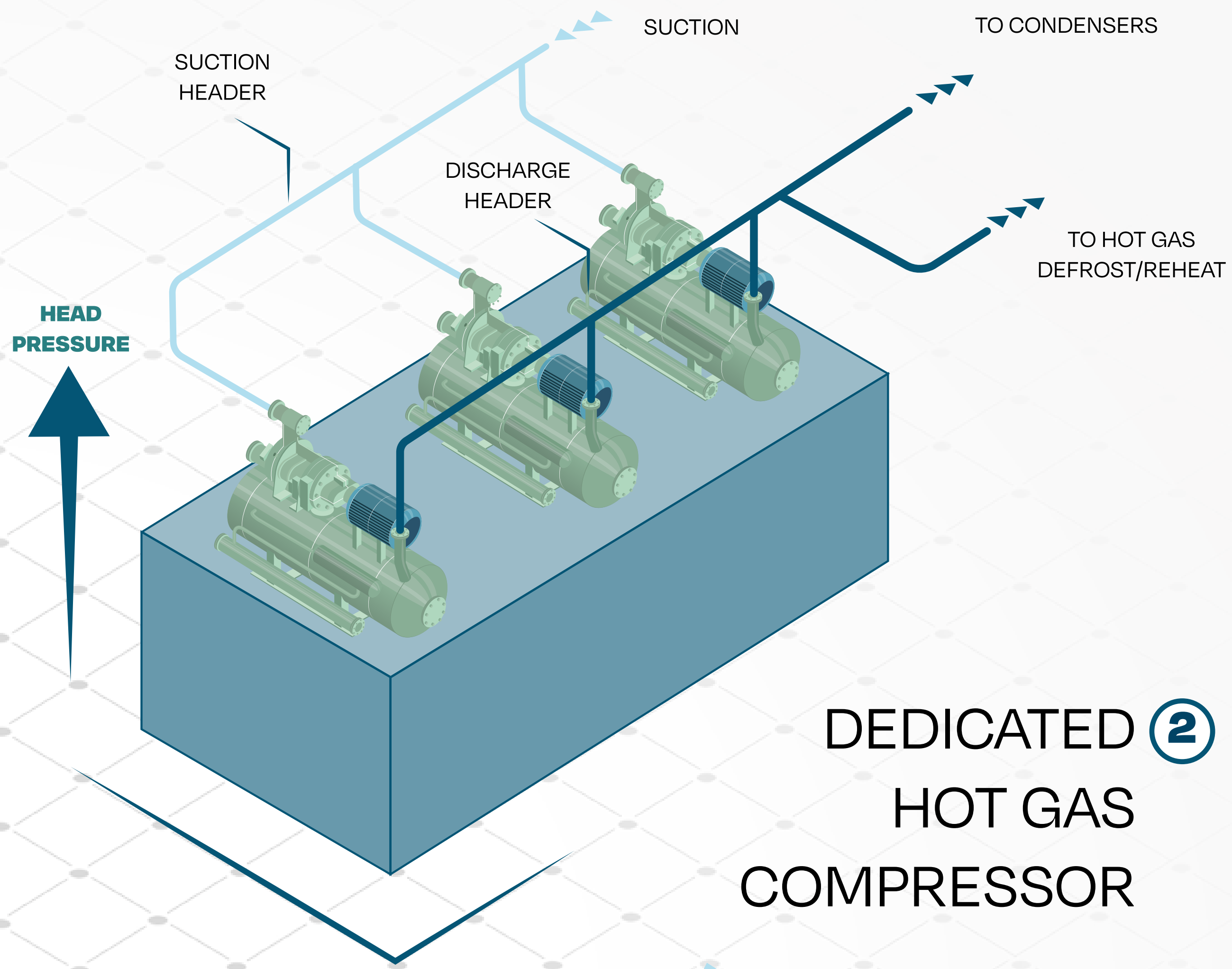
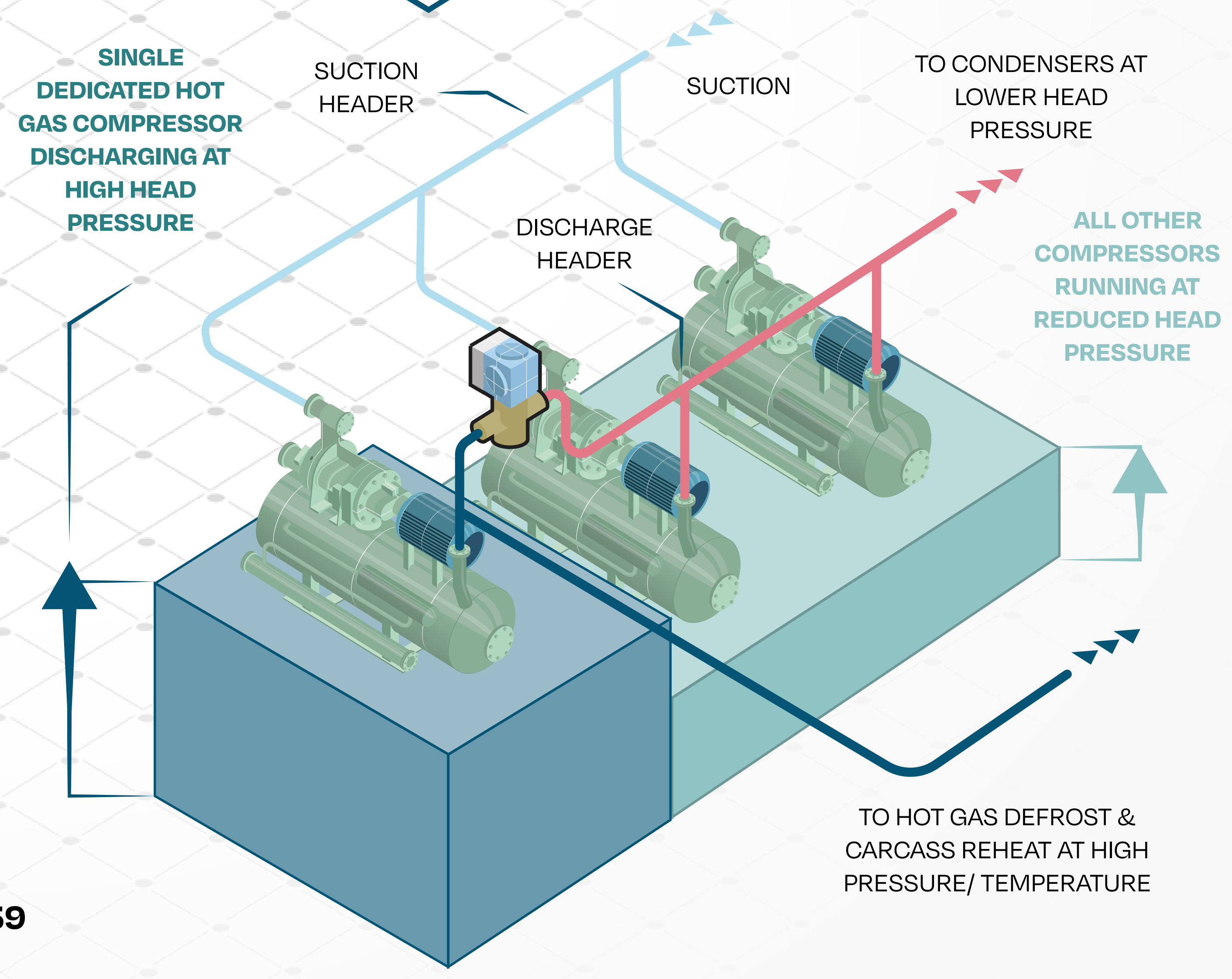
DEDICATED 2 HOT GAS COMPRESSOR





Instead of running the entire high stage with a hefty energy penalty, you can run a single **dedicated hot gas compressor** at higher head pressure to provide the hot gas needed.

To be able to do so you need to **install a pressure regulating valve i**n the compressor's discharge line and run **hot gas piping** to said compressor.

Program your PLC to **fully open the pressure regulator when no hot gas is needed** and to **increase pressure during defrost/reheat.**

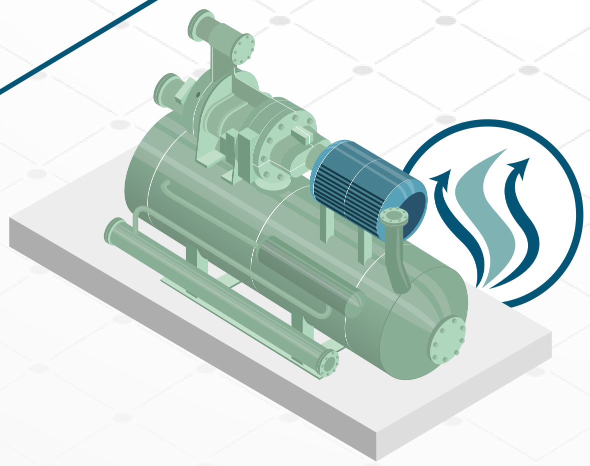
Extra bonus:

Abattoirs that do **carcass reheats** often struggle to achieve high head pressures on **Monday/winter mornings** before the first shift starts when very little load is on the system. They often help themselves by turning off condenser fans and creating "artificial" load on the system by dropping temperatures in big rooms like the boning room even lower. This set-up **prohibits hot gas from being lost to the condensers** and should make your life much easier in these situations.

3 DOES THIS WORK FOR ME?

- Do you have to **raise head pressure setpoint** to get good defrost/carcass reheat?
- Do you **struggle to achieve higher discharge pressures**, especially on Monday mornings?
- Do you have **difficulty with carcass reheat** on cold mornings?
- Are you using **Variable Head Pressure** or are planning to do so?

If **Yes** to any of these questions, a hot gas compressor will help.



4 SYNERGIES

Follows:

A **Control & Monitoring Upgrade** can make it easier to implement pressure regulator logic.

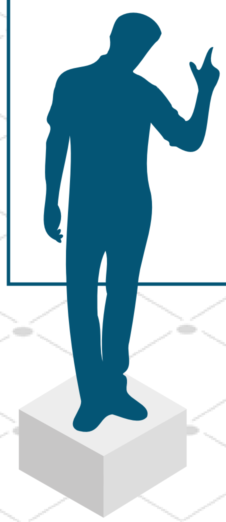
Enables:

Variable Head Pressure Control in particular benefits from a hot gas compressor, as you would be limited to the extent that you could reduce head pressure in times of hot gas need.

You can do more **Defrost Optimization** by running even higher hot gas pressures/temperatures.

The same goes for **Hot Gas Float Valves** which focus on carcass reheats. The latter can be "short and crisp" by increasing evaporator temperatures by means of higher discharge pressure of the hot gas compressor.

5 GOOD TO KNOW

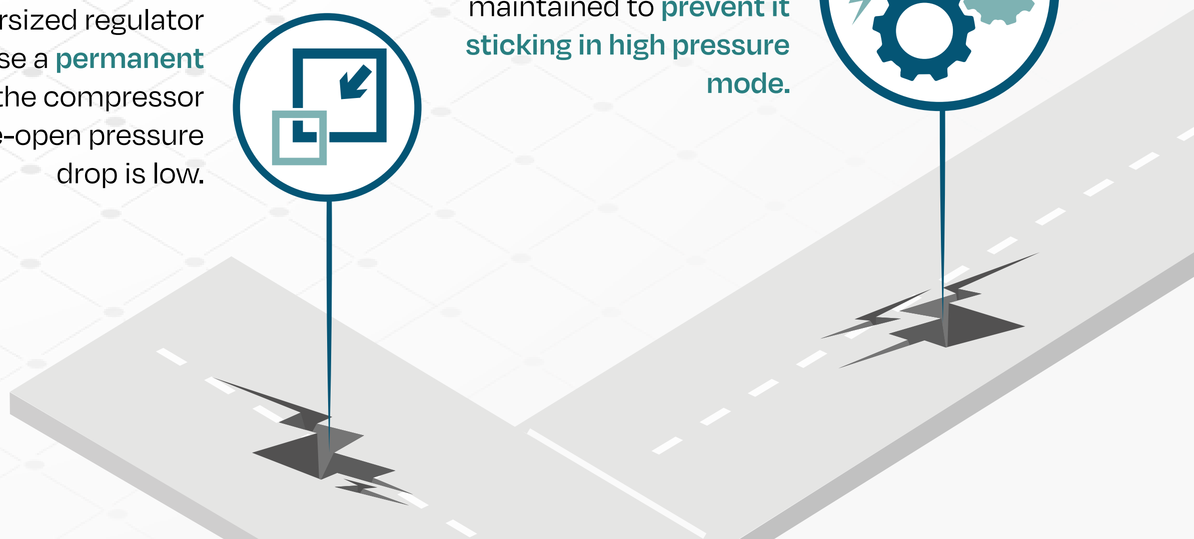


- You can have **several** hot gas compressors and rotate or stage them to meet your hot gas needs. **Each** compressor will need a pressure regulator and the accompanying pipe work.
- By using motorized regulators, hot gas pressure can be varied as needed by setpoint change on the PLC.

POSSIBLE POTHOLES 6

Make sure the pressure regulator is properly commissioned and maintained to **prevent it sticking in high pressure mode.**

Incorrect or undersized regulator selection can impose a **permanent energy penalty** on the compressor – make sure wide-open pressure drop is low.



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HOT GAS FLOAT VALVES

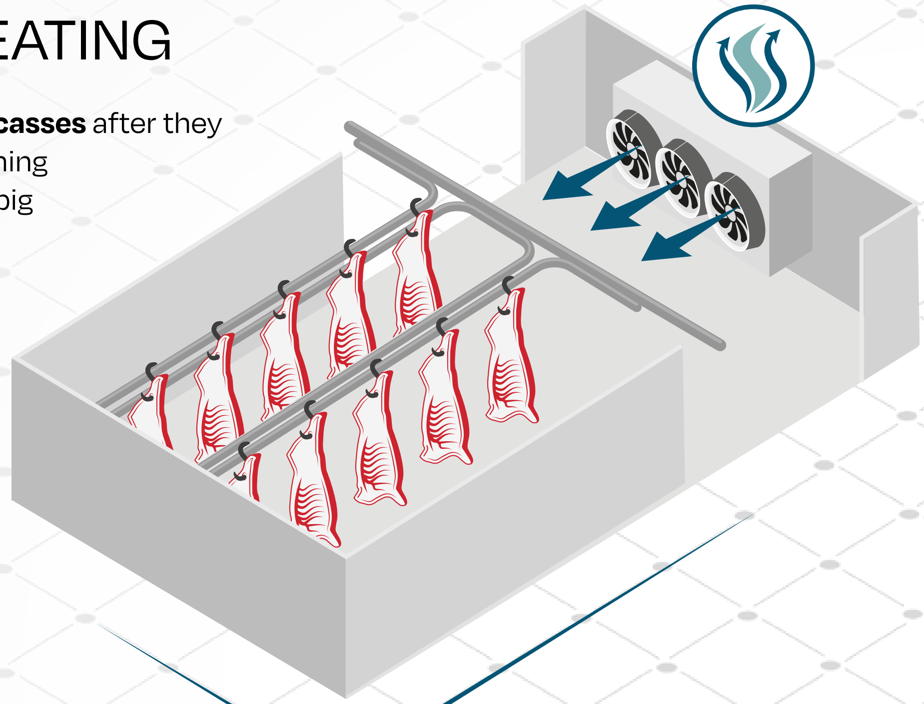
FOR OPTIMISED DEFROST RELIEF & CARCASS REHEAT

1 CARCASS REHEATING

Some abattoirs **reheat the carcasses** after they have been cooled down, so boning becomes easier, especially on big bodies with thick layers of fat.

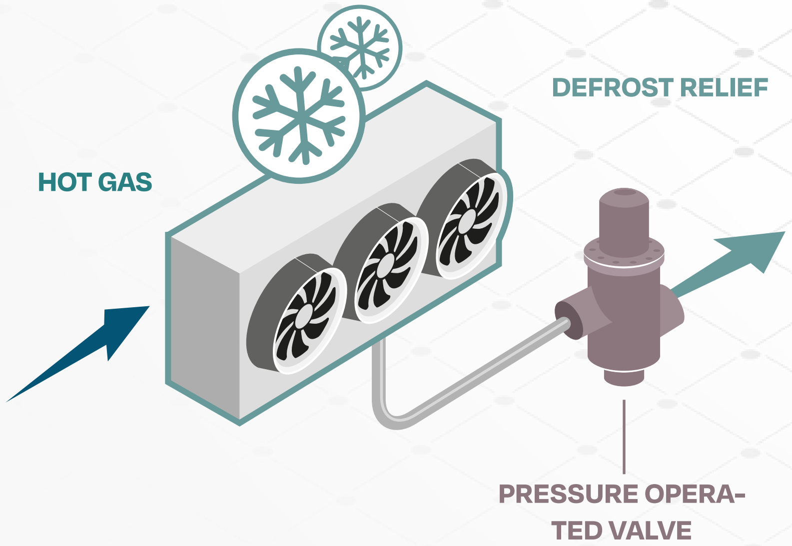
▼

If you do this by using the hot gas defrost, this EEO is probably for you!



2 HOT GAS DEFROST

Most hot gas defrost systems in Australia use pressure operated defrost relief valves.



During **normal** defrost:

Pressure in the evaporator slowly rises as it warms up .

→ When certain pressure is achieved the relief valve opens and liquid refrigerant & some gas leave to the intercooler.

→ Defrost cycles are short & the evaporator is still relatively cold by the end of it. Consequently, most of the hot gas **condenses** and only **manageable amounts** of gas are directly introduced into the intercooler.

3 NOT DESIGNED FOR THIS

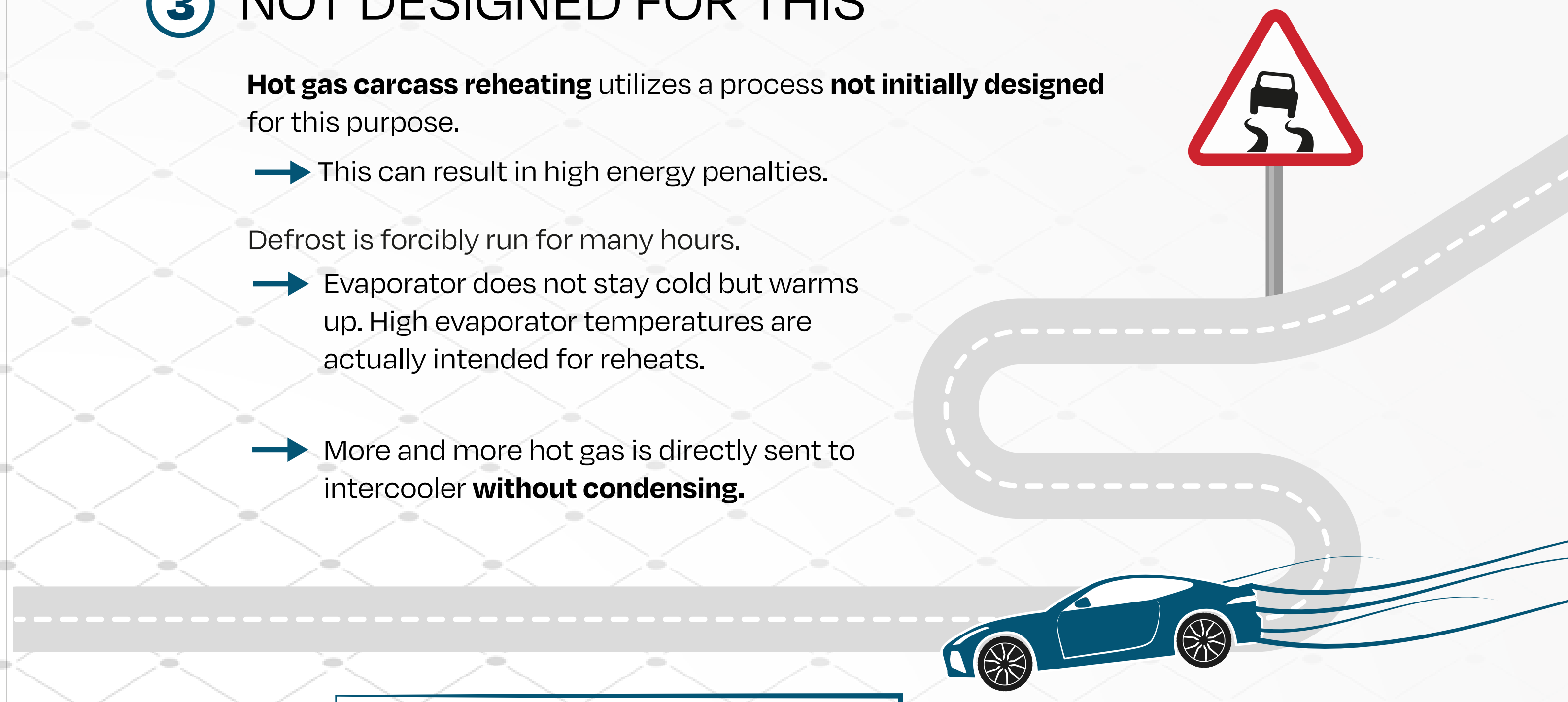
Hot gas carcass reheating utilizes a process **not initially designed** for this purpose.

→ This can result in high energy penalties.

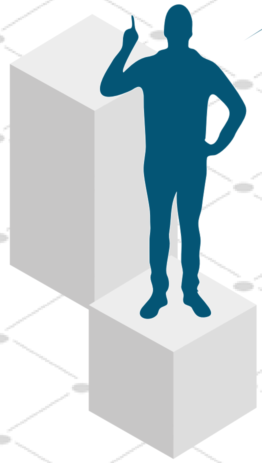
Defrost is forcibly run for many hours.

→ Evaporator does not stay cold but warms up. High evaporator temperatures are actually intended for reheats.

→ More and more hot gas is directly sent to intercooler **without condensing.**



"Hot gas releases most of its heat by condensing"

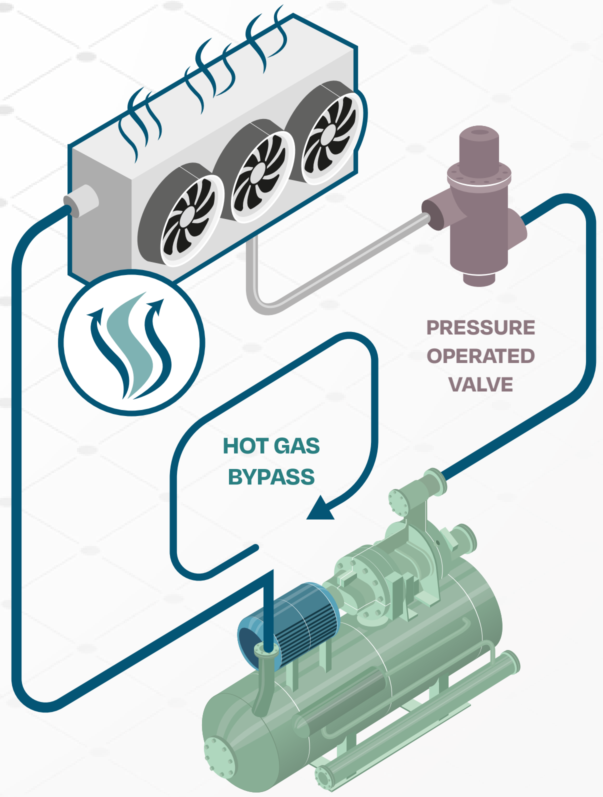


→ By relieving it as a gas, its heating capacity has **barely been used.**

→ Liquid refrigerant could actually be put to good use for cooling. Evaporators in which hot gas condenses basically work just like condensers and take load off the actual condensers.

This in essence is a **hot gas bypass.**

→ Gas is **pumped in a loop** whilst consuming precious compressor power without getting much use out of it.



WHAT IS THE SOLUTION?

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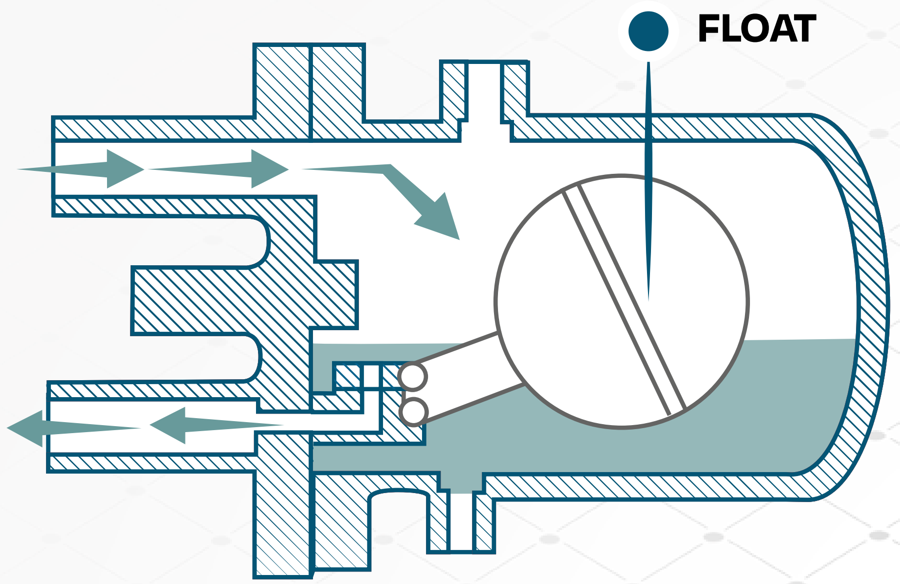
4 DEFROST RELIEF FLOAT VALVES



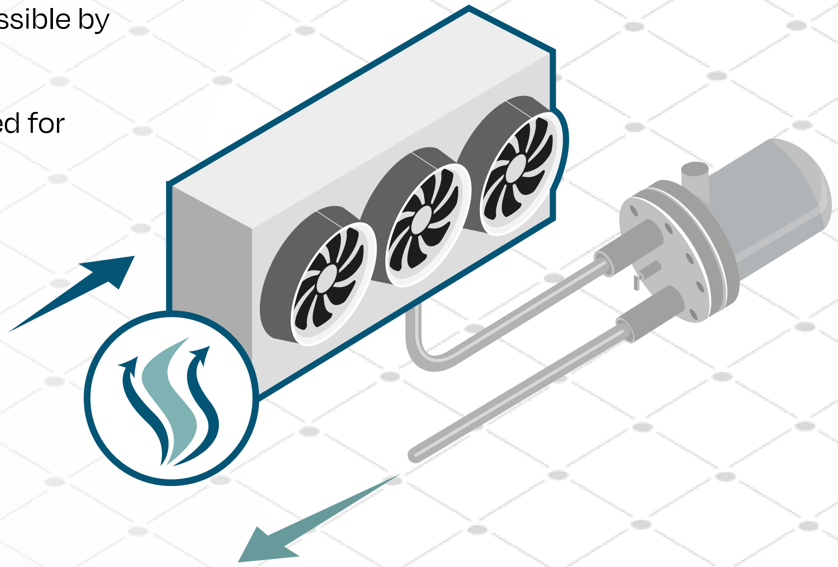
- Float valves possess a **float** on the inside as the name suggests.
- When the body of the valve fills up with liquid the float rises and opens the valve.
- Lets only liquid refrigerant pass.

→ Hot gas releases **all heat** possible by condensing.

→ Liquid refrigerant is then used for cooling.

→ **Efficient** use of hot gas.

→ Energy Savings



Additional Benefits:

- **Pressure regulating valves** commonly used for defrost must be set to open at a certain pressure. This **set-point is a compromise**, just ask the person responsible for setting it. The pressure must not be too high and cannot be too low.
- **Float valves** let only liquid pass, **no matter what pressure**. They also make sure all **liquid is always removed** as soon as it forms.
  - → You can run **higher pressures/temperatures.**
  - → The evaporator is always **completely drained,** offering the entire surface area for heat exchange.
- Float valves therefore enable a **short and crisp reheat** which is desired to **only heat the outer fat layer without penetrating deep** into the meat.

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DOES THIS WORK FOR ME? 5

- Are you reheating chilled carcasses using prolonged hot gas defrost?
- Do you have pressure operated defrost relief valves in those chillers?

If you answered both questions with **yes**, then you should consider defrost relief float valves.

6 SYNERGIES

Follows:

- A **Dedicated Hot Gas Compressor** allows you to run at aforementioned higher hot gas pressures without energy penalty on the rest of the plant.

Enablers:

- The hot gas bypass from misusing the pressure relief will cause an additional step load on the compressors. By preventing this from happening, float valves help **Plant Stabilisation.**

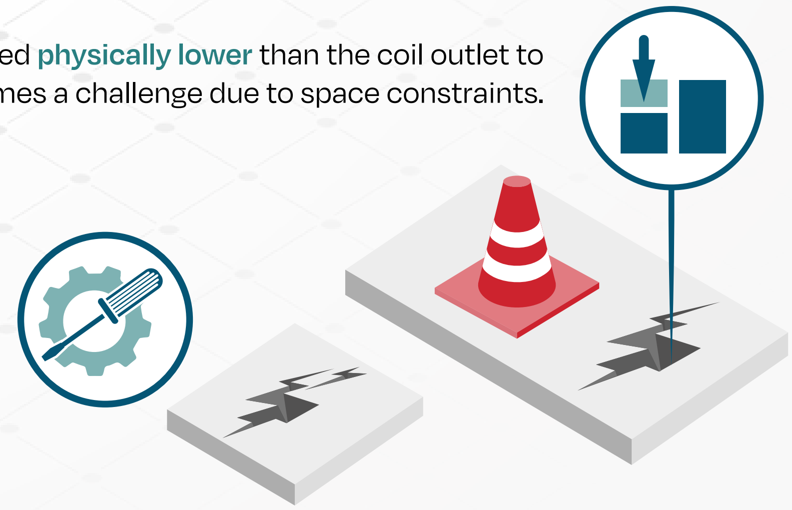
GOOD TO KNOW 7

- Defrost float drains will enhance the **efficiency and speed** of defrost cycles which is their original design goal.
- The practice of reheating cold carcasses just to cool them again after boning is very inefficient from an energy perspective. Try to keep it to a minimum.
- Float valves might need additional piping like bypasses and other considerations depending on the specific application. Get **expert advice.**

8 POSSIBLE POTHOLES

Float valves are best located physically lower than the coil outlet to function – this is sometimes a challenge due to space constraints.

Float valves have moving parts and will need service in future, e.g. to replace valve needle & seat.



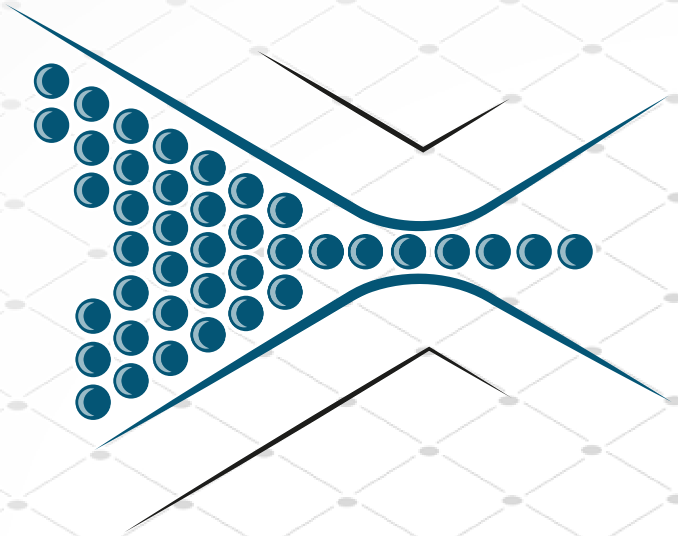
BOTTLE NECK REMOVAL

① WHAT IS THE PROBLEM?

Centralized industrial refrigeration plants are efficient, but also **complex**.

Pressure losses can **propagate throughout** the system and cause large energy penalties along the way. They should be prevented where possible.

Apparently small problems can be bottle necks for the entire plant.



WHY IS IT A PROBLEM? ②

Decreased pressure due to a bottle neck dictates the pressure level for the **entire** corresponding stage.

All vapour, including from other parts of that stage, must be compressed from this **decreased pressure** level.

Other applications become less efficient causing **higher energy consumption** across the plant. This directly translates into **higher energy costs**.

Energy losses **scale with plant size**. That is why they should be eliminated in big industrial refrigeration plants.

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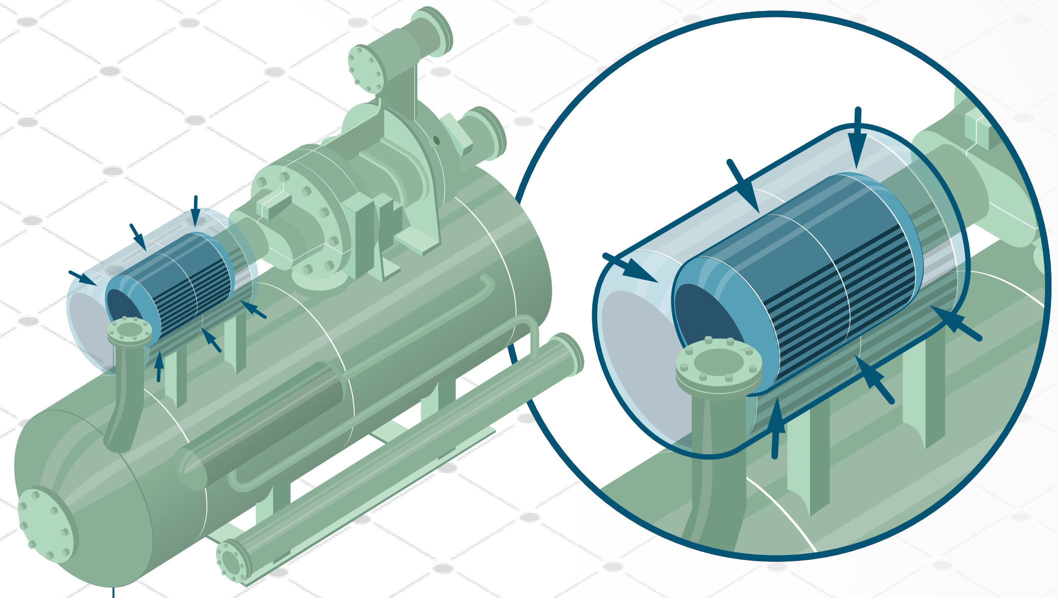
The following pages show are some of the **most common** bottle necks encountered on many sites. Keep an eye out for them when you inspect your plant:

③ UNDERSIZED COMPRESSOR MOTORS



PROBLEM

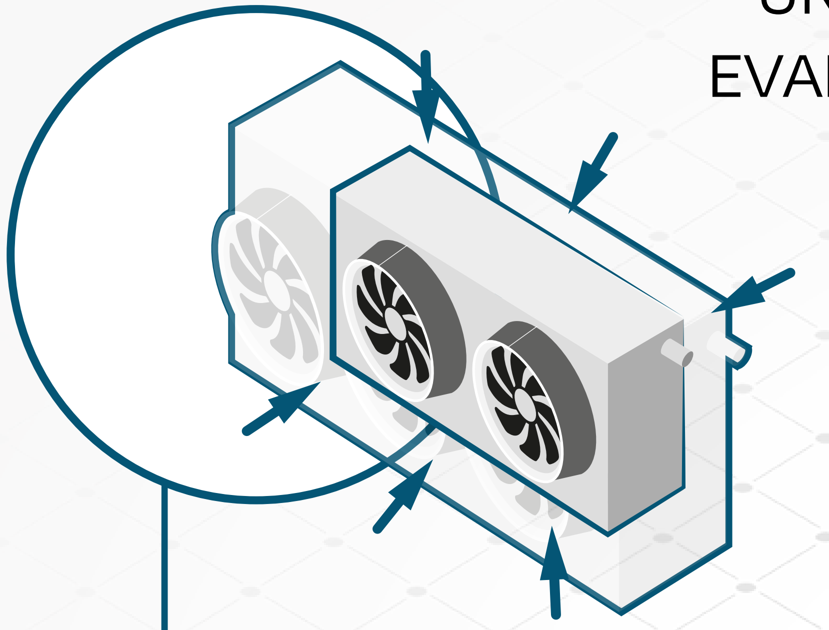
Small motors on the low-stage/booster compressors may keep the plant from running more efficiently.

EXAMPLE

It has been identified that it would be beneficial to raise the intermediate pressure. But the resulting higher pressure difference on the low-stage would overload its motors.

SOLUTION

Replace the small motors on the affected compressors with bigger more powerful motors



UNDERSIZED ④ EVAPORATORS

PROBLEM

Undersized evaporators do not have enough capacity to cool at the **intended evaporation temperature**. To make up for it, evaporation temperature/pressure **must be reduced**. But **be aware**: this pressure reduction takes place in the **entire** stage and all its evaporators making other applications less efficient!

EXAMPLE

One of the chillers does not hold temperature. This is probably due to an undersized evaporator. As a temporary fix the intermediate pressure which feeds into the chillers is reduced, triggering efficiency losses across the plant.

SOLUTION

Replace the undersized evaporator. This will not only save you energy but most probably also resolve process issues like too long cool-down periods due to insufficient cooling.

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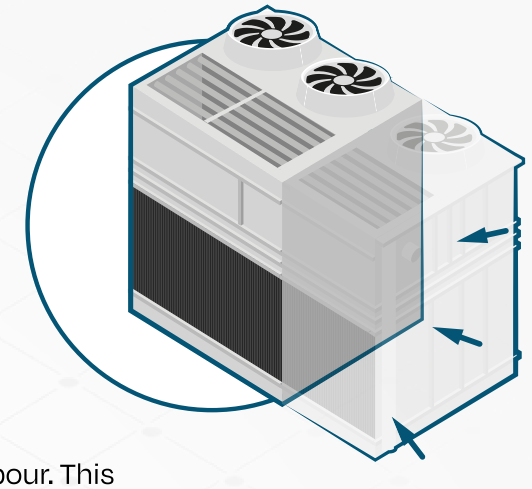
⑤ UNDERSIZED CONDENSERS



PROBLEM

If during operation the condensing capacity is insufficient, **condensing pressure will rise** and with it the power needed to compress the vapour. This happens more often and to a higher degree if the condenser is undersized.

EXAMPLE

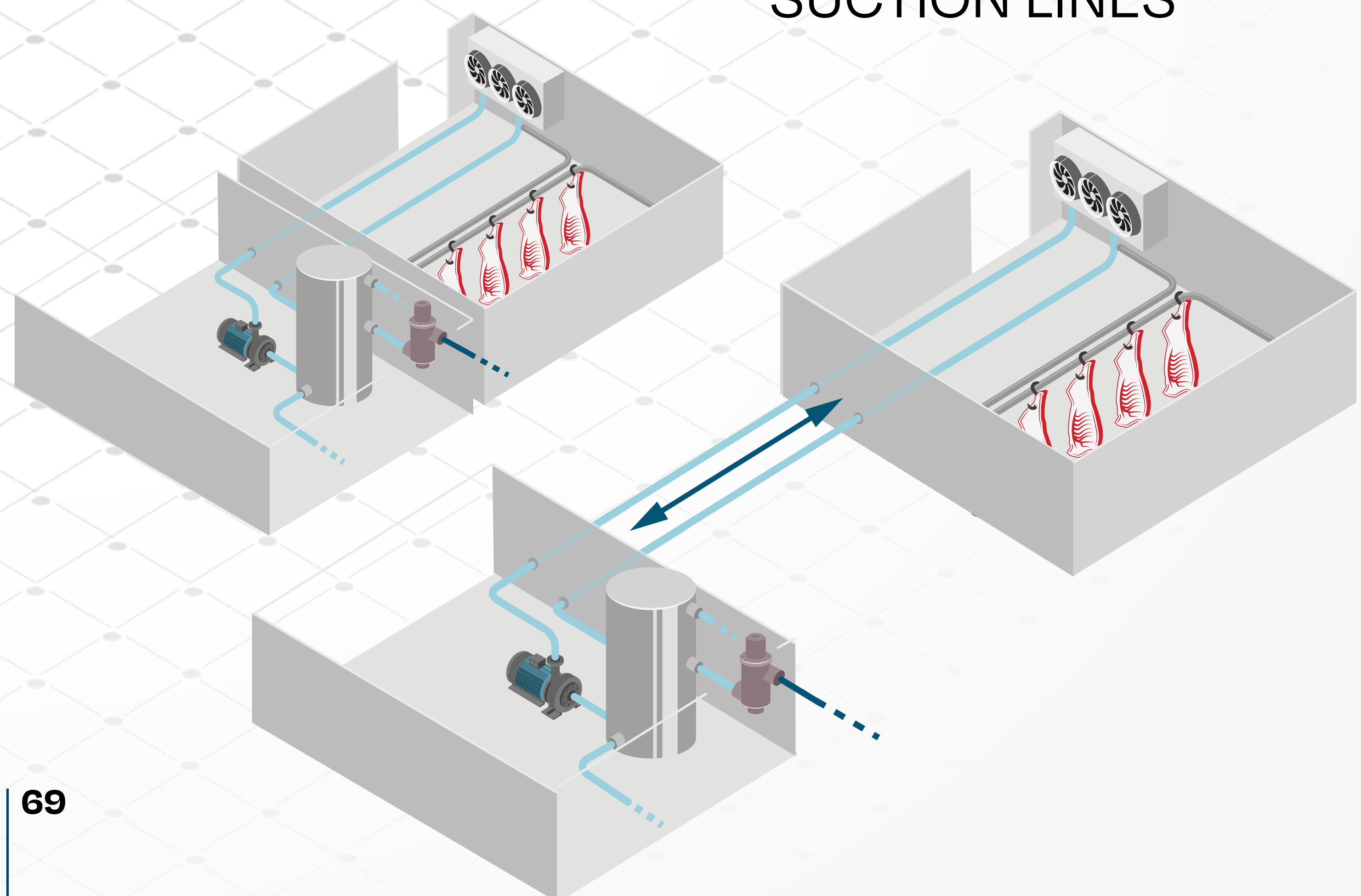
Condensing capacity was undersized during design, or the plant was later expanded without installing more condensers, or the condensers degraded over time. Many things are possible, but the effect is the same .

→ insufficient condensing capacity

SOLUTION

Replace/add condensers so the condensing capacity matches the load.

LONG WET ⑥ SUCTION LINES



PROBLEM

Inside wet suction lines of liquid overfeed systems flows a vapour-liquid mixture. This so-called two-phase flow comes with high pressure losses, which is why wet suction lines should be as short as possible.

EXAMPLE

A new chiller was added during a plant expansion and connected to the original liquid accumulator located further away. Due to higher pressure drop, the accumulator pressure must be reduced to achieve temperature.

SOLUTION

Install an additional liquid accumulator and refrigerant pump close to the evaporator. This way two-phase flow is reduced to a minimum.

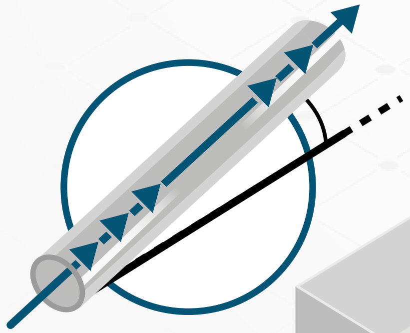
7 WET SUCTION RISERS - AVOIDANCE & REMOVAL

PROBLEM

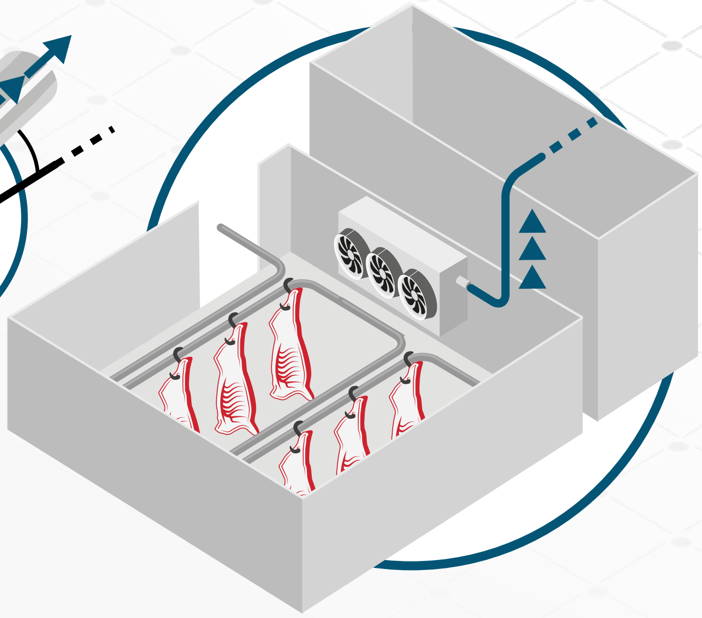
Pressure losses due to two-phase flow are significant in risers.

EXAMPLES

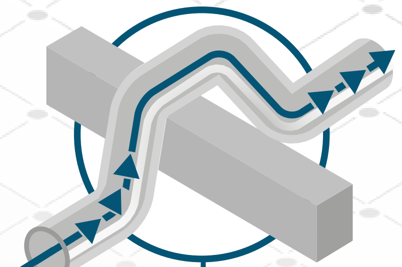
WET SUCTION LINES WITH AN UPWARD GRADIENT IN DIRECTION OF FLOW.



EXCESSIVELY LONG WET SUCTION RISERS



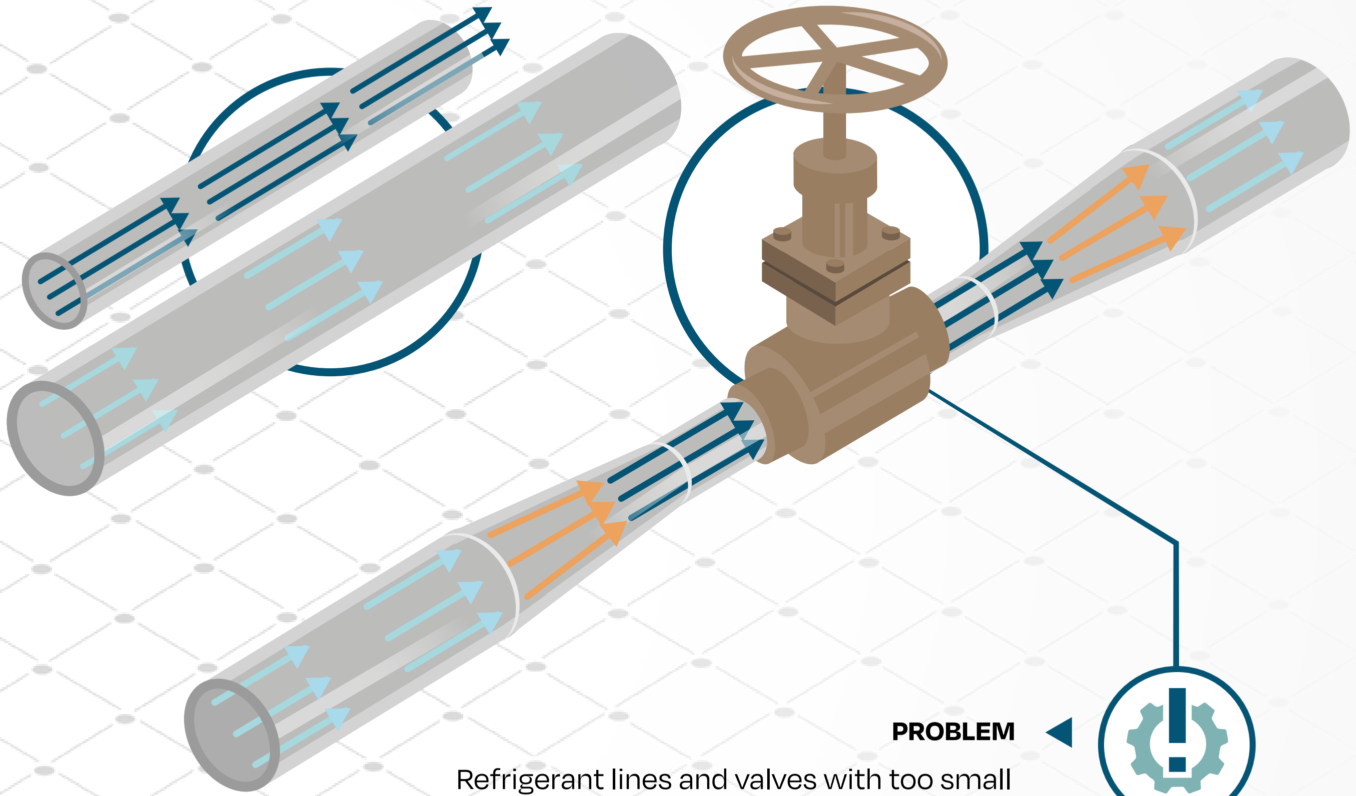
PIPE BEND TO BRIDGE PRE-EXISTING OBSTACLE.



SOLUTION

Rework identified wet suction lines to eliminate risers or reduce them to a minimum if they cannot be avoided. Rule of thumb: if the solenoid valve on the evaporator shuts, the wet suction should empty itself just by gravity. Which is why wet suction lines should always have a **downward gradient** in direction of flow.

8 HIGH LINE & VALVE PRESSURE LOSSES



PROBLEM

Refrigerant lines and valves with too small flow-diameters cause pressure losses.

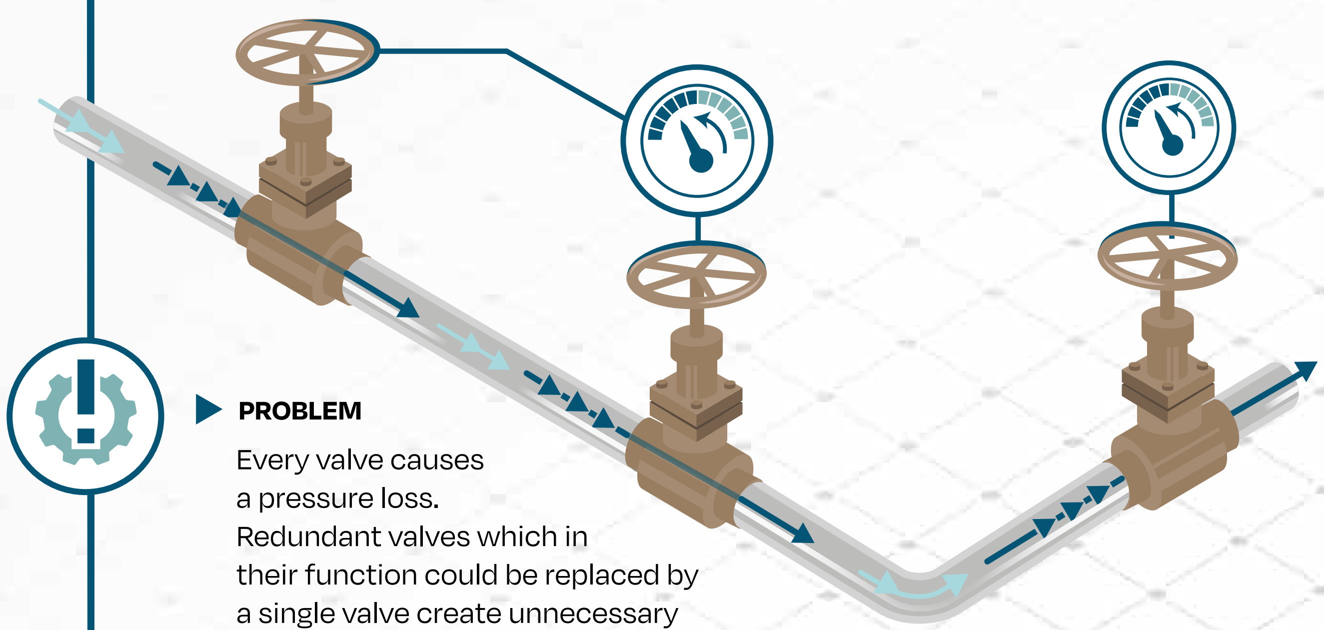
EXAMPLE

Refrigerant lines and/or valves were undersized during design or more cooling load was added during an expansion without upgrading adjacent suction lines. Cases of correctly sized lines which are tapered to fit undersized valves have occurred as depicted.

SOLUTION

Replace undersized suction/discharge lines and valves.

REDUNDANT VALVES



PROBLEM

Every valve causes a pressure loss.
Redundant valves which in their function could be replaced by a single valve create unnecessary pressure losses that could be avoided.

EXAMPLE

Older plants which were later expanded often exhibit redundant valves. For example, a new pipe junction was added including more valves making some of the older ones redundant, or an older part was decommissioned, but its piping and valves remained and so on.

SOLUTION

Check for redundant valves and remove them.

9 WHAT CAN I DO?

- **Identify bottle necks in your plant and remove them!**
- Of course, this might be easier said than done. There are many things that could be bottle necks and not all can be covered here.
- Inspect your plant and be critical. Ask yourself if some issues might have the far-reaching effects described here. It might help to **consult an expert.**

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10 SYNERGIES

Enables:

- Without the need to run lower suction pressures due to bottle necks you can lift them and do **Suction Pressure Optimization.**
- Some bottle necks can have a negative effect on **Plant Stabilization**, e.g. insufficient condenser capacity and poorly designed wet suction risers.
- **Condenser Fan Speed Control** is less effective, if fans need to run flat out due to undersized condensers.
- The need to swap undersized compressor motors could be an incentive to invest in **Efficient Compressor Motors.**

11 GOOD TO KNOW

- **Be aware of the "easy fix"**! An improvised fix often has unforeseeable negative consequences that reach a lot further than at first glance.
- Ask yourself: What room/application struggles to hold temperature? Do you have to reduce suction pressure to help it? Chances are the evaporator is undersized.
- Undersized condensers will put you at risk of a brownout during hot summer days! An investment into a new condenser not only saves energy but also enhances plant operation and provides security against system failure.

→ **Plant Stabilisation!**

- Avoid vertical risers on wet suction lines whenever possible, especially on low temperature lines! These cause both energy penalties and operational issues.
- See if you can find two or more stop valves in the same suction line and ask yourself if you can replace them with a single valve.

12 POSSIBLE POTHOLES

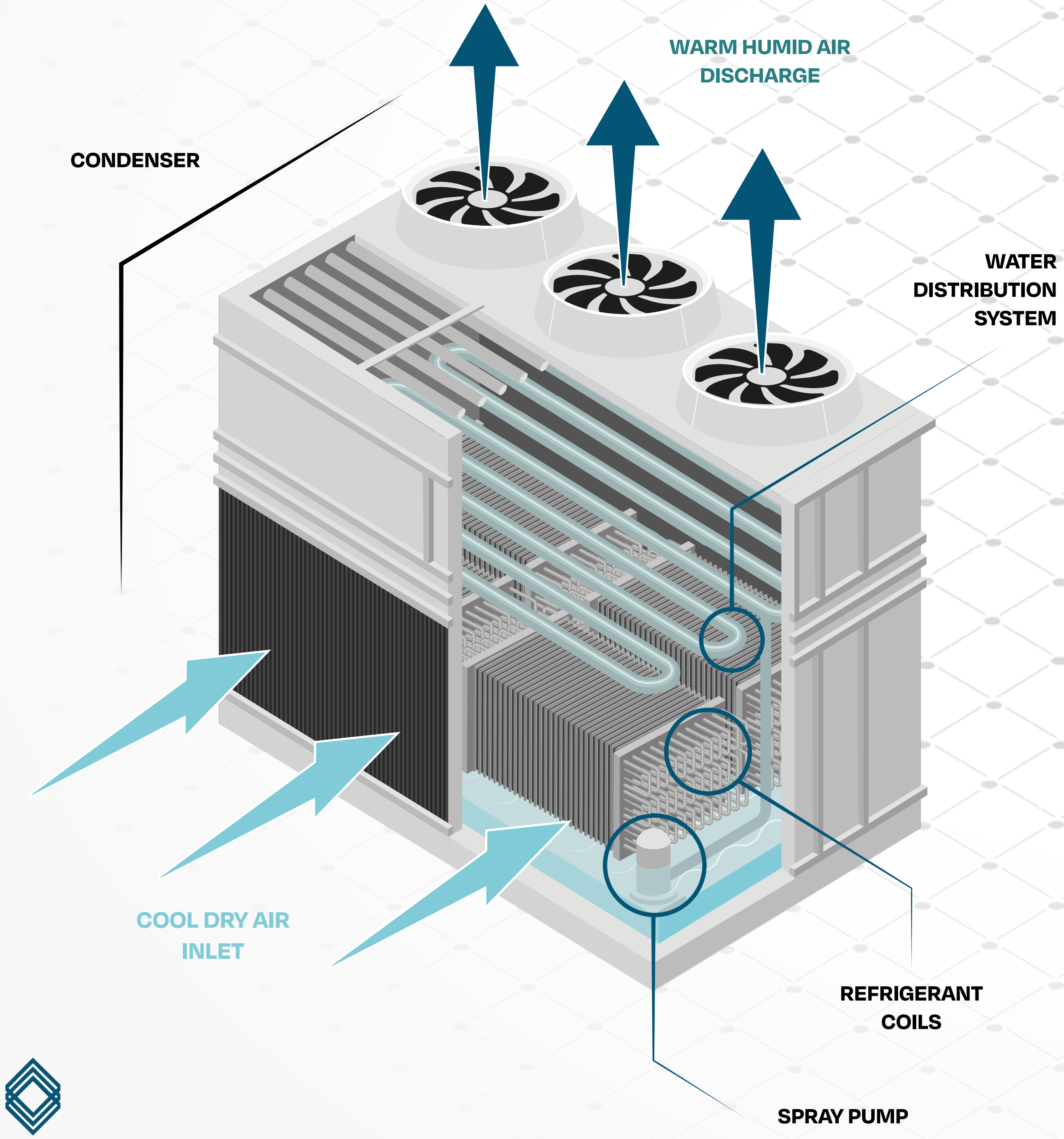
Old valves often do not **seat well** - sometimes a challenge when cutting out excess valves or undersized lines.

CONDENSER UPGRADE

FOR FAN EFFICIENCY & ADDED CAPACITY

1 HOW DOES A CONDENSER WORK?

The hot refrigerant discharged from the compressors flows through the condenser where it rejects its heat into the air flowing through the coils - most of it by **condensing** from gas to liquid, hence the name.



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The amount of heat rejected by the condenser depends mostly on 3 factors:

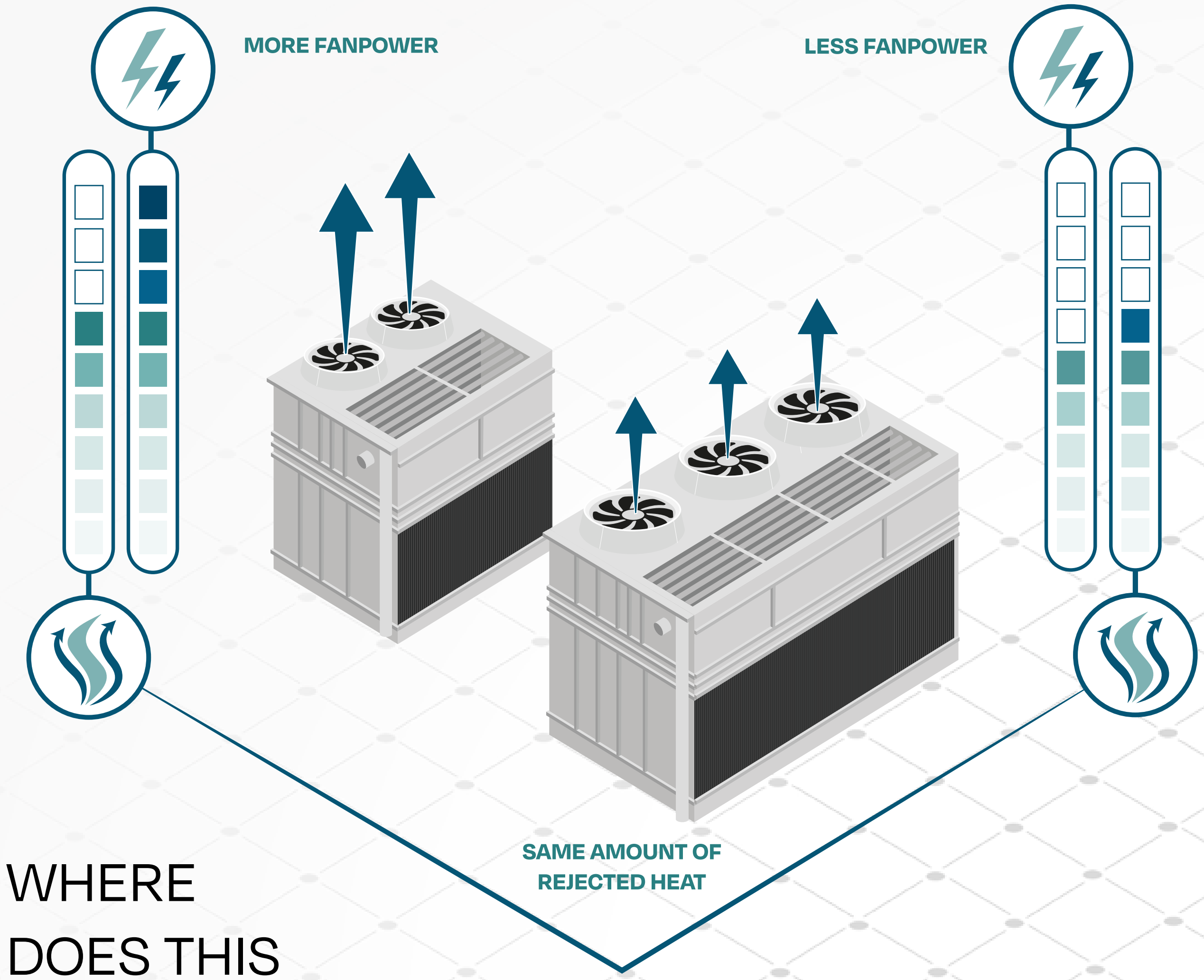
Ambient wet-bulb temperature (air-humidity) - fluctuates with the weather. The lower the wet-bulb temperature gets the higher is the temperature difference towards the refrigerant and with it the amount of heat rejected. **If the temperature difference is not big enough** the discharge pressure and with it the **condensing temperature rises to compensate.** This is why you might have experienced trouble with head pressure during thunder storms/high air-humidity.

Heat exchanger surface - is fixed depending on the model. Different coil shapes, flow designs, etc. can make heat exchange more effective, but rule of thumb: The more surface area the more heat is rejected. During design this must be specified to suit cooling demand and local climate conditions. Which is why you need **bigger or more condensers in hot/humid climates** like north and coastal Queensland to compensate for high wet-bulb temperatures! **Air accumulation and corrosion** effectively **reduce** surface area!

Air flow - gets forced through the condenser by its fans. The more air flows the more heat is rejected. **This is the only of these 3 factors which can be actively managed** by means of fan control.

EFFICIENT VS. INEFFICIENT 2

- Example: Instead of using a bigger condenser (more surface area, more expensive) **for more condenser capacity** you can simply force through more air. Of course, this uses **more fan power** (surface area just chosen as an example, there are other factors such as pressure losses from geometries for cheaper manufacturing, etc.).
- Different condensers use different amounts of fan energy to reject the same amount of heat.
- Figure of interest: kW rejected heat per kW fan power.
  → Can differ by a **factor of 5-10!**
- You probably know your condenser's capacity, but do you know if it is efficient?



3 WHERE DOES THIS BECOME A PROBLEM?

In general, it is always good to be **energy efficient**, same applies to condensers.

Having said that, areas with **colder dry climate** like the south of Australia can rely on smaller condensers with less capacity, simply because these condensers reject enough heat due to lower ambient wet-bulb temperatures.

Condenser power consumption in these areas tends to be **smaller portion of overall system power** usage.

The same condenser **would be undersized** for the same system and cooling load in a hot humid climate like north Queensland. There you need much bigger condenser capacities and more fan power.

Condenser power tends to make up larger portion of system's energy consumption in **hot humid climates.**

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"Efficient condensers are of special interest in hot humid climates"

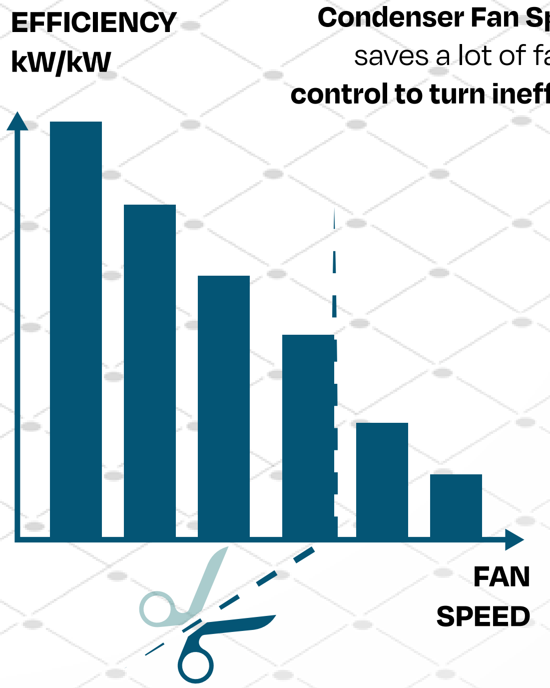
4 ADD CONDENSER CAPACITY

Having a **surplus in condenser capacity** helps **compressors** to save energy.

Keeps head pressure down even on hot days and during peak production when head pressure would otherwise rise due to capacity limit.

Allows to drop head pressure even lower when using **Variable Head Pressure Control** and doing so more efficiently.

FIX INEFFICIENT CONDENSERS 5



Condenser Fan Speed Control (see pg. 30 - 33) by itself saves a lot of fan power. However, you can use **speed control to turn inefficient condensers** into efficient ones.

Slowing fans down decreases fan power at a quicker pace than it does with capacity. So, the **kW of rejected heat per kW fan power increases** making the condenser more efficient. By **capping fan speed** on a condenser you will effectively make that condenser more efficient.

This still reduces condenser capacity to some extent. You **might need to add more condensers**. But you do not fully have to get rid of old inefficient models and can operate them more efficiently at reduced capacity instead. **Plus**, you can keep the lost capacity as a **control buffer** for hot days and implement logic that overrides the set speed limit, if more capacity is needed. This is spelled out in more detail in the **How-To Manual.**

6 DOES THIS WORK FOR ME?

Does head pressure regularly **rise above set-point** on warmer days or during midday when the system is running near full load? Do you even have to **stall production** so you do not overwhelm your condensers?

Add condenser capacity.

Are you planning on **replacing** an old condenser or **adding** a new one?

It is probably not feasible to replace an inefficient condenser, if it is still in a good condition. However, you can use the fix to improve efficiency. If you are investing into a new condenser **do not** simply **pick the cheapest model. Energy consumption and life-time costs need to be considered!**

Are you in a **hot humid climate**? (Climate zones 1 and 2)

Condenser fans probably make up a considerable portion of energy used and having efficient condensers make even more sense.

SYNERGIES 7

Follows:

A Control & Monitoring Upgrade can make it easy to implement sophisticated controls like the aforementioned fix.

Condenser Fan Speed Control makes condensers more efficient in general. It also helps you to cap fan speed to fix inefficient units.

Air Removal helps to maintain condenser capacity. Air accumulation would drop capacity!

Enables:

Added condenser capacity helps Condenser Fan Speed Control to run fans slower and save more energy.

Extra capacity and efficient condensers allow for the effective use of Variable Head Pressure Control.

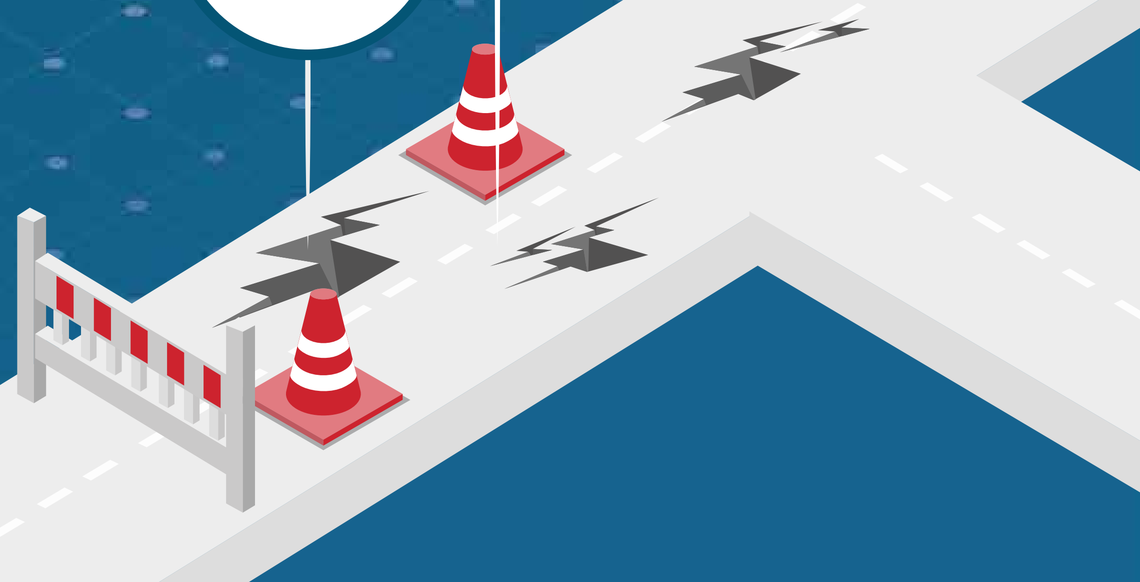
8 GOOD TO KNOW

- It is hard to tell if you have an efficient condenser. You can use the manufacturer's design software or **ask your contractor or refrigeration specialist**, if they can help you with this.
- Condenser efficiency varies from **model to model** even within one manufacturer's range.
- An efficient condenser is not necessarily more expensive than an inefficient one – **be careful during selection.**
- Additional condenser capacity can **help to reduce demand costs** (see "How to interpret your electricity bill" in the How-To Manual) by reducing head pressure during **production peak.**

POSSIBLE POTHOLES 9

Problem of justifying **higher up-front costs**

Possible **space restrictions** might prevent you from installing condenser models with a bigger footprint.



AMPC

This Guidebook is one of five 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 Guidebook subtitled "INDUSTRIAL AMMONIA SYSTEMS PART 1" is the first of two parts aimed at medium- to large-sized meat works which use industrial type ammonia refrigeration systems.

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