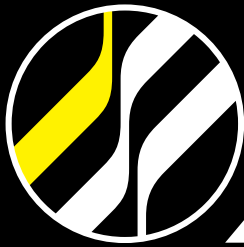


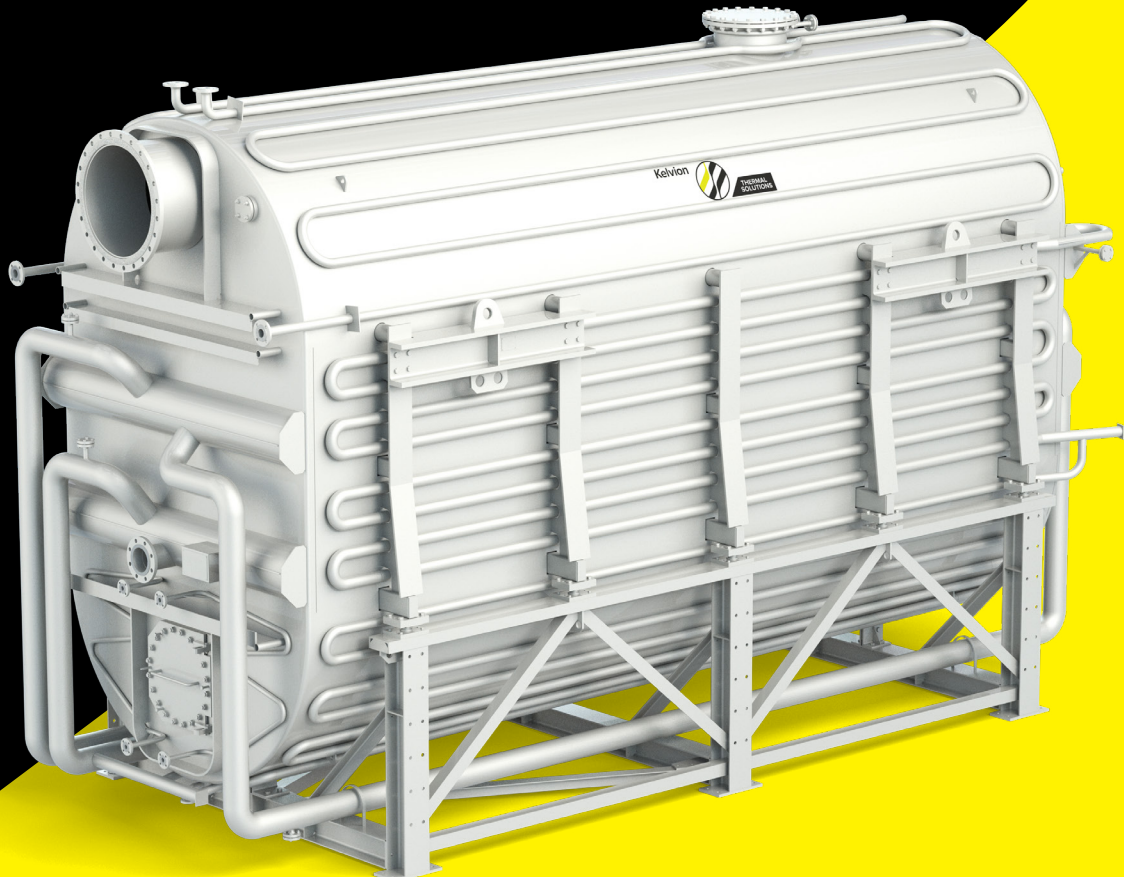
Kelvion

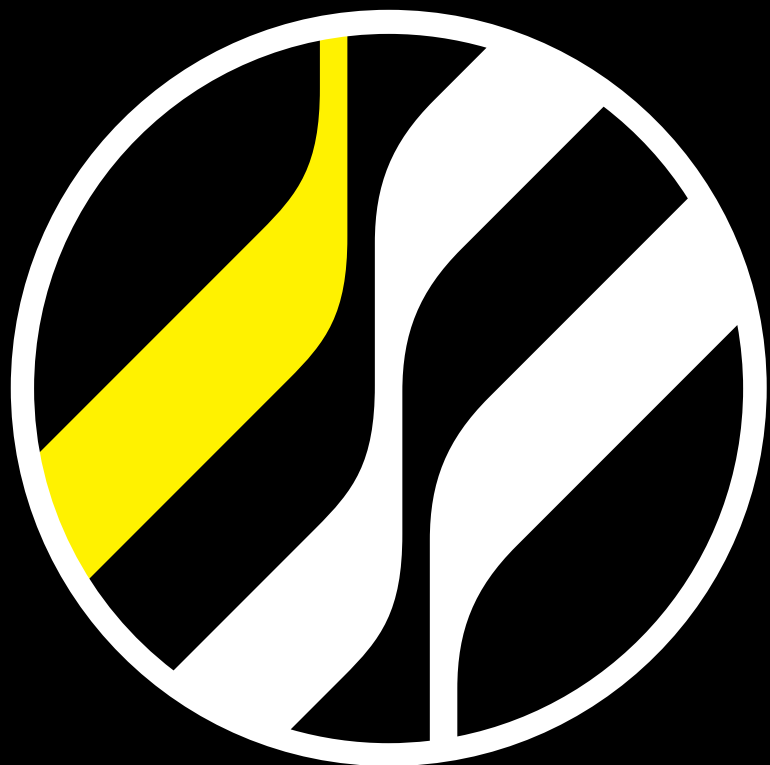


THERMAL
SOLUTIONS

Product Line: Desublimators

**ALWAYS ONE
STEP AHEAD**





LEADERS IN ENGINEERED THERMAL SOLUTIONS

Kelvion Thermal Solutions is your global partner for improved process efficiency. We offer world class expertise and tailored heat exchange solutions that continue to set new standards. As our name suggests, we are part of the Kelvion Group - a global manufacturer of industrial heat exchangers since 1920.

Our extensive know-how can be applied to a wide range of applications and industries, including **Data Centres**, **Hydro-gen** production and distribution, waste to energy, **Carbon Cap-ture** and Oil & Gas. In particular, we are supporting the reduction in fossil fuel dependency through Green-Tech and High-Tech oriented technologies, and through our capabilities to offer integrated solutions. Our sales organization and our engineering and manufacturing plants are present **globally**, allowing us to be your perfect partner for heat transfer solutions, **in every Region**.

Developing, supplying products and solutions is one side of our business – comprehensive service offerings is the other. Supporting you after you have made a purchase is paramount. With our more than 30 service centers worldwide, we are always near by to ensure uninterrupted operation.

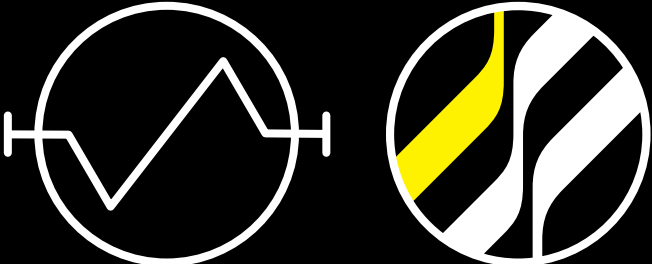
Kelvion Thermal Solutions – Leaders in Engineered Thermal Solutions!

KELVION – A TRIBUTE TO LORD KELVIN (1824 - 1907)

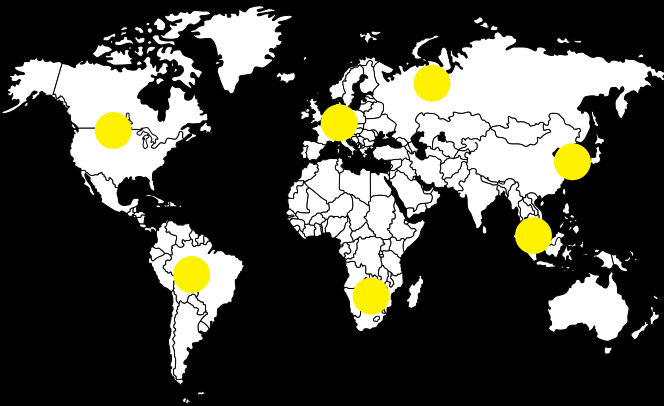


Lord Kelvin formulated the laws of thermodynamics and absolute units of temperature are stated in kelvin, in his honor.

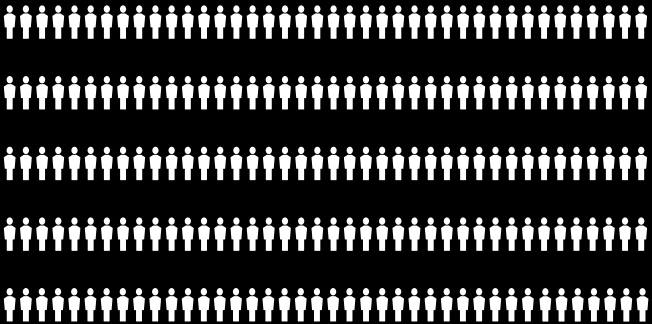
OUR LOGO – INSPIRED FROM THE SCHEMATIC FOR HEAT EXCHANGER



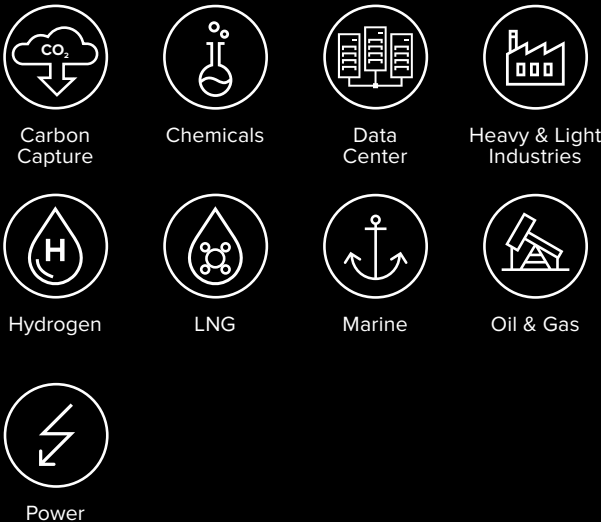
SALES BRANCHES WORLDWIDE



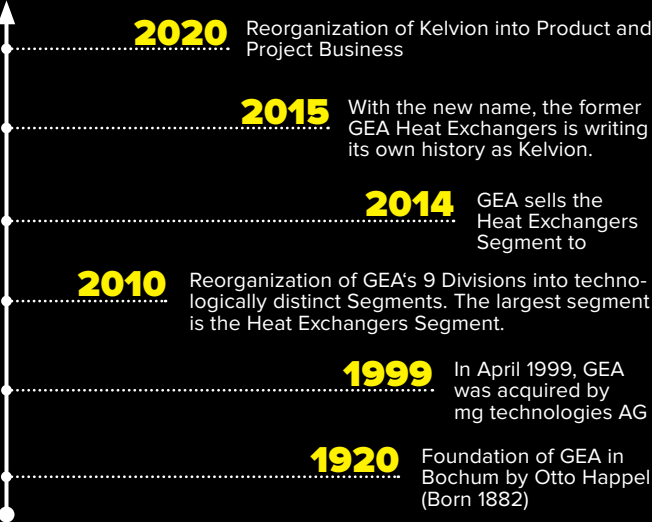
1,500 EMPLOYEES WORLDWIDE



YOUR MARKETS ARE OUR MARKETS

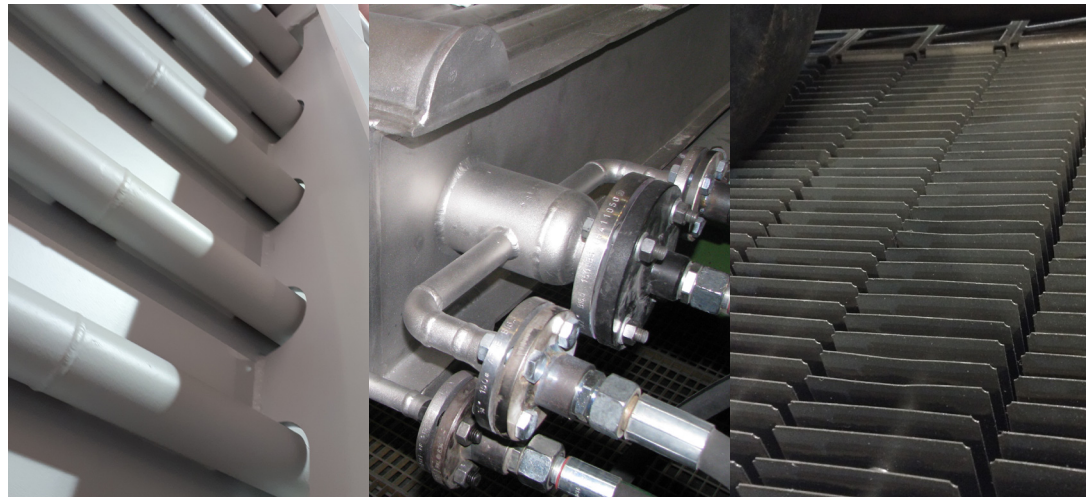


KELVION HAS A LONG HISTORY



We invest in Quality and Sustainability

60 YEARS OF RESEARCH & DEVELOPMENT



In 1954 Kelvion engineers invented the first desublimator, called the Switch Condenser, for the phthalic anhydride (PA) process. Today the technology can be found in most PA plants around the world.

Over the last 65 years we have continued to refine and further develop our products, in co-operation with our customers, making us the global market leader in desublimation technology.

The latest generation Switch Condenser was introduced in 2012, while Mini Desublimator, our smallest model, has been a popular choice since 1982 for protecting the vacuum system of the distillation in the PA process, as well as many other applications.

Our engineers not only focus on thermodynamics and heat engineering, but also work closely with our customers to provide a desublimator that will integrate fully with their specific process-engineering requirements.

With their intimate knowledge of manufacturing and applications, Kelvion experts analyse production environments and processes. They then develop recommendations and help to implement them. Our approach is holistic, but the solution is specific and individual.

Our extensive manufacturing and welding engineering know-how enables us to offer all weldable materials when designing the unit. Our range of services is rounded off by support during plant start-up and optimisation in day-to-day operation.



KELVION INNOVATIONS

- Innovation through continuous development in cooperation with universities and institutes
- Continuous development driven by customers' experiences
- Optimum use of surface area for highly-efficient product separation
- Long lifetime due to flexible design for cyclic operation
- Lighter weight for reducing energy consumption

DESUBLIMATION PRINCIPLE



Desublimation is the direct phase change of a substance from a gas to a solid, without an intermediate liquid state. This phenomenon naturally occurs in the formation of hoarfrost when water vapour from the ambient air freezes on contact with cold surfaces as ice crystals. Frost on the window in winter is a familiar example. Another is the frost formation in home freezers.

Kelvion engineers reproduced this process in a desublimator to separate substances from gas mixtures.

The log p/T diagram shows that desublimation is separate from condensation. Whereas water from the ambient air condenses above the triple point, the water below the triple point can only desublimite from the gas phase. As well as direct desublimation just below the triple point, indirect desublimation is also possible. The result is crystallization, but indirectly via previous condensation. The gaseous substance first condenses, but then freezes immediately on the cold surface – in nature this manifests as freezing rain.

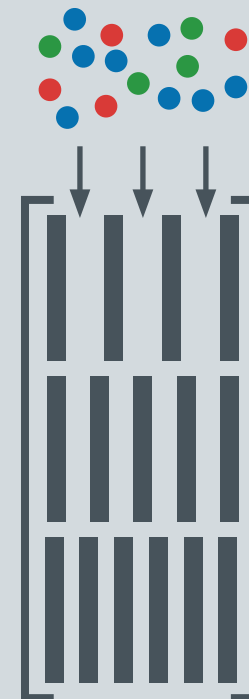
GOOD TO KNOW

- ▶ Desublimators are not “regular” heat exchangers.
- ▶ The purpose of desublimators is material separation through phase change.
- ▶ Desublimation is a thermodynamic material separating process.
- ▶ Desublimation can be an attractive alternative to adsorption, absorption or cyclon separation methods.

DESUBLIMATOR OPERATION

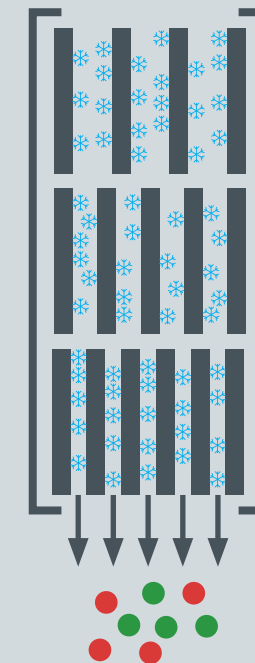
STEP 1

Gas mixture enters the desublimator.



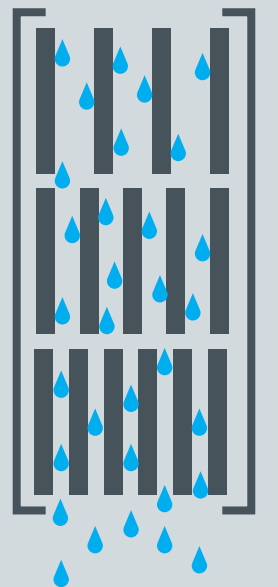
STEP 2

The gas mixture flows through cooled lamellas/fins where the part to be separated desublimates either around or below its triple point, and adheres to the cold surface in crystalline form.



STEP 3

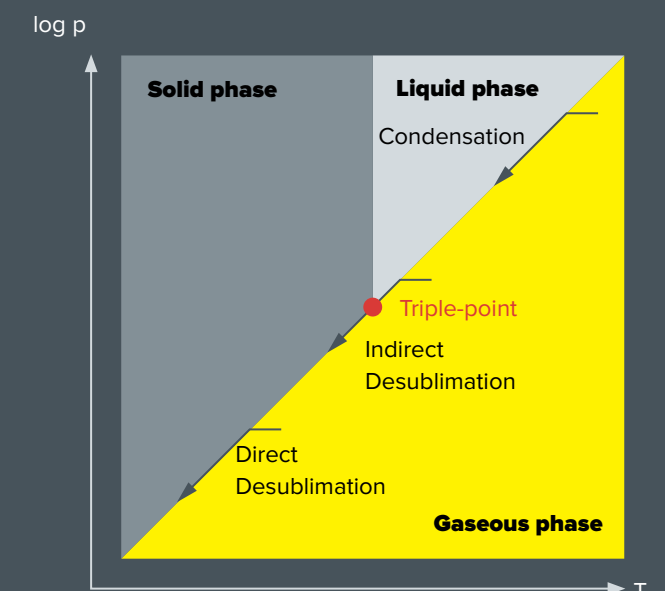
The crystallized product is melted off as soon as the desublimator is fully loaded. Using a minimum of two desublimators allows a continuous process.



log p / T DIAGRAM: PARTIAL PRESSURE AS FUNCTION OF TEMPERATURE

PHASE CHANGES

- ▶ **Condensation:** phase change above the triple-point
e. g. rain, dew formation
- ▶ **Indirect desublimation:** phase change just above the triple-point
e. g. freezing rain, freezing moisture on cold surfaces
- ▶ **Direct desublimation:** phase change below the triple-point
e. g. snowfall, crystallization on cold surfaces



OUR SOLUTIONS

Technical Desublimaton

Desublimation is a thermodynamic process for separating product from a gas stream and is an alternative to adsorption and absorption. The separation is achieved by cooling and heating in batch-operation. It is used, for example, in chemical and pharmaceutical processes, to secure vacuum pumps or for tank venting. The separated component can be an invaluable raw material or may be hazardous for the environment.

Kelvion desublimators are available in a range of vessel sizes, materials, certificates and tests to support customer requirements worldwide.

Desublimator Technology

The design philosophy of our desublimators is the optimal use of the entire installed surface for collecting substances. For that reason, we have introduced at least three sections with different designs and functions.

For example, the desublimator for the PA process, called a Switch Condenser has high density, high yield and high efficiency sections. The high density section is located next to the gas inlet to collect PA in a very compact form. The high yield section in the middle of the unit is not only for PA collecting but also for gas cooling. Finally, the high efficiency section next to the gas outlet is designed mainly for gas cooling. In addition, it has a special filter function for PA needles, which guarantees the very high efficiency of our Switch Condensers.

While the Switch Condenser is a tailor-made solution for the PA process, the Mini Desublimator Mini Desublimator is well established for many other applications, using the same design philosophy.



Mini Desublimator Mini Desublimator



Switch Condenser

WHY TO USE KELVION DESUBLIMATORS



Highest separation efficiency of components from gas-streams at optimum product purity.



Low energy consumption achieved through optimized equipment design

Highest ecological compatibility by avoiding solvents



Innovative and advanced product due to our co-operation with international universities and institutes, as well as with industries



EFFICIENCY OF...

... POWER PLANTS



40 - 45 %

... HEAT EXCHANGERS



approx.
80 %

... FILTERS / DEMISTERS



approx.
98 %

... DESUBLIMATORS



approx.
99.5 %

THE BIG SMALL



In the Mini Desublimator unit the gas mixture comes into contact with cooled lamella/fin. Here that part of the gas mixture to be separated desublimates either around or below its triple point and adheres to the cold surface in crystalline form. The Mini Desublimator unit is split into several sections to achieve an optimum distribution of the product inside the desublimator. This special design feature ensures the highest separation efficiencies and longest loading times.

A range of lamella/fin designs are available for optimum utilization of the heat exchanger surface – and the sectors are adapted individually to each process requirement to achieve superior separation efficiency of over 99.5 percent. The crystalized product is melted off as soon as the desublimator is fully loaded. The heating medium flows through the same channels as the cooling medium. A continuous process is achieved by using a minimum of two Mini Desublimators.

Mini Desublimator comes in standard sizes, as well as a wide range of tailored design configurations and internal fittings. Thanks to its compact design the unit does not take up too much space. Mini Desublimator is available in all weldable materials. For operational safety and to reduce the risk of leaks, there is no direct welding between the gas and cooling/heating sides. Also, the number of welds is minimized. Design, manufacturing and testing to the highest international standards prove Mini Desublimator's reliability.

BENEFITS


- ▶ Clean process: no chemicals or water needed
- ▶ Excellent separation efficiency of 99.5 %
- ▶ High product purity
- ▶ Minimal space requirements due to compact design
- ▶ No moving parts: low wear, high operational reliability, virtually maintenance-free
- ▶ Low energy consumption

DESIGN DATA



DESIGN PRESSURE

▶ **VACUUM UP TO 50 BAR**



GAS FLOW

▶ **5 - 500 KG / H**



DESIGN TEMPERATURE

▶ **-150 °C TO 350°C**

Applications



Product separation in chemical & pharmaceutical processes



Environmental protection



Tank venting



Protection of vacuum systems



Recovery of valuable (raw) materials

Typical substances that can be separated by desublimation:

AMINOPHENOL
Water Oligomers
PTHALIC ANHYDRIDE
Polylactide NAPHTHALENE
Chloro aniline
Polymers IODINE
Naphthol TDA (diamino toluene)
GLYCOLIDE Amylphenol



INTERNATIONAL CERTIFICATION

- ▶ TÜV NORD
 - ▶ TÜV Rhineland
 - ▶ TÜV Austria
 - ▶ Det Norske Veritas
 - ▶ Class NK
- ▶ Lloyd's Register of Shipping
 - ▶ Bureau Veritas
 - ▶ American Bureau of Shipping
 - ▶ Germanischer Lloyd
- ▶ Urzad Dozoru Technicznego
 - ▶ Inspection and Quarantine of the PRCh
 - ▶ Gost – RT
 - ▶ U-Stamp acc. ASME Code



Product separation in processes

When the PA process was established in 1954, in co-operation with chemical and pharmaceutical industry pioneers, Kelvion provided valuable support with the launch of its first desublimators. Since then, our thermodynamic separation technology has provided a reliable alternative, with significant advantages, to the traditional separation methods of adsorption, absorption and cyclones.

In the PA process ambient air is enriched with a feedstock, which reacts to generate the PA. This is then separated from the reaction gas stream and used commercially as an industrial chemical and raw material.

The Kelvion desublimators can handle large amounts of gas and therefore separate a significant amount of PA – at the highest efficiency in the industry of 99.5% minimum. Today the PA process remains the main application for our desublimators in the chemical industry, which are installed in most PA plants worldwide.

In recent years we have successfully introduced this technology into other processes. For a continuous process at least two desublimators have to be installed. The PA process commonly requires four desublimators per production line.

Environmental protection and tank venting

Another application for the Kelvion desublimator is cleaning polluted waste gas streams, for example, venting of industrial fuel or storage tanks. The vent gases leave the tanks as a mixture of inert gas saturated with the stored substance. The desublimator acts as a vent cooler to reduce the amount of substances that can be desublimated escaping into the environment. The waste gas is reliably cleaned in the desublimator by separating the substance enriched in the inert gas. In this application it is generally sufficient to install only one desublimator directly on top of the tank.

Recovery of valuable (raw) materials

In the chemical and pharmaceutical industries it is not unusual for valuable raw materials to be found in the production process. These may only be required as reaction intermediates, not for inclusion in the end product.

An example of this is iodine, which is a very expensive halogen. Iodine contained in gaseous substance streams desublimates even at room temperature. When used as an intermediate, it can be easily recovered in Kelvion desublimators.

In the production of polyphenylene sulfide (PPS) several desublimators are installed in certain process steps to separate the valuable iodine. Using desublimators, iodine can be almost completely recovered, making the continuous production process of PPS economically viable.

Desublimation offers the following advantages over other substance separation processes, such as washing with solvents:

- ▶ low operational cost
- ▶ environmentally friendly
- ▶ no solvents to be disposed of
- ▶ high product purity
- ▶ high separation rates

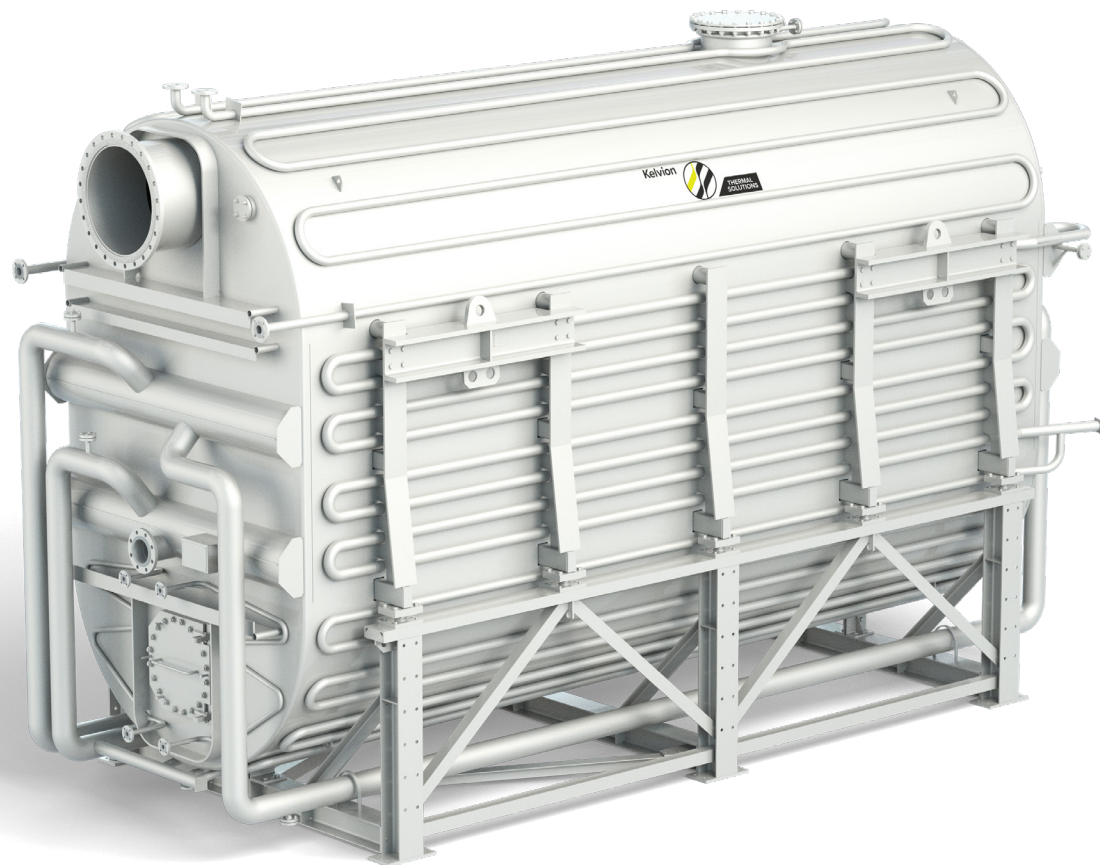
Protection of vacuum systems

A problem encountered in process engineering is when the vacuum generator draws in substances contained in the suction stream. These can desublime in the inner part of the generator, causing blockages. To avoid this, desublimators can be used to clean the substances from the suction stream.

For example, in vacuum distillation two desublimators will clean the saturated suction gas from the distillation section. In this way, a continuous and safe process is guaranteed.

Switch Condenser

THINK BIG



Since the invention of the Switch Condenser in 1954, Kelvion has delivered more than 1,500 units globally for PA processes. We have continuously developed the mechanical as well as the process design of our Switch Condensers. In particular, we have adapted the specially designed fin tube system of rectangular fins to meet the latest PA process requirement of increasing feedstock loading of the air.

The design philosophy behind our Switch Condensers is the optimal use of the entire surface for collecting PA, to ensure economical loading times. For that reason, we have introduced three sections of fin tube systems with different designs and functions.

The main task of the high density section is collecting PA in a very compact form. Next, there is a high yield section, which also collects PA and cools gas. Finally, the high efficiency section has a special filter function for PA needles. This guarantees the very high efficiency rate of Kelvion switch condensers.

Our engineering excellence has convinced our customers worldwide, who have confirmed our technological advantages in their processes and daily operation. As a result, Kelvion is the undisputed world market leader in desublimator technology.

Based on our extensive knowledge of the PA process, Kelvion engineers have developed further valuable solutions for this process. In particular, the GasKat (postreactor) and Precondenser (partial PA condenser), both of which are standard in a modern PA plant.

DESIGN DATA

GAS FLOW

► **MAX. 40,000 NM³/H**

CAPACITY

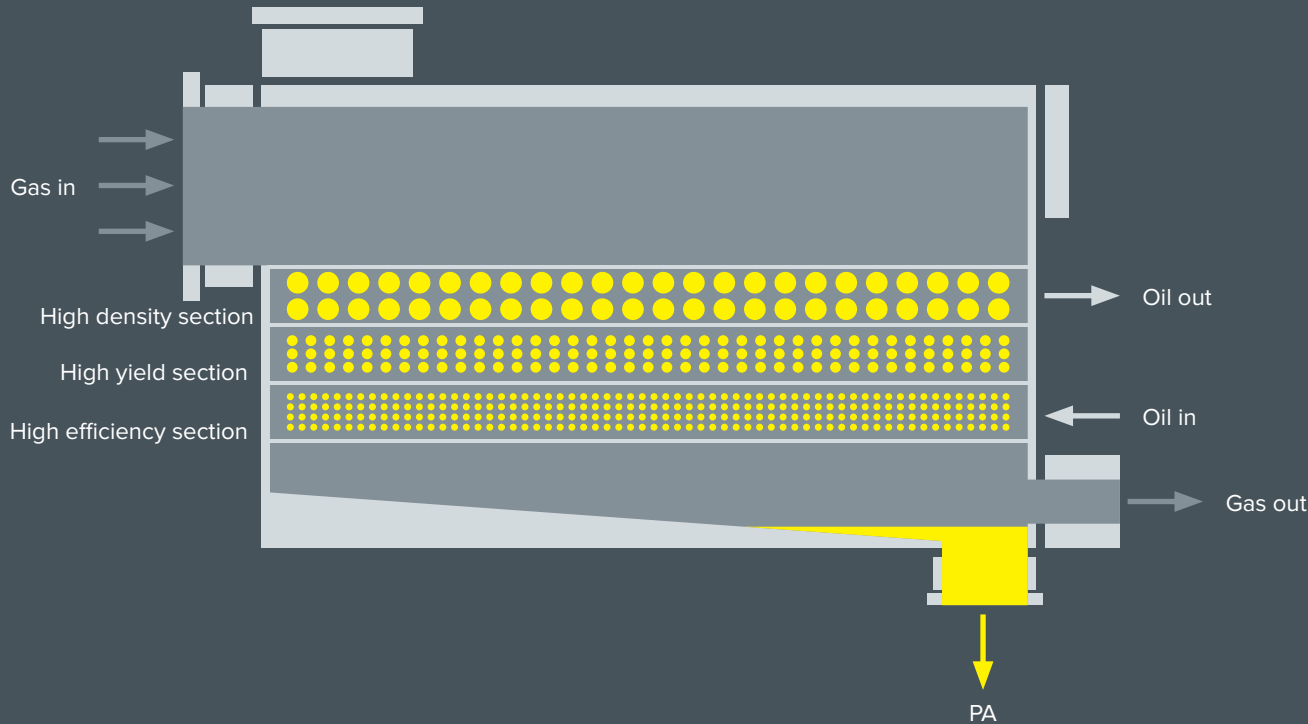
► **MAX. 10,000 KG PA/CYCLE**

EFFICIENCY

► **MIN. 99.5 %**

O-XYLENE LOADING

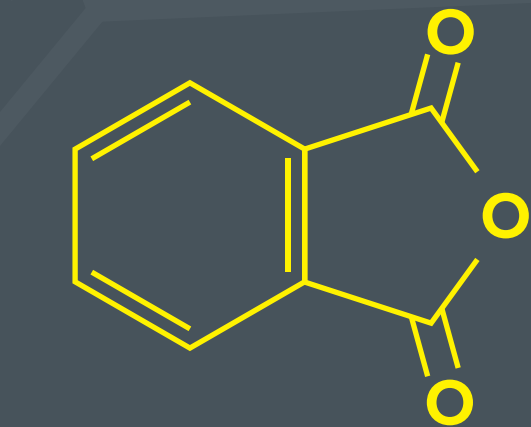
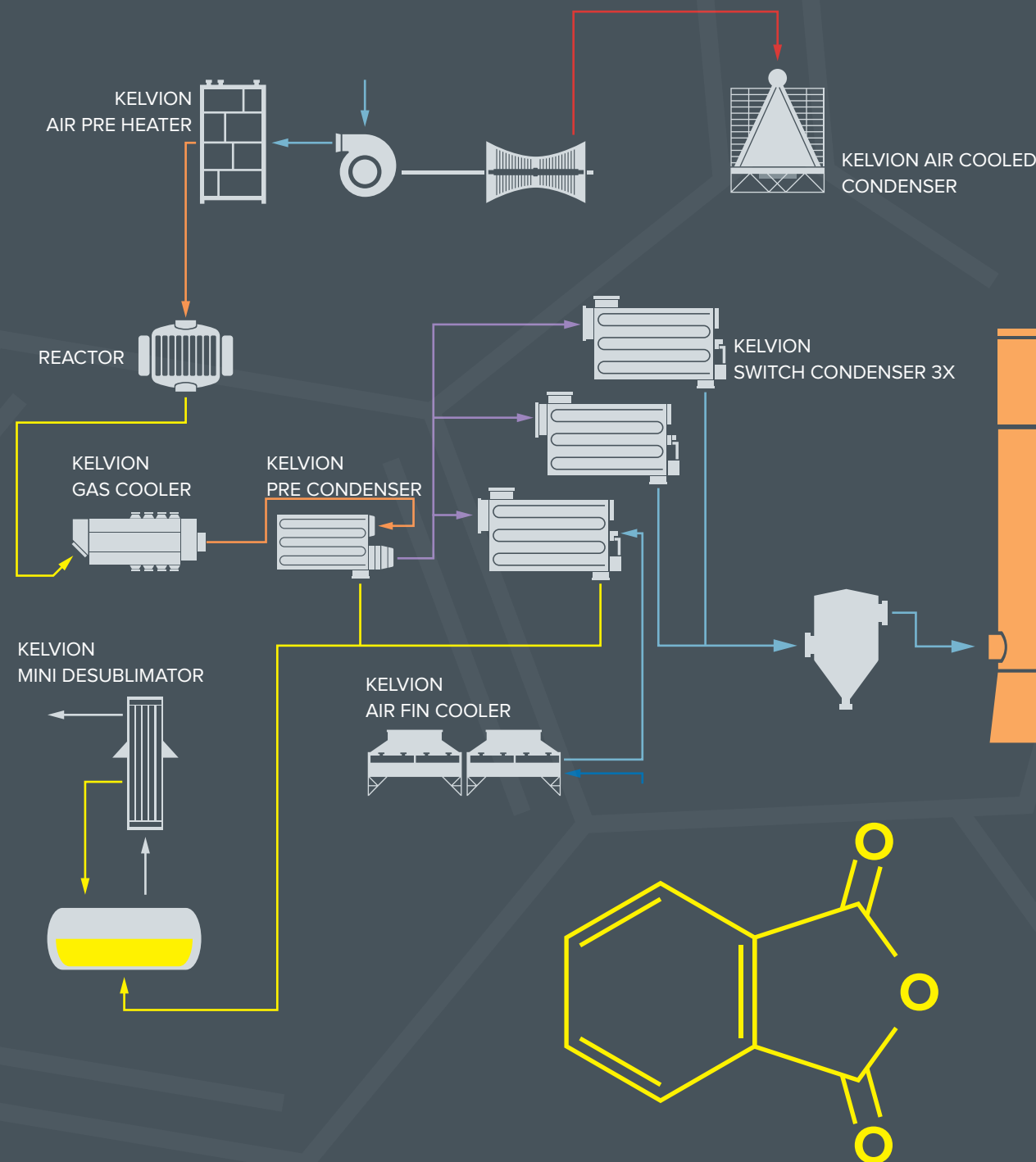
► **100 G/NM² AIR & HIGHER**



BENEFITS

- Highest efficiency/minimum PA loss
- Low weight
- Low operating cost
- Low energy consumption
- High reliability
- Minimized risk of fatigue failures
- Long lifetime
- Maintenance friendly

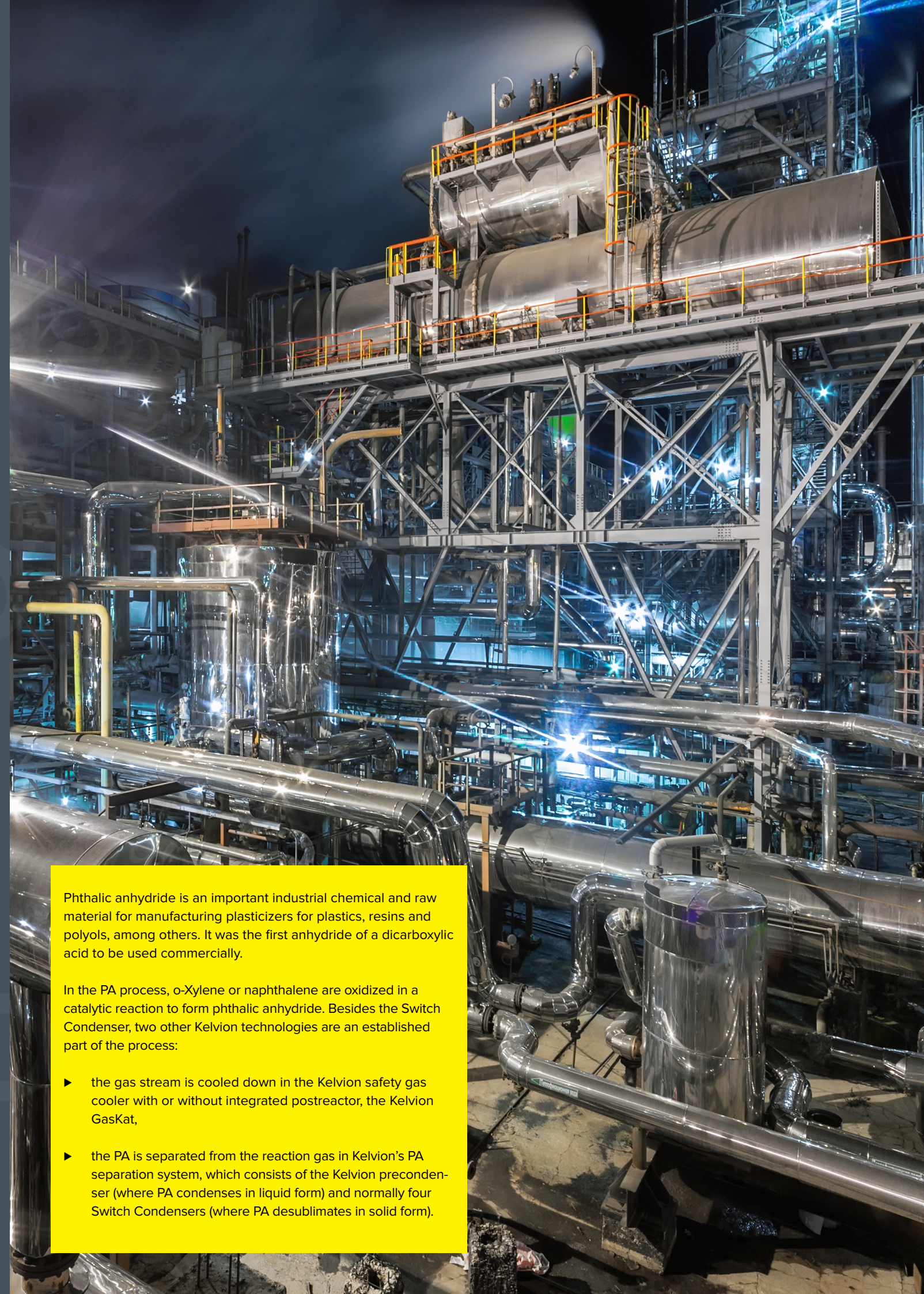
PHTHALIC ANHYDRIDE PRODUCTION



Phthalic anhydride is an important industrial chemical and raw material for manufacturing plasticizers for plastics, resins and polyols, among others. It was the first anhydride of a dicarboxylic acid to be used commercially.

In the PA process, o-Xylene or naphthalene are oxidized in a catalytic reaction to form phthalic anhydride. Besides the Switch Condenser, two other Kelvion technologies are an established part of the process:

- ▶ the gas stream is cooled down in the Kelvion safety gas cooler with or without integrated postreactor, the Kelvion GasKat,
- ▶ the PA is separated from the reaction gas in Kelvion's PA separation system, which consists of the Kelvion precondenser (where PA condenses in liquid form) and normally four Switch Condensers (where PA desublimates in solid form).



KELVION SOLUTIONS EXPLAINED

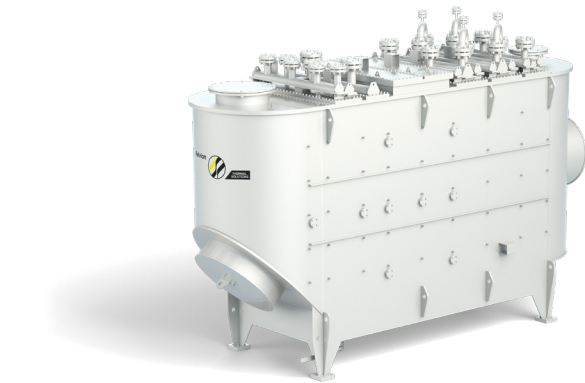
SWITCH CONDENSER

The Kelvion Switch Condenser is an essential part of any PA plant. Its special process and mechanical design guarantees the highest separation efficiency and a long operational lifetime. Because of its relatively low weight, Kelvion's SWC is low on energy consumption.



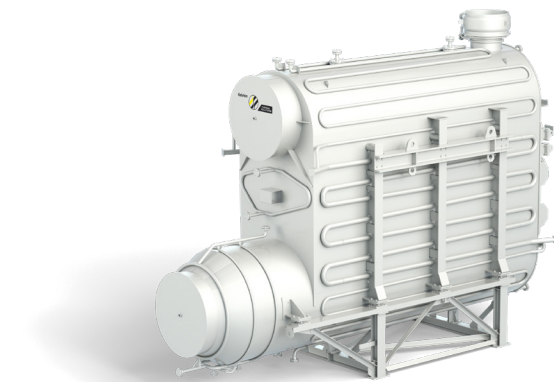
SAFETY GAS COOLER/ GASKAT

Downstream of the reactor, the gas must be cooled down to allow the separation of PA. The Kelvion Gaskat, which combines a safety gas cooler with a post-reactor in one casing, is the ideal solution. The gas is cooled by the combination of superheating the steam, water evaporation and/or heating of boiler feed-water. Gaskat has removable bundles (screwed into the casing) for easy maintenance and laser welded fins – no added materials to the welding seam. The use of finned tubes provides a very compact unit.



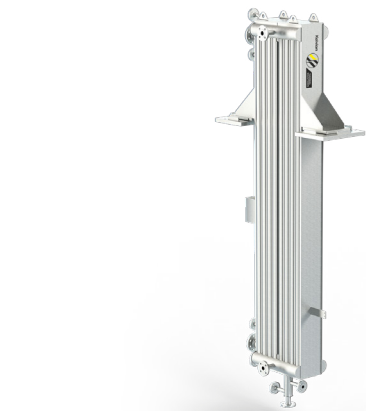
PRE CONDENSER

Kelvion developed the Pre-condenser in 1990 specifically to enable the continuous separation of PA in high loading PA-plants, where concentrations are way above the triple point. The Pre-condenser separates the PA from the gas in liquid form, before the gas enters the Switch Condensers.



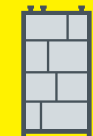
MINI DESUBLIMATOR

The Mini Desublimator has two main applications in the PA process. Firstly, in distilling the crude PA, where vacuum is required. The Mini-Desublimator protects the vacuum generator against blockages in the vacuum system. The second application is for venting tanks of PA or naphthalene.



AIR PREHEATER

The Kelvion Air Pre-heater plays an important role in heating the ambient air to approximately 200°C, to allow the reaction to take place. This safety finned-tube heat exchanger is a compact unit. It comes with removable bundles (screwed into the casing) for easy maintenance.



AIR FIN COOLER (AFC)

The Switch Condenser requires a cold oil circuit to operate effectively. The oil has to be re-cooled downstream to keep it at the correct temperature. An Air Fin Cooler is the tried and tested technology for this task.



AIR COOLED CONDENSER (ACC)

The PA process is highly exothermic. In many high-loading PA plants, this surplus of energy is used for power generation in a turbine. For condensing the steam downstream of the turbine, Kelvion offers Air Cooled Condensers.

