SATAIR

Cabin Air Treatment

50 years behind the scenes in the commercial aviation industry

AN **AIRBUS** SERVICES COMPANY

We take it for granted today that we can jump on an aircraft at our local airport and emerge a few hours later in another city, state, or even continent. The aircraft maintains a comfortable temperature, the air pressure remains close to what we experience on the ground, and the air itself is clean and easy to breathe – the entire trip!

Today's commercial aircraft routinely carry hundreds of passengers thousands of miles at 35,000 feet and above. Outdoor temperatures at this elevation can fluctuate from -30 to -70°C. The air is so thin at this elevation that people would lose consciousness after about a minute. The environment at this altitude is not a place humans can survive for more than a few seconds. The science and engineering keeping passengers and crew safe and comfortable in modern jets is truly amazing.

For the past 50 years, BASF has been providing cabin air converter solutions to the aviation industry. Founded in Germany more than 150 years ago, BASF is one of the largest companies in the world. It employs over 100,000 people and operates in more than 80 countries. From enabling agricultural solutions, to providing the building blocks of drugs like ibuprofen and technical end-user products such as catalytic converters, there is a good chance BASF products are a part of your everyday life already!

BASF is the global leader in catalyst technology across several industries including aerospace. From boarding, to flying near the edge of the atmosphere and back down to our arrival gate, BASF's catalyst technology provides front-line protection from ozone gas and volatile organic compounds (VOCs). BASF is the inventor of the technology and has been chosen as the original equipment provider on more aircraft than any other provider.

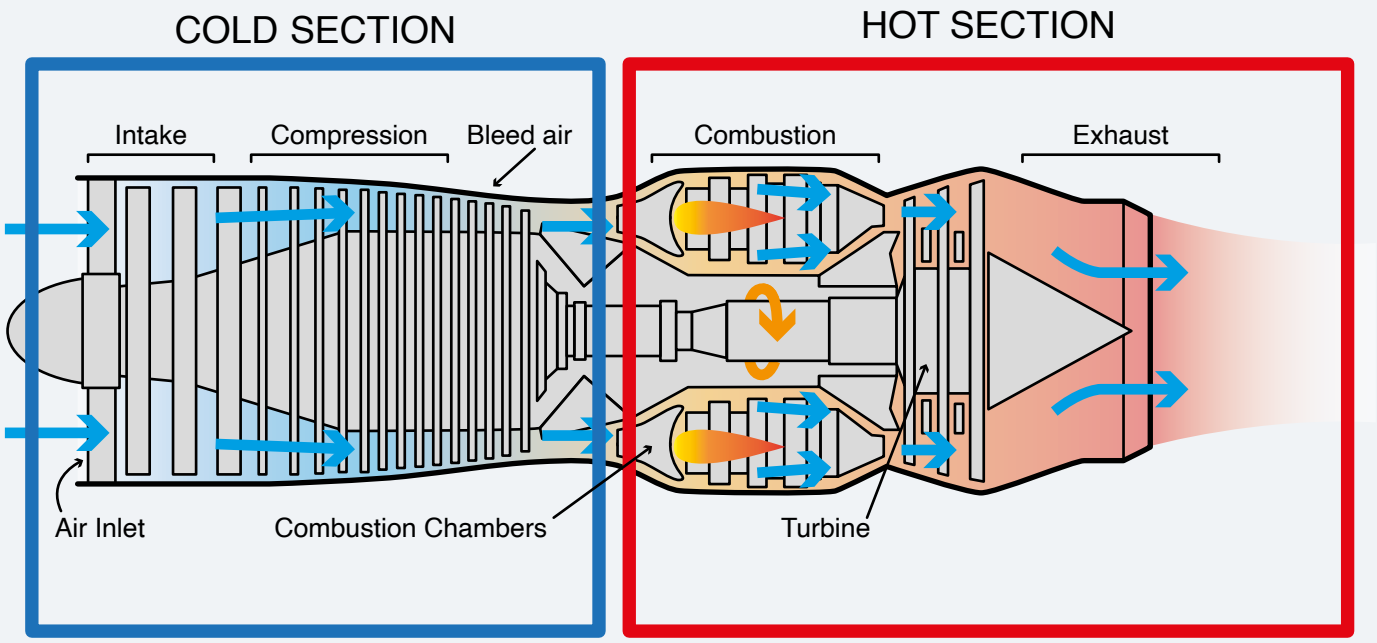
BASF's story in aviation began over 50 years ago when aircraft began flying high enough for passengers to experience the effects of ozone gas. The 1973 Oil Crisis drove the aerospace industry to find the most efficient means of getting from point A to point B. Aircraft were designed to go higher than ever to take advantage of the thinner air to fly faster and use less fuel. But at this elevation, there can be elevated levels of naturally occurring ozone (O_3). If ozone is inhaled, it reacts adversely in our respiratory system and could cause passenger discomfort.

Therefore, high ozone concentrations must be addressed in the aircraft cabin. BASF provided the aerospace industry with the first ozone converters and pioneered the first VOC (Volatile Organic Compound) converters. They are still leading the way with new technologies to deliver the highest quality cabin air to passengers and crew.

In 2024, BASF launched its latest converter technology, Volatile Organics and Ozone Combined Converters (VOZC), for the Airbus A320 family of aircraft. Not only does it reduce ozone, but delivers next generation VOC conversion performance.

The Airbus A320, is one of the most popular commercial aircraft ever designed. Over the past few years BASF has worked alongside Airbus to design and test the most effective converter yet – so there's no better time to take a look at the current challenges airlines face and this new game-changing innovation.

In this e-book, expect to learn about:



1 Air – how does it flow through an aircraft?

It starts with bleed air, but what is bleed air?

As air enters a jet engine from the outside environment, it is compressed from the ambient atmosphere by a series of fans or compressors. As pressurisation occurs, the air reaches temperatures in excess of 200°C. Some of this incoming compressed air is used to pressurise essential aircraft systems – including the Environmental Control System (ECS). This air is diverted from the engine's 'cold section' before any combustion occurs and hence is called 'bleed air'.

The outside air at cruising altitude is very clean and very cold (-30 to -70°C), but depending on the route, it might contain high levels of ozone gas. Ozone (O_3) is a powerful oxidant and elevated levels can cause damage to mucous membranes and respiratory tissues. Ozone also degrades rubber seals and plastics over time and its pungent smell slightly resembles chlorine.

For US operators ozone concentration in aircraft is regulated by FAA (Federal Aviation Administration) section 25.832. Operators in other parts of the world adhere to similar regulations.

The EPA (Environmental Protection Agency) regulates ambient air quality standards at ground level to protect public health via the National Ambient Air Quality Standards (NAAQS).

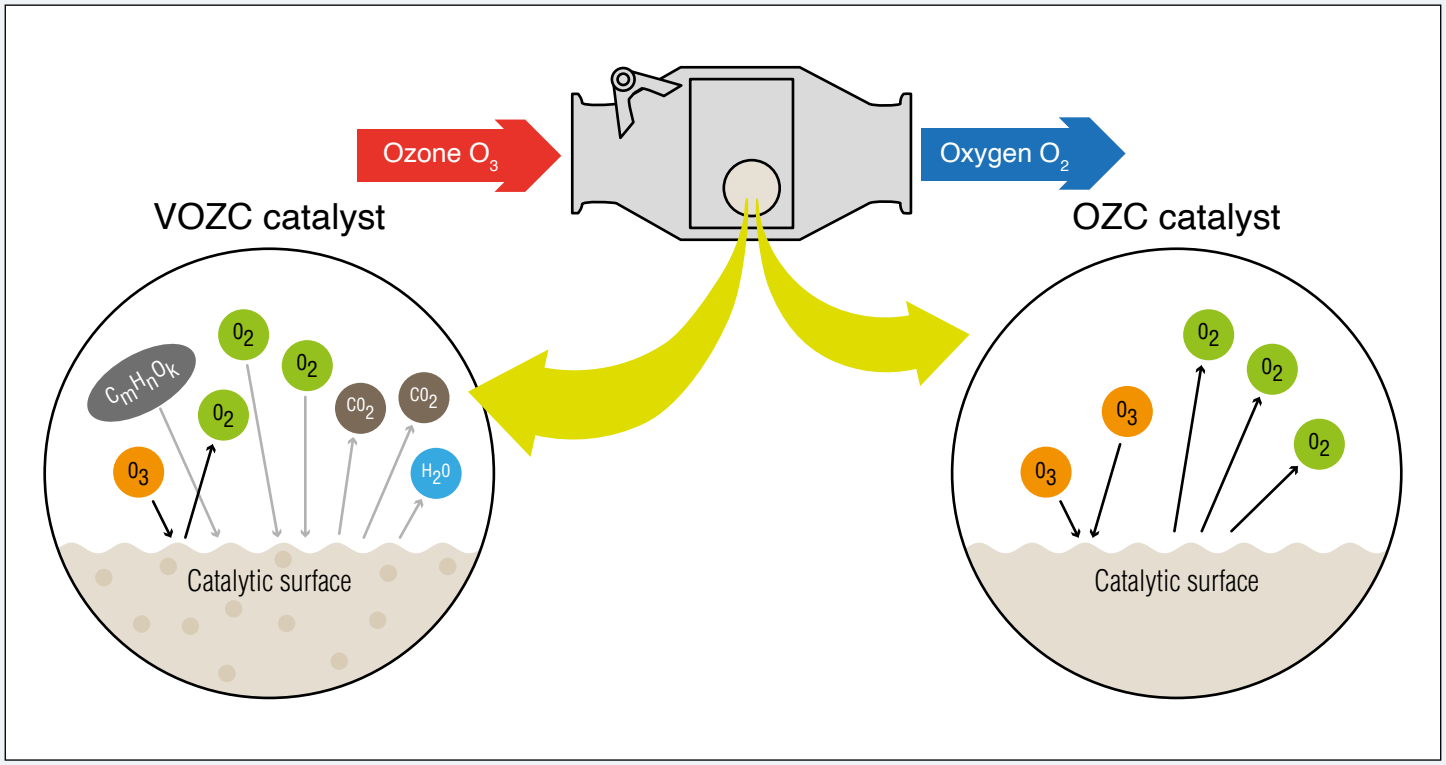
Bleed air travels from the compressor section of the engines and auxiliary power units, so once it enters the BASF catalytic converters, it is extremely hot and highly pressurised. The only cabin air treatment in the bleed air stream is the converter.

The most effective means of reducing ozone in aircraft cabins is to utilise BASF ozone converters to remove it from the bleed air before it enters the air conditioning system. The intentional design of the converter, from inside out, leads to the efficient conversion of ozone to into breathable oxygen. This technology is extremely durable and protects passengers for thousands of flight hours when maintained properly!

The technological leap forward presented by BASF and Airbus for A320 aircraft is the development of new catalyst materials that break down a wider array of VOCs much more effectively than ever before.

Some aircraft today are equipped with VOC converters – both new and legacy technologies. Representative VOCs include exhaust from other aircraft, kerosene vapours, de-icing fluids, hydraulic fluids, engine oils and lubricants.

These Dual Ozone/VOC converters are the best available technology for mitigating environmental odours entering aircraft cabins, and they are also the only



The ozone conversion process (simplified).

in-line solution to treat outside air before it reaches passenger compartments for most aircraft. The next-generation technology Ozone/VOC converters (VOZC) are available today via line-fit, retrofit and upgrade (UpCore) and can be retro-fitted to many aircraft.

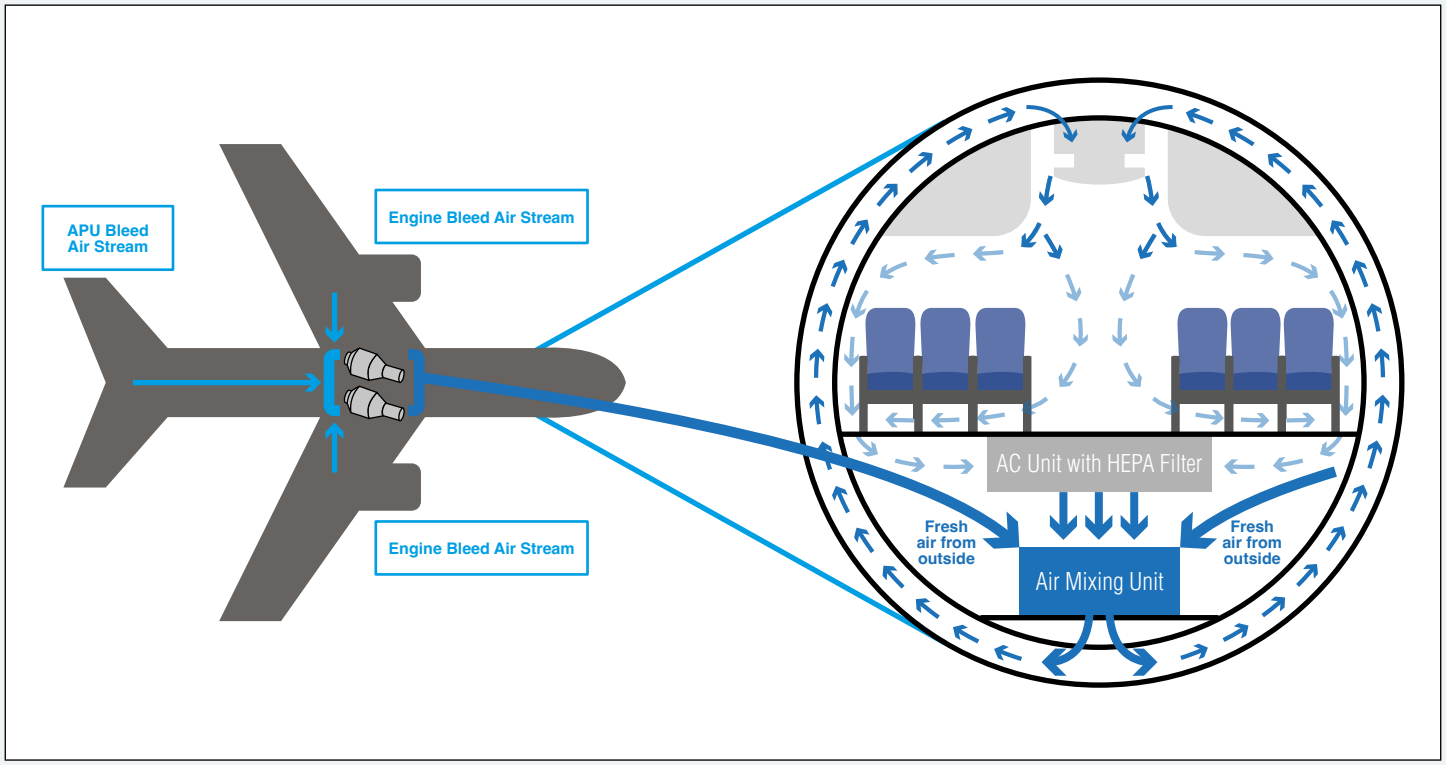
The air conditioning system
Bleed air is routed into the air conditioning packs. At this point it is still extremely hot and highly pressurised. Air conditioning packs combine a series of heat exchangers, compressors, turbines, condensers and valves to bring the temperature and pressure to comfortable levels and remove excess water from the air on ground in hot and humid environments.

After the air conditioning packs, air travels to the mixer unit where it is combined with filtered recirculated air from within the cabin, which ensures optimal supply temperatures are maintained and no temperature or pressure spikes occur. It also improves the humidity level in the cabin during flight. The mixer unit maintains a ratio of approximately 50/50 outside air and recirculated cabin air. Ducts connected to this chamber direct air through the aircraft and into the cabin via vents on the ceiling.

Airflow within the cabin begins at the overhead vents and gaspers. It pours down over passengers in their seats and is then pulled out through floor vents by recirculation fans and outflow valve(s) located beneath the floor. This process means most of the air provided at passenger's seats flows from the ceiling to the floor. This system provides a mixture of filtered recirculated air and outside air to the cabin every two to three minutes.

Cabin air filtration
Once beneath the floor, air is either dumped overboard via automatic outflow valves maintaining adequate cabin pressures or pulled back into the mixing chamber by powerful recirculation fans. In front of these fans are highly effective air filters called HEPA (High Efficiency Particulate Air) filters. These filters, which are also used in hospital operating rooms and computer chip manufacturing clean rooms, are the next stage of cabin air protection and are fitted to almost all commercial aircraft. They remove at least 99.95 percent of dust, allergens and microbes, including viruses and bacteria from the air, before the air re-enters the mixing unit. These filters address cabin air after it has already been circulated through the cabin, and they effectively capture particles that may have been created within the cabin itself.

Many airlines now utilise next generation Advanced Cabin Air Filtration (A-CAF) HEPA filters introduced by Pall Aerospace.



Cabin airflow: Fresh and filtered air circulates top-to-bottom for continuous ventilation and comfort.

They combine HEPA filtration with an additional activated carbon matrix capable of further reducing VOCs and other unpleasant odours. These filters are replaced at regular maintenance intervals close to or equaling the life of standard HEPA filters and require no change to the aircraft systems to implement their use.

So during all phases of flight and at all altitudes the ECS system is able to regulate the temperature and pressure whilst supplying clean air for passengers and crew. The process is largely automatic, but pilots have built-in controls throughout the system to carefully maintain comfort levels. The system enables thousands of aircraft to move millions of passengers every year comfortably through a hostile environment.

Those were the days: A stewardess lights a cigar for a passenger aboard an American Airlines flight in 1949. Credit: Bettmann/ CORBIS

2 No Smoking!

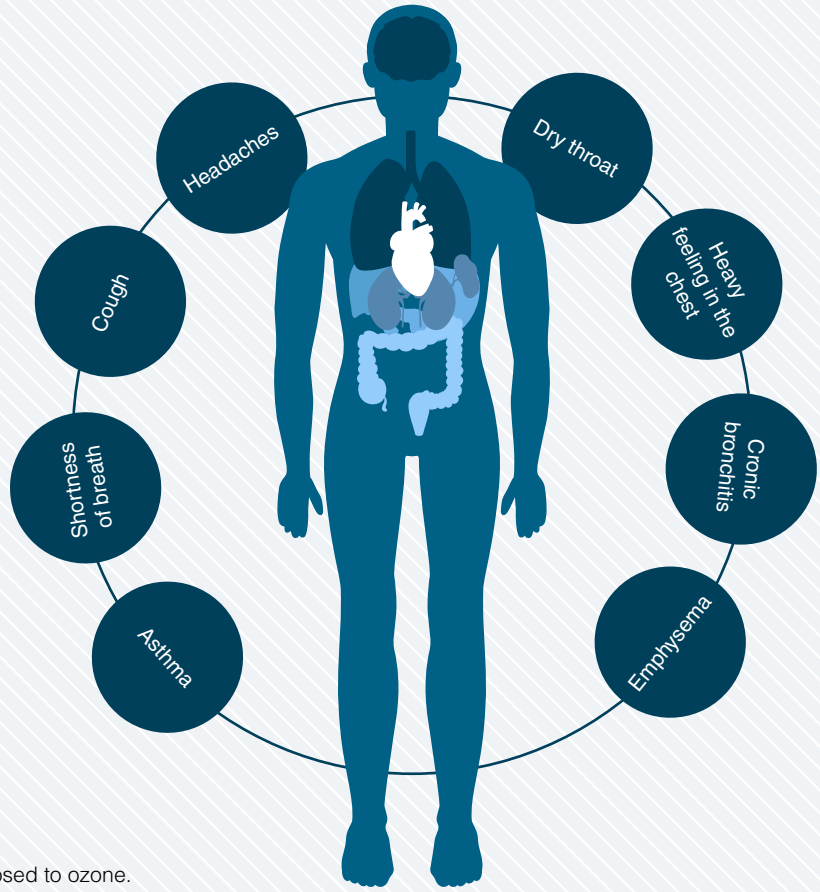
From the earliest days of commercial air travel, passengers were mostly free to smoke onboard. Not until 1966 did any organised opposition to the practice emerge. Patty Young, an American Airlines flight attendant, began the fight for the right to work in a smoke-free environment in the skies. Today it's tough to imagine it was ever allowed!

Even so, meaningful progress towards banning smoking on aircraft eluded advocates until 1986's National Academy of Sciences report, 'The airline cabin environment: air quality and safety, was released. It unanimously and forcefully proposed "that smoking be banned on all commercial flights within the United States."

The first US federal ban on smoking came into effect in 1988 – but only on domestic flights of less than two hours. By 1990, despite efforts by the tobacco lobby, cigarette smoking was banned on all domestic flights of less than six hours. Delta became the first American airline to ban smoking on all worldwide flights in 1994 – that's not a typo, it was 1994! In the US smoking was not completely banned on all domestic and international flights taking off or landing in the country until 2000.

At that time carriers such as the Italian flag carrier Alitalia offered and marketed both smoke-free and smoking-permitted flights between Rome and New York. But, by that time passengers had already experienced air quality improvements on most domestic flights without smoking and many considered flights on which smoking was still allowed as "miserable". When the ban was finally implemented, the FAA estimated 97.7 percent of all flights between the US and other countries were already smoke-free due to customer preference and bans in place from other countries and airlines.

Before finally enacting smoking bans, it would have been tough to focus on any other odours onboard. It is pretty incredible to even imagine that aircraft had smoking and non-smoking sections simply delineated by a random row. Air quality standards have come a long way!



Typical symptoms of being exposed to ozone.

3 Why Ozone?

Ozone gas standards are regulated in the US by the EPA, Occupational Safety and Health Administration (OSHA) and (specifically onboard aircraft) the FAA, and around the world by other national organisations.

Exposure to ozone may cause headaches, coughing, a dry throat, shortness of breath, a heavy feeling in your chest and a build-up of fluid in the lungs. Individuals with lung diseases such as asthma, emphysema and chronic bronchitis may feel the effect of ozone exposure more acutely than others. Before ozone converters were introduced on aircraft, the solution was to simply fly lower where ozone wasn't found.

However, the 1973 Oil Crisis exerted pressure on airlines to become more efficient due to fuel shortages, which meant flying higher where the air was very thin to go further and faster on less fuel.

Today, every airline's biggest overhead cost is fuel and the quest to keep that cost manageable has driven many of the technological advancements in aerospace.

But flying higher brought new challenges. Ozone converters and robust environmental control systems (ECS) were added to keep the cabin environment more comfortable for passengers and crew alike – all the while enabling airlines to fly higher, faster and further.

These eco-friendly developments maintain a pleasant atmosphere throughout the entire journey.

4 The Regulations

The FAA and the European Aviation Safety Agency (EASA) have strict cabin air quality standards. According to their regulations, aircraft flying within its jurisdiction must supply passengers and crew with the equivalent of approximately 250 grams of fresh air per minute per occupant. This is a consistent amount with the rules governing indoor public spaces.

The air onboard modern aircraft is completely exchanged every two to three minutes. This means an aircraft like an A320 is taking on approximately 100 cubic metres per minute of new air from outside and also ejecting that same amount via the outflow valves found beneath the cabin. The air you experience at your seat arrives via vents on the ceiling before being pulled out by vents at your feet.

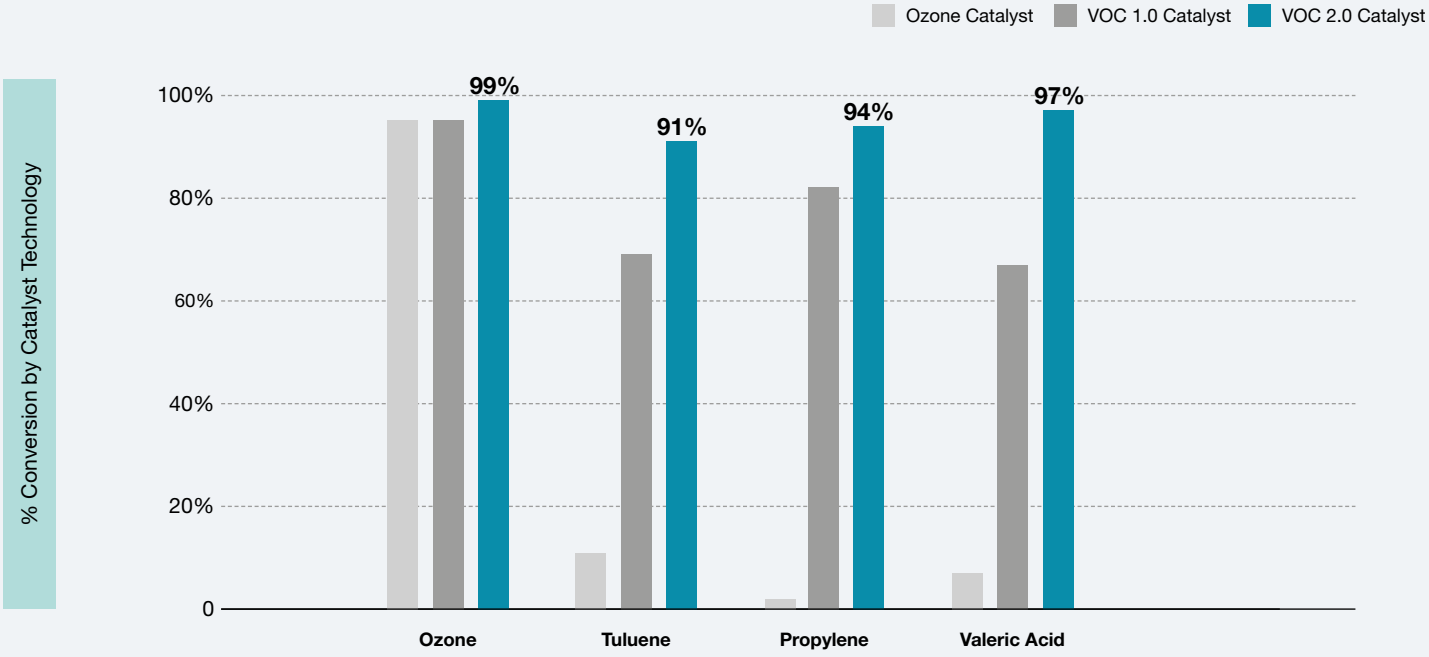
The FAA notes that onboard aircraft passengers are provided with an "acceptable environment which is equivalent to or better than other forms of commercial transport."

A report published in 2017 by EASA states: "To state the obvious, there is no contaminant-free indoor environment. The aircraft cabin is no exception. However, due to the exceptionally high air exchange rates in aircraft, the cabin air has been proven to be less polluted compared to normal indoor environments (e.g offices, dwellings etc)."

The values observed for VOCs in the cabin can be considered quite normal for indoor environments. EASA also recommends continued focus and research on cabin air quality and a need for further technological developments to better analyse cabin environments.

Selected VOC Conversion

Ozone-only, Ozone-VOC and Enhanced VOZC converters treatment of bleed air



5 Volatile Organic Compounds – the next challenge

After tobacco bans significantly improved the cabin environment, the industry continued to develop additional technologies to further drive down odour events onboard. VOCs – which can have strong odours, both pleasant and unpleasant – have become the next challenge in the quest for onboard quality cabin air.

On a busy airport tarmac, there are multiple aircraft running engines, plus additional support vehicles loading aircraft, deicing trucks spraying down aircraft when it's cold, and diesel generators running to provide auxiliary power to aircraft before they start their engines.

Even the most advanced engines might release small amounts of lubricating fluids through seals, and any fluid may become vapour in particualar as it flows through the pressurised and hot bleed air system before entering the air conditioning system.

Many airlines have reported odour events as one of their leading causes of flight delays, cancellations and air turnbacks, and therefore air quality improvement has become one of the most important means of driving down unnecessary operational disruptions and costs.

6 The Cost of Odour Events

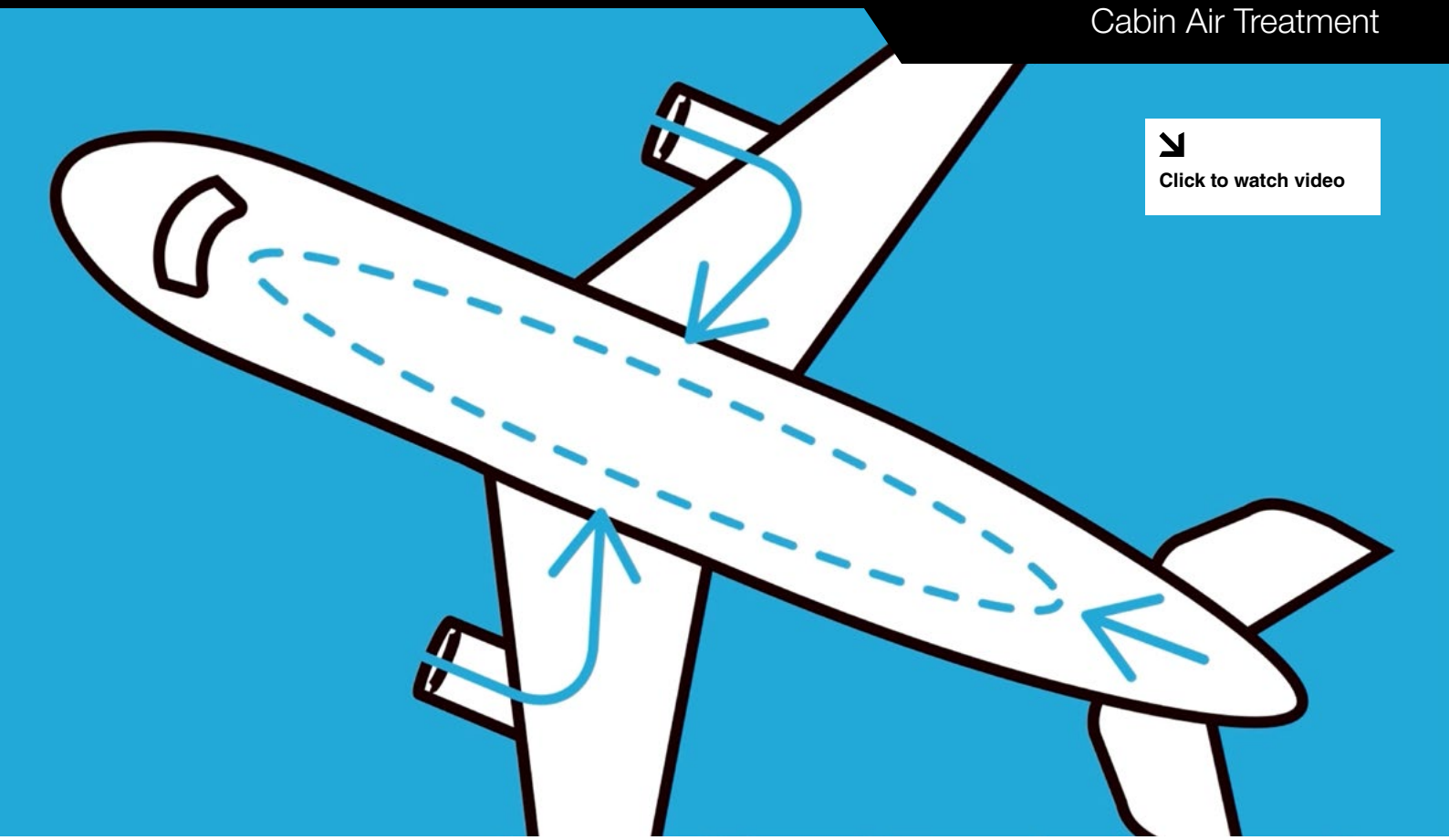
On every flight the crew's number one priority is safety. Any crew member is able to delay, cancel or turn back an aircraft if they believe there is a need for maintenance troubleshooting. That can include some odour events.

Any time an odour event is noticed or reported it may lead to maintenance checks and activity that can take anything from a few minutes, to multiple days keeping aircraft out of service, even though there may be no actual technical root cause.

One airline reported that every flight cancellation or turnback wiped out their profits for eight to ten on-time flights. Jet fuel today costs approximately $0.55 per litre and a regular single-aisle civil aircraft will burn close to $2,000 of fuel per hour, so it's easy to comprehend the wasted fuel costs and environmental impact of turning a flight around due to an odour event.

Boeing estimates the average cost of a cancelled flight is as high as $130,600 per event.

In Europe passengers are now protected by a passenger bill of rights that sets forth monetary compensation for all passengers affected by long delays, thus adding another layer of unplanned costs. Passengers can receive up to €600 each for delayed or cancelled flights, so on single-aisle aircrafts carrying up to approximately 200 passengers that is €120,000. Airlines all over the world are working tirelessly to prevent these events and costs from impacting their passengers, crew and bottom line.



Click to watch video

7 The Solutions

Airbus has selected BASF VOZC converters for their most popular aircraft family, the A320. BASF's new VOZC technology is the most effective converter to treat VOCs in the bleed stream – all while enhancing the ozone conversion efficiency. BASF employs a proprietary catalyst and substrate design to achieve the highest conversion efficiencies ever recorded for an aircraft catalytic converter. This technology promises an even more pleasant onboard experience. The newest generation VOZC converters are selectable on new A320 aircraft and can be retrofitted onto A320 aircraft currently in service.

HEPA filters have been the standard in commercial aviation for decades. They are also utilised in hospital operating rooms and chip manufacturing clean rooms. They're even widely available today for home air filters. They remove at least 99.95 percent of dust, allergens and microbes, including viruses and bacteria, before recirculated air is mixed back into the cabin.

Many airlines have now instituted the next generation of Advanced Cabin Air Filters (A-CAF). Introduced by Pall Aerospace, the filters offer all the benefits of standard HEPA filtration with an additional activated carbon matrix capable of further removing VOCs – including VOCs and other unpleasant odours generated within the cabin itself and by passengers.

Taken together and properly maintained, the VOZC converter and A-CAF represent the pinnacle of available technology for airlines to drive down costly unjustified delays, cancellations and, in some cases, even in-flight turnbacks.

The airlines' commitment to the cleanest cabin environment technologies can proudly assert to their customers and staff that their comfort is a high priority by choosing both VOZC converters and A-CAF for their fleets.

> *No other company produces converters across more industries than BASF. Next-generation VOZC technology is proven to reduce VOCs more than any solution previously available.*

8 FAQ

When an airline chooses to install BASF's VOZC Catalytic Converter, what benefits can it expect?
BASF VOZC catalytic converters are OEM-approved products with the ability to treat VOCs commonly found in the bleed air stream. They are a useful equipment to reduce potential VOC exposure: whether that's from another aircraft exhaust, localised pollution, deicing fluids or engine oil lubricants. The catalyst technology requires no moving parts or electronics; their robust, continued effectiveness only requires servicing at C-Checks.

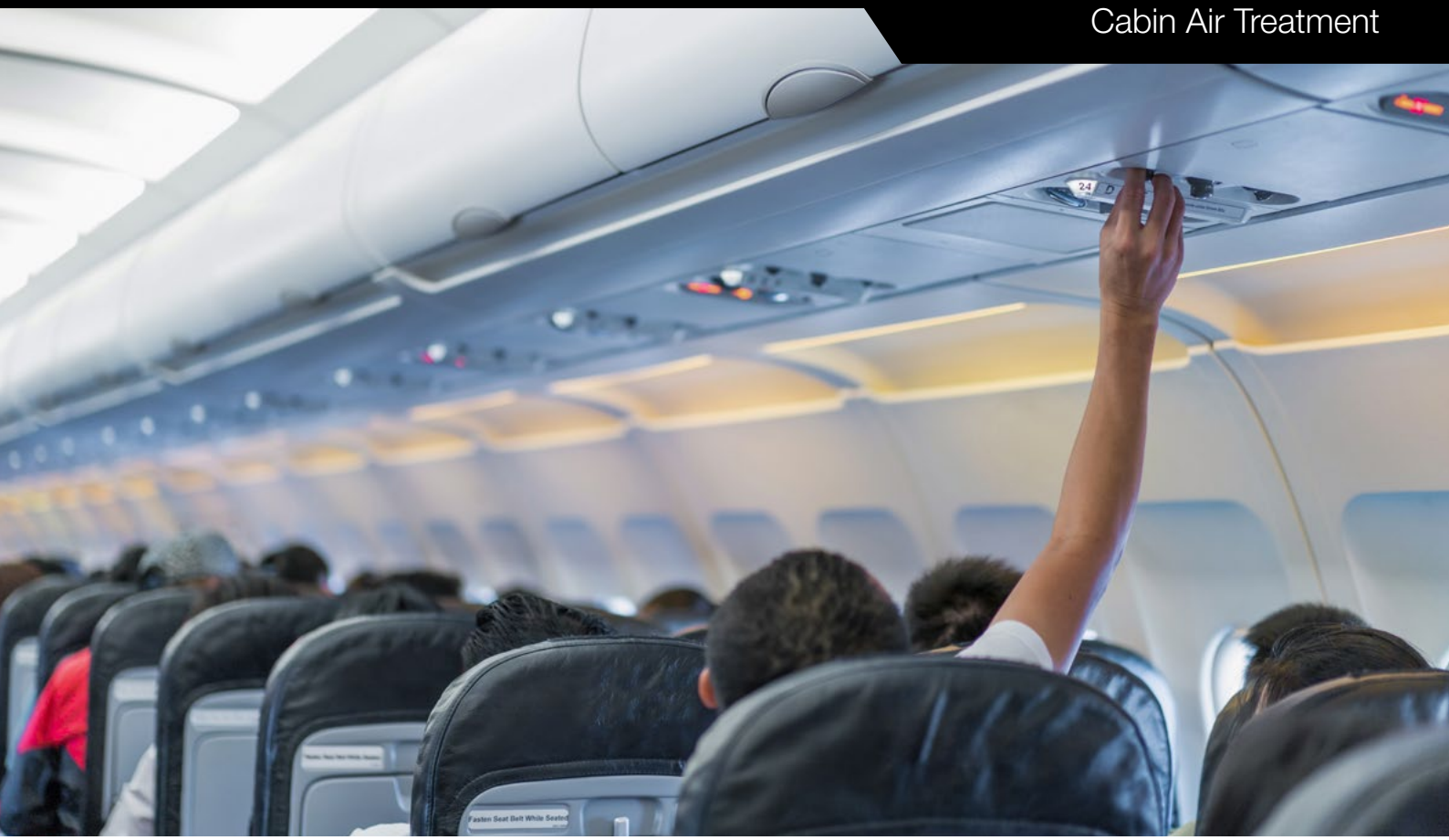
Does BASF provide customised converter solutions for each aircraft type?
BASF works closely with aircraft manufacturers to design a converter to their specifications. The converter will be designed to fit within the required space envelope to the required tolerances, and each aircraft manufacturer may request specific performance criteria.

How do BASF converters compare to others on the market?
BASF pioneered VOC and ozone catalytic converters in aerospace. No other company produces catalytic converters across more industries than BASF. Next-generation VOZC technology is proven to reduce VOCs more than any solution previously available.

How often does BASF release new converters?
Next-generation catalyst technology is not something that happens often. A performance upgrade like VOZC comes around once every decade or so. UpCore services will allow operators to follow their existing maintenance schedules to upgrade their current converters with upgraded technology at roughly half the cost of purchasing factory-new units. Additionally the UpCore procedure can be accomplished with a 30-day turnaround time. VOZC is the most economical way to minimise ozone and VOCs in the cabin.

How should airlines maintain their converters?
BASF operates MRO facilities globally to support operators. BASF converter maintenance is carried out by the same people at the same manufacturing facilities, employing the same materials and techniques used to build brand new units for new aircraft. The only way to know if a serviced unit has the same technology and catalyst materials as the OEM unit is to use the only OEM-approved service provider. Third-party repair shops do not use the same materials as the OEM products, and they don't know the formulation or methods to meet OEM requirements for effectiveness and efficiency over the service life.

How strongly would you advise an airline to have their converters regularly serviced by an MRO operator approved by BASF.
Non-OEM approved services have not been evaluated or approved by aircraft manufacturers and their effectiveness



over time is unknown. MRO services by non-approved MROs can void OEM warranties. Overcoating OEM catalyst materials with unproven materials may not last to the next service interval.

What problems might they encounter if they choose an MRO operator not approved by BASF?
Warranty is void if service or repair is carried out by non-approved MROs.

How satisfied are customers with the support of your designated MRO?
BASF partners with VAS for MRO service and repair management. BASF maintains best in class TAT across all regions. VAS repair administration follows stringent AS9100 quality standards.

How often should they be serviced/ replaced?
The OEM service recommendation is part dependent. For VOZC, BASF recommends a 9,000 FH interval or five years. Units are cleaned and tested for efficiency at this interval.

What is BASF's standard TAT for MRO services?
Turnaround times at BASF facilities are 10 days for the wash test procedure and 30 days for recore/UpCore procedures. Typically services are aligned with C-Check maintenance procedures and easily returned before aircraft are scheduled for return to service. Also VAS now offers exchange units to customers to meet tougher deadlines.

How is the lead-time for a factory-new spare converter?
Satair stocks factory-new inventory of the most common ozone and ozone/ VOC converters from BASF. Regular orders for converters are delivered within seven days from our locations around the world and can be delivered much faster in AOG and high-priority cases, thus meeting the strict OEM operational performance requirements put in place by manufacturers such as Airbus.

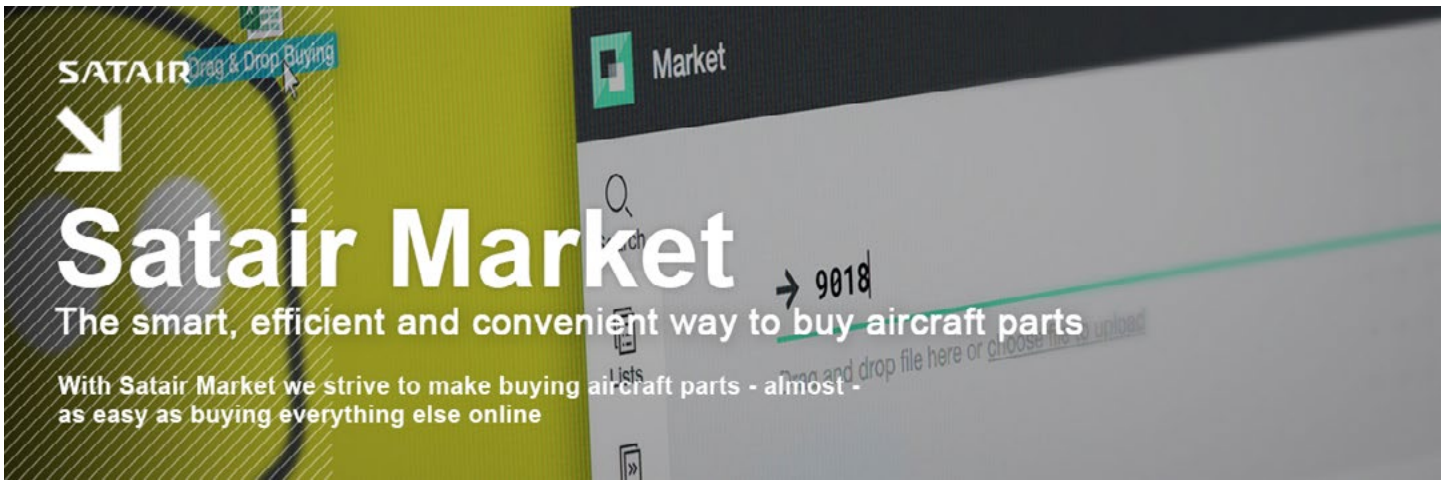
Are BASF converters cheaper or more expensive than comparable converters?
There are no comparable converters available for BASF VOZC products. Some repair facilities may be cheaper, but when the total cost of ownership is considered, including operational reliability and performance, there is no way to provide the same value as BASF.

What aircraft platforms is VOZC available on?
VOZC converter technology is available on the Airbus A320 family series of aircraft. BASF converters are available on a wide range of commercial aircraft as OEM factory-fit products.

9 Discover which BASF products best fit your aircraft

Currently available BASF ozone and ozone VOC converters:

Cage	Part Number	Aircraft Manufacturer	Application Model/Family	Type
1KGC9	20499004	Airbus	A320	Ozone
1KGC9	20499005	Airbus	A320	Ozone
1KGC9	20499006	Airbus	A320	Ozone
1KGC9	40997003	Airbus	A330/A340	Ozone
1KGC9	43885001	Boeing	737	Ozone
1KGC9	44018003	Airbus	A320	Ozone/VOC
1KGC9	44018004	Airbus	A320	Ozone/VOC
1KGC9	44018005	Airbus	A320	Ozone/VOC
1KGC9	44142002	Airbus	A330/A340	Ozone/VOC
1KGC9	48067001	Boeing	777	Ozone
1KGC9	D19333-5	Boeing	747	Ozone
1KGC9	D19772-001	Airbus	A300/A310	Ozone
1KGC9	D19811-3	Boeing	757/767	Ozone



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