SMC
Expertise – Passion – Automation

Quality compressed air for efficient pneumatics

An industrial air quality roadmap

Contents

The invisible fluid

Most people never give the incredible fluid we're surrounded by much thought, even though all of us have over a tonne of pressure pressing on us constantly throughout our lives. We generally take air for granted, and it's only when things are clearly not right that air quality enters the public mind. Vehicle pollution in cities, smog from wildfires and volcanic ash grounding planes, for instance, quickly make people take note.

For the engineer, however, air quality is a persistent consideration because even the cleanest natural air available is not fit for engineering purposes. From compressor intake to application outlet, air must pass through a variety of steps before it's pure enough to be used in industry.

Pure air is typically comprised of four parts nitrogen to one part oxygen, with small amounts of argon, carbon dioxide and other trace gasses. In this pure state, it's colourless, odourless and dry.

The air we inhabit is anything but pure, however. The presence of moisture and dust makes untreated air unsuitable for most industrial processes

For engineers, compressed air is such an important resource that it is often cited as the fourth utility in industry – after electricity, water and gas. Studies estimate that ten per cent of all industrial energy is used just to compress air.

Examples of air used in industry include pneumatic tools, paint spraying, powder dispersion and product drying. And just as each of these processes require specific equipment and infrastructure to perform to the required standard, the air quality requirements are similarly specific.

Where does the contamination come from?

Water

Air contamination can be classified into five types – simple water moisture, and larger molecule contaminants like oil and tar, as well as particulates like rust and carbon char.

Water is inevitable when handling air. The substance covers over two thirds of our planet, after all, so it's not particularly surprising that a substantial amount finds its way into the atmosphere.

As temperature and pressure drop, so does the ability of the air to hold water vapour in solution and thus water condenses out as droplets Similarly, an increase in temperature or pressure increases the water carrying capabilities of air.

To be useful in industry, air is usually compressed, which initially increases this water capacity. When that pressure is released to operate a tool or other use, the local conditions around the outlet become perfect for the formation of condensation. These water droplets, often invisible to the naked eye, can have a range of negative effects on many processes and equipment.

Under normal conditions - at 20 degrees Celsius and ten kilopascals of atmospheric pressure - one kilogram of air can hold around 15 grams of water vapour. For a sense of scale, a compressor running for a few hours can extract multiple decalitres of water from the air, and a substantial amount of water will still be dissolved into the outlet air.

Oil, carbon and rust

The other four contaminants – oil, carbon, tar and rust - are instead composed of larger-molecule hydrocarbons and metal oxides. These contaminants are distinct from moisture as they're introduced as the air is processed, instead of being natural constituents of the intake air.

For instance, oil and carbon contamination can be introduced during hot-running air compression, tar and carbon can be introduced by failing rubber seals, while rust will find its way into the system as the equipment and piping ages.

Whatever their source, these contaminants must be tackled before the air reaches the production line.

Air must pass through a number of processes before reaching industrial qualities, at each step getting a little purer. Air siphoned off at these relative quality levels can be used for industrial applications, depending on the requirements of the process.

This is SMC's six step roadmap to clean-room quality air, with application requirements, risks and recommendations at each level of air quality. By following along, you can be confident in designing and building an air purification system that exactly matches the needs of the task at hand with no frills. There's little benefit to overcompensating things, but using substandard air will only cause problems.

Air classification

Because of the diverse range of applications that require air in industry, there are a number of industrial air qualities, standardised by ISO 8573 and tested under ISO 12500. The classifications range from simple dust-filtered air suitable for internal combustion engines, all the way to incredibly pure and dry air suitable for clean-room use.

The ISO air quality standard uses three numbers in its classifications. In order, they are upper limits on particulate matter, moisture and oil contamination carried in the airstream. Class 1, 1, 1 represents the cleanest, purest air under the standard, while -, -, - would represent air too contaminated to make the scale.

ISO 8573.1 & ISO 12500 air quality classification chart

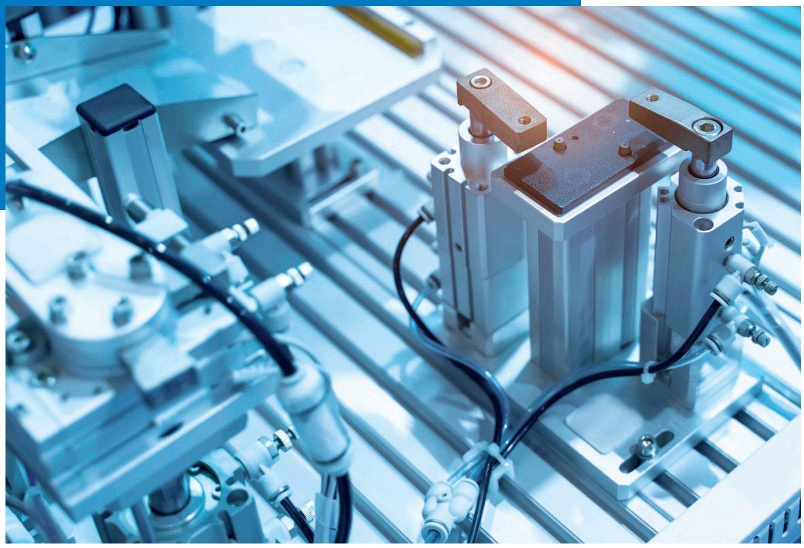
Class	Solid particles, particle size, d(mm)				Humidity and liquid water		Oil
	Maximum number of particles per cubic meter as a function of particle size d [µm]			Mass concentration Cp	Pressure dew point	Concentration of liquid water Cw	Concentration of total oil
	0.10 <d ≤0.5	0.5 <d ≤1.0	1.0 <d ≤5.0	[mg/m³]	[°C]	[mg/m³]	[mg/m³]
0	As specified by the equipment user or supplier and more stringent than class 1						
1	≤20000	≤400	≤10	—	≤-70	—	≤0.01
2	≤400000	≤6000	≤100	—	≤-40	—	≤0.1
3	—	≤90000	≤1000	—	≤-20	—	≤1
4	—	—	≤10000	—	≤3	—	≤5
5	—	—	≤100000	—	≤7	—	—
6	—	—	—	0 <Cp ≤5	≤10	—	—
7	—	—	—	5 <Cp ≤10	—	Cw ≤0.5	—
8	—	—	—	—	—	0.5 <Cw ≤5	—
9	—	—	—	—	—	5 <Cw ≤10	—
x	—	—	—	Cp >10	—	Cw >10	<5

“While the ISO standards are extremely useful in grading air qualities, they are merely recommendations that allow for a reasonable amount of freedom. This is beneficial in many ways, but also makes ensuring the ideal air quality for a certain process may be more difficult. This is because when faced with a complaint, the equipment suppliers will often just cite the ISO rating of the equipment, without actually testing the air to find out what’s wrong. While the air might meet a certain ISO standard, it should still be tested at the point of use.

Besides testing, there are a few other ways of improving air quality without additional filtering steps. One way is to simply move the air intake where it will suck in fewer contaminants, for instance moving a ground level intake to a roof. Pollen is a particularly pervasive contaminant as it is very sticky, and therefore clogs filters quickly. Just moving the intake can dramatically reduce the occurrence of contaminants in the system.”

Vit Reichelt, Customised Services Specialist, SMC Czech Republic.

Steps for the best process



1. First dehumidification step

The pressurised, wet, warm and rough-filtered air output by the main-line filter is now one step away from the quality where it finds limited use within industry. When passed through a water droplet separator, such as SMC's **AMG**, 99 per cent of the water droplets are removed and the air can be used in general air blowing. Uses include the drying of larger objects, as well as powering low tolerance pneumatic tools.

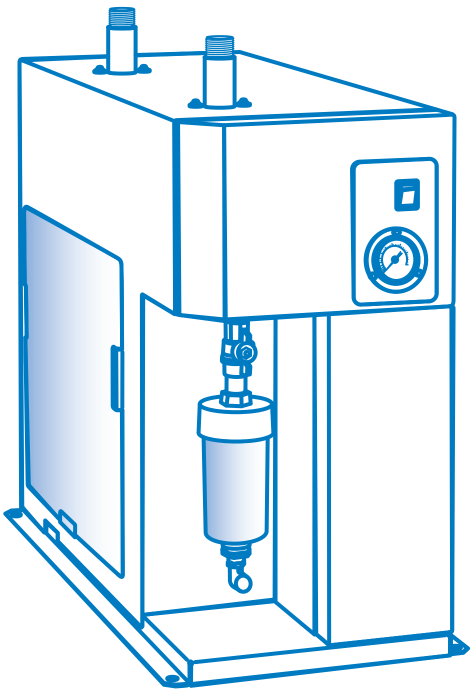
Failing to perform these minimum filtering steps before the air is used in blowing or pneumatic equipment can lead to short term and long-term problems. When drying paint, for instance, substantial particles in the air can lead to a poor finish that can only be avoided with adequate air quality.

Particularly wet and dirty air also causes build-up of corrosion and other contaminants, leading to reduced performance, an increased need for maintenance and a general reduction in the operational lifespan of the device. Poor air quality in high power pneumatic tools, for example, can lead to hydrostatic lock, causing compressor-parts to mechanically seize or, in rare cases, lead to fire or explosion.

For systems where the air experiences a large temperature drop along its path to the application, the risk of water droplets condensing in the pipe increases dramatically and SMC recommends a further step of dehumidification.

As previously mentioned, lowering the temperature of air causes water vapour to condense out into droplets, which has knock-on effects. The temperature at which these droplets start forming is known as the dewpoint, which gets progressively lower as the air is made drier.

Refrigerated air dryers exploit this phenomenon to both cool and dry the air. For instance, the **IDFA** refrigerated air dryer from SMC produces air with a dewpoint of around three degrees Celsius at 700 kilopascals. Air with a dewpoint this low is suitable for the majority of indoor, unrefrigerated applications.



2. First separation step

So far, we've achieved air of class 3, 4, -, meaning that we should expect no condensation from air above three degrees Celsius at 700 kilopascals, and for every cubic metre of air we expect to find fewer than 10,500 particles larger than half a micrometre.

* See ISO chart on page 8 for reference.

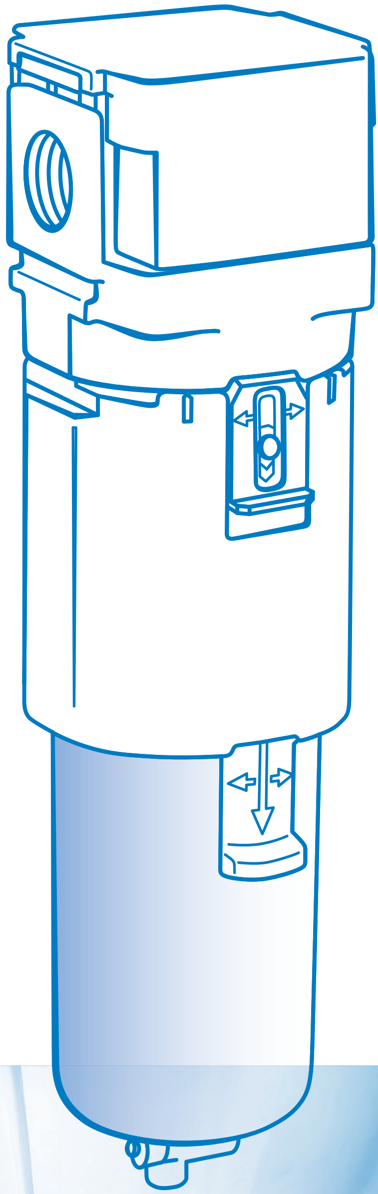
As discussed, this quality is acceptable, if not particularly ideal, for general blowing applications and pneumatic tool actuation. While the humidity and particulates won't affect these applications, they will shorten equipment lifespan and reduce quality. For higher-tolerance, high-power pneumatic equipment such as piston actuators, however, this air is still too contaminated with particles and oil introduced by the compression step.

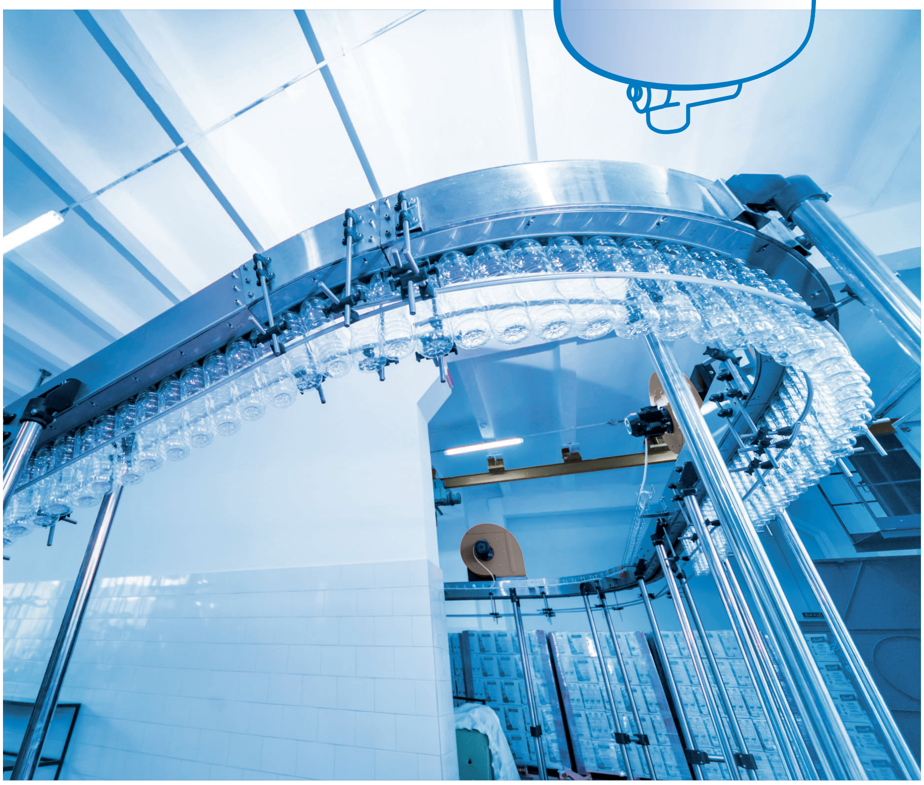
For instance, pneumatic pistons are often controlled by a solenoid valve. Compared to pneumatic tools, the tolerances on these parts are far higher, and they are therefore more susceptible to derating and failure from contamination. The small amounts of rust, carbon tar and oil carried by the air collect around the valve and degrade its performance, eventually to the point of failure.

Considering the incredible forces that pneumatics can achieve, feeding 3, 4, - air to a pneumatic piston represents a serious risk to health and safety when the operator cannot rely on the reliability of the valve.

A mist separator, such as the **AM** from SMC, is the key in this scenario. While leaving the humidity untouched, these devices separate the oil from the air and condense it so it can be siphoned off through a drain valve. Mist separators also simultaneously filter the air for particulates once more, removing any contaminants larger than a third of a micrometre.

The air leaving the mist separator – now class 2, 4, 3 – rates on all three of the ISO air quality criteria. When evaluating air of this quality, one should expect fewer than 1,010 particles larger than half a micrometre, fewer than 100,000 particles between a tenth and half a micrometre and an oil content below one milligram per cubic metre.





3. Second separation step

One of the major industrial uses of pressurised air is paint dispersion. Spray-painting is an industry standard, offering faster and wider application with a better finish than other methods.

This practise depends heavily on the quality of air used to disperse the paint. Any significant contamination ruins paint finishes, causing blisters, cissing and other blemishes. Contaminants trapped under paint against a metallic surface can also cause corrosion, causing further blistering as well as undermining the paint and its purpose in acting as a protective barrier against the elements.

2, 4, 3 air may be used in rougher paint spraying applications where quality and finish aren't a major concern, but it's still far too contaminated for high-quality paint application.

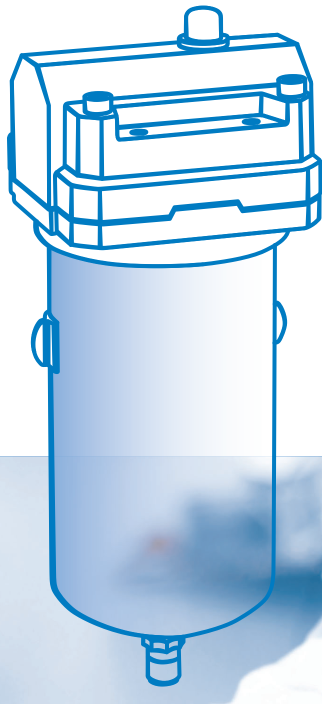
Similarly, while 2, 4, 3 air is fine for many pneumatics, it is too dirty to be used in the most intensive and delicate applications. Aerostatic pneumatic bearings, for instance, expose the air to incredible dynamic pressures while operating within extremely strict tolerances.

Any fouling from oil or particulate matter on the bearing surfaces or air pathways ruins the operating smoothness, efficiency and lifespan of this type of bearing – undermining arguably its greatest asset. Because these bearings are often employed in high speed, high energy applications, failure is particularly undesirable and potentially hazardous.

At the opposite end of the energy scale, air requirements for pneumatically actuated measurement and test equipment are similarly stringent. When measuring lengths to accuracies of a fraction of a micrometre, accuracy and repeatability is crucial. Any friction or pressure inconsistencies caused by contaminants have predictably negative effects on the required precision of these devices.

SMC produces the **AMD** micro-mist separator, an example of a filter which is ideal in purifying 2, 4, 3 class air up to the 1, 4, 2 required for the applications mentioned.

These micro-mist separators, in combination with a regular mist separator, provide filtering for particles as small as ten nanometres – well within the top ISO standard for solid particulate. The oil content is similarly further reduced, from less than one milligram per cubic metre of air to less than a tenth of a milligram.



4. The second dehumidification step

You may have noticed that we've not dehumidified the air any further since step one, where the dewpoint was reduced to three degrees Celsius at 700 kilopascals by the refrigerated air dryer. This is shown by the 4 in the 1, 4, 1 classification. While this air meets the top standard for oil and particle contamination, and will fulfil the needs of many industrial processes, the water content remains a serious issue in many others.

For example, attempting to dry electronics or other water-sensitive components with 1, 4, 1 air will at the very least take longer, but the high humidity could also damage the products. Comparably, chemical filling tanks are often air-dried, and any moisture left behind has the potential to react with the chemical in the tank, lowering product quality and yield.

Another application is the transport and dispersion of powders, where excess moisture causes adhesive clumping, poor dispersion characteristics and potential equipment damage from powder solidification.

One last niche process where dry air is required is ozone production by corona discharge. Just as lightning generates ozone when striking, here ozone is created by passing hot electrical arcs through the air. Issues arise when water is present, as it reacts with the normally inert nitrogen in the air to form nitrogenic species, such as nitrogen monoxide, nitrogen dioxide and nitric acid.

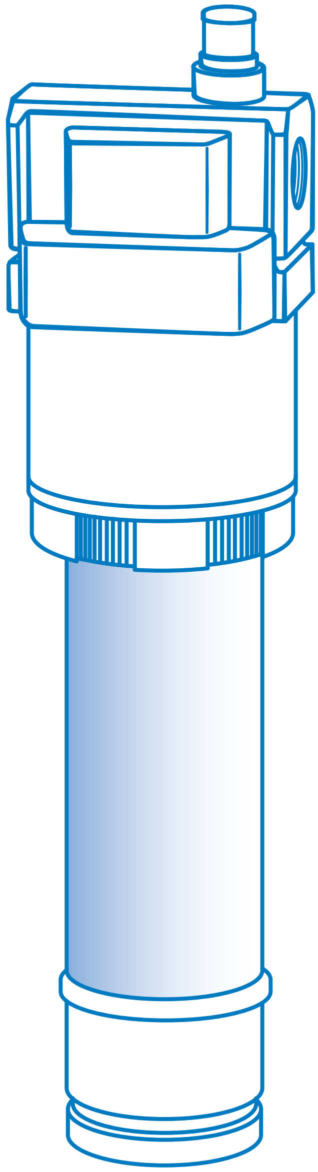
Besides sapping energy away from ozone creation and therefore lowering efficiency and yield, these nitrogenic biproducts are also corrosive to equipment and hazardous to humans.

So, for air to be safely and efficiently used in the above scenarios, the moisture content must be reduced.

First dried by the refrigerated air dryer, the air now goes through a second dehumidification step performed by a membrane air dryer, such as the previously mentioned **IDG**.

Depending on operating conditions such as inlet air temperature and flow rate, this step drops the dewpoint to between -20 and -70 degrees Celsius at 700 kilopascals of pressure. In practical terms, this represents between an 87 and 99.9 per cent reduction of the already low remaining humidity and pushes the air quality up to 1, 3, 1 or 1, 2, 1 or 1, 1, 1.

The air leaving the system has been compressed, filtered, dried, mist separated, mist separated



once again, membrane dried and then finally mist separated a third time. The air entering the system will have been dirty and humid, potentially containing tens-of-millions of particles of moisture, dust and other foreign contaminants.

After processing, the air now being output is incredibly pure and dry. Analysis of air at 1, 1, 1 would find fewer than three molecules of water for every million particles of air, as well as fewer than 100 particles larger than 100 nanometres and less than ten micrograms of oil per cubic metre.

Taking a side road

The air has gone on quite a journey to reach this point. It's been compressed, passed through an **AFF** main line filter, dehumidified through an **IDFA** refrigerated air dryer and further filtered and cleaned through **AM** and **AMD** mist separators. From there to here, the air has gone from common, dirty and wet air to clean and relatively dry 1, 4, 2 air.

As with many concepts in engineering, however, there's often more than one way to reach a desired goal. This is particularly true when working towards air quality, because every process or production line will be different from the last. A huge emphasis is placed on modularity and flexibility in air purification equipment and processes as a result.

To prove that point, consider the scenario where the **IDFA** dryer is removed from the system. Is it still possible to achieve 1, 4, 2 air with such a seemingly integral component missing?

With a bit of thought, it most certainly is. In this process, the hot and wet compressed air is first filtered through a combined **AM** and **AMD** micro-mist separator to filter particulate and separate oil. This clean air is then passed to an **IDG** membrane air dryer where the vast majority of its water is stripped out. This lowers the dewpoint to -15 degrees Celsius at 700 kilopascals, far below that of the three degree dewpoint air output by the **IDFA**.

When passed through one last mist separator, such as SMC's **AME** super mist separator, the output air reaches a quality of 1, 4, 1 – in fact one step up when measuring oil content when compared to the 1, 4, 2 we're currently working with on our journey. While this roadmap will get you where you need to go, the options are available for you to take the engineering decisions that best suit your particular, potentially bespoke process needs.

“The approaches industries take to reach particular air qualities are widely different, just as much as the processes the air is used in vary.

This is one of the great benefits that modular systems, such as one composed from the SMC products mentioned, allow for. Depending on the application in question, different system configurations will have distinct advantages and disadvantages.

That’s what makes SMC such a good partner for air quality. Cost, ongoing maintenance, flow rate, air quality and other factors are all considered when a customer approaches SMC for consultation.

For instance, the ***IDFA*** *shines in larger use cases where high flow rates and wide distribution is needed. The alternative route described above, featuring the* ***IDG****, will likely be more effective for smaller scale, lower flow applications where one or two discrete uses of the air are needed. If you have only a few uses, a powered centralised air dryer like the* ***IDFA*** *will exceed your needs. Likewise, using passive dryers like the* ***IDG*** *for a multitude of individual uses will quickly cause maintenance costs to rocket.*

Of course, the modular nature means that these – and other SMC air purification products – can be combined together to create even cleaner air than either one individually.”

Jorge Salgado, Industry and Specifications project leader, SMC Spain

5. The final, precision separation step

This air is now perfectly applicable to the vast majority of industrial processes, and far exceeds the requirements for many of them. There's still one last step to be taken, however, before the air is top quality and pure enough to be used under the tightest and most stringent parameters around – industrial clean rooms.

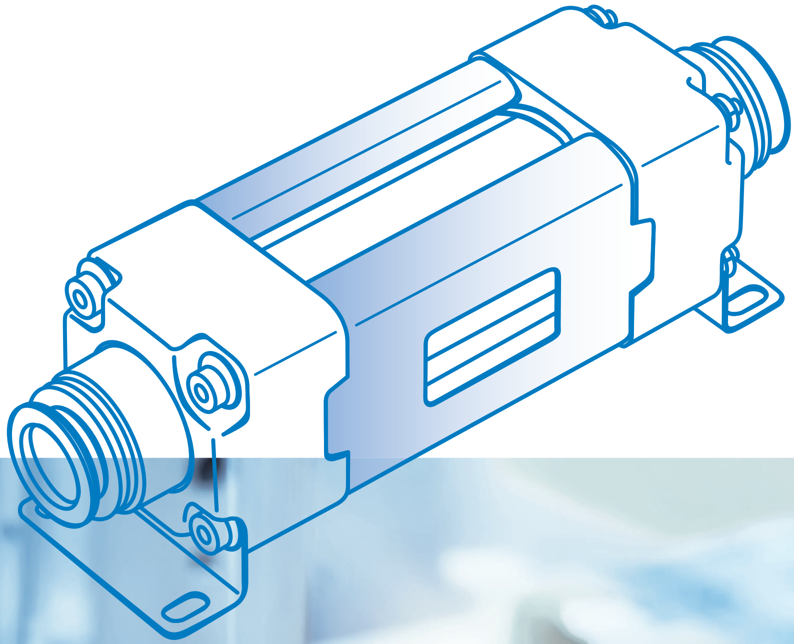
Air this clean and pure is often used for industrial and scientific research, where any contamination could ruin processes or bias results. This is a strict requirement in semiconductor and microelectronic manufacturing, for instance, where tiny particulate contamination can alter the electrical properties of these high-tolerance devices, corrode delicate contacts or even cause direct shorts.

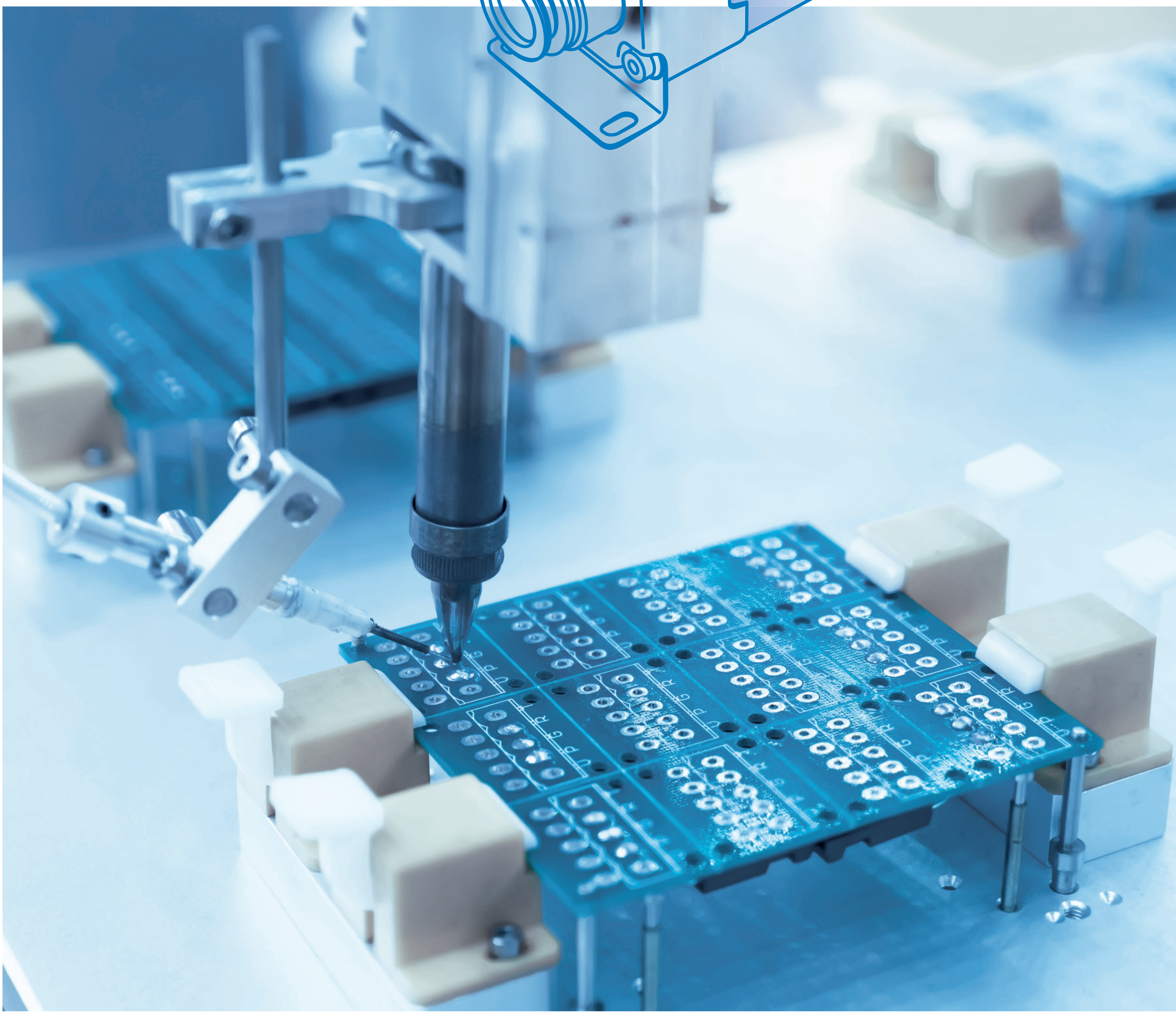
Even the incredibly small amount of moisture left in 1, 3, 1 or 1, 2, 1 air – fewer than 1,020 or 150 parts per million, respectively – can cause similar issues if the requirements are particularly stringent. The tiny amounts of particulates and odorous chemicals can be similarly damaging, so while the air might be nominally the highest quality possible, there's still one or two further steps that can be taken.

To achieve this, SMC recommends that the air pass through every step discussed so far – compression, filtering, refrigerated drying, mist separation, micro mist separation, membrane drying, super mist separator and finally deodoriser – with two extra steps to ensure the output air is stripped of the last few remaining particles and chemical contaminants.

For these steps, the air leaving the **AMF** deodoriser passes through an **SFD** clean air filter and then one last filtering step through an **SFC**, **SFB** or **SFA** clean gas filter. Each of these filters strips out 99 per cent of the remaining particle contaminants, meaning these two filtering steps combined provide a filtering efficiency of 99.99 per cent.

Considering that the 1, 1, 1 air entering this step only contains a maximum of 100 particles per metre cubed already, analysis of air leaving the **SFA** clean gas filter would find an average of one particle of contaminant per one hundred cubic metres of air. This is the equivalent of one part of contaminant for every 253 septillion parts of air – a comparable ratio to that of the sun and the estimated number of stars in the entire universe.





Take a breath...

We've made it

With these steps complete we've finally reached the end of our journey. We started with regular air, packed with moisture and billions of particles, and through a few steps and processes are left with astoundingly clean and dry air.

The raw numbers give all the context needed. Air classified as high quality for breathing may contain hundreds of particles of contaminant per million particles of air, and hundreds of thousands of molecules of water.

Contrast that with the clean room quality air we've reached through the above processes. This air has fewer than a tenth of a particle of contaminant per cubic metre, with none exceeding a hundred nanometres in size. The water content has been similarly annihilated, with fewer than three molecules of water per million of air.

The ratio of particle content between intake and outtake is on the order of multiple millions, and depending on the humidity of the intake are, a reduction of humidity by a factor of between four and eight thousand.

Admittedly, using this clean room quality air to dry paint, for instance, would be a bit of a waste – but this highlights the advantages of a flexible, modular air purification system, because at any point along this journey, if your particular application requirements are met, air can simply be siphoned off there and used.

> *The trick is getting it right and not over or underdoing it, for the sake of the maintenance budget and process quality respectively. We hope this journey we've taken together has made that task a little easier to grasp.*

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