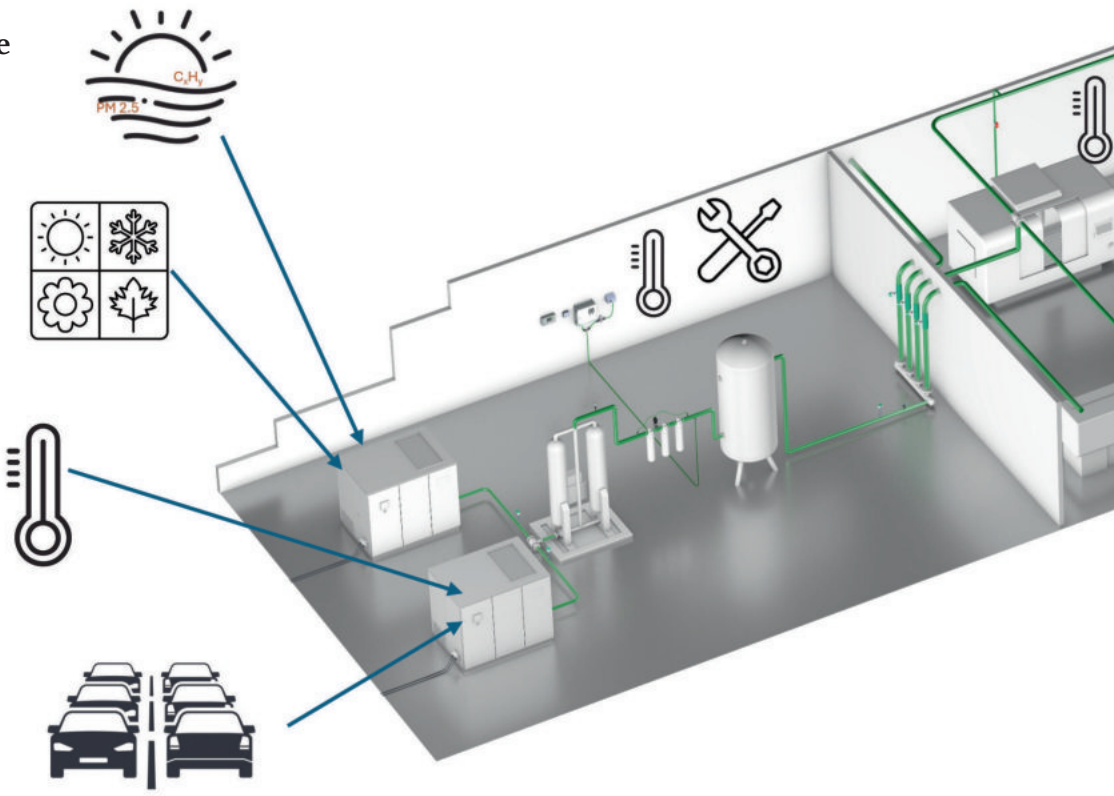
Purity of compressed air in the meat industry

Define the purity class, design the treatment system, measure and verify it



Compressed air is a critical utility in cutting and packaging. It can come into direct contact with unpackaged meat, yet it is often not given sufficient consideration. Water, raw materials, and cleaning agents are subject to established testing programs. This is often not the case to the same extent for the air from the blow-off gun. It is crucial to note that the purity class is not a characteristic of any single component of the treatment system, such as the compressor, but ultimately depends on the point of use. Anyone who takes the compressed air purity seriously will adopt a different testing plan than to merely measure the air quality downstream of the treatment system once a year.

By Christian Kuhn

The practical trigger for addressing compressed air purity often stems from a question posed by the auditor. The current GFSI (Global Food Safety Initiative) standards have tightened their requirements for process media in recent years and call for a risk-based approach.

International Featured Standards (IFS) Food version 8. The quality of compressed air that comes into direct contact with food or primary packaging must be monitored based on a hazard analysis and an assessment of the associated risks (4.9.10.1); compressed air must not pose a contamination risk (4.9.10.2). Brand Reputation through Compliance Global Standard (BRCGS) Issue 9. Air that comes into direct contact with products must be monitored; compressed air in direct contact with products must be filtered at the point of use (4.5.3). Safe Quality Food (SQF) Edition 10. Compressed air must be clean and must not pose a risk; the systems must be maintained and monitored on a risk-based basis, at least annually (9.5.5). Food Safety System Certification (FSSC) 22000 version 6. ISO/TS 22002-1 requires an overview of compressed air applications, including type, purpose, and measures taken.

None of these standards specify concrete values, but they do require a justified determination. The figures are derived from ISO 8573-1 and, for application-specific purposes, from technical recommendations like VDMA 15390-2 or BCAS 102-1. In summary, the requirements boil down to four pieces of evidence:

- a complete register of all extraction points, including the type of connection
- a specified purity class for each extraction point, justified by the hazard and risk analysis
- a test plan specifying parameters, points of measurement, test procedures, and frequency
- a defined procedure for handling deviations, including records of previous results and corrective actions

The application determines the requirements

The required compressed air quality cannot be determined based on the industry or the compressor type, but only on the specific application. A practical starting point is therefore to inventory all extraction points and determine whether the compressed air can come into contact with the food. These include drive and control air without product contact, where availability, pro-

Compressed air contaminants

Tab. 1: Compressed air contaminants, typical sources, and effects on the process

Contamination	Typical Sources	Possible Impact on the Process
Particle	Intake air, corrosion, filter abrasion, moisture	Foreign matter, abrasion and wear, malfunctions
Water	Intake air, condensates, insufficient drying	Microbial growth, corrosion
Oil	Compressor, treatment system, maintenance	Chemical contamination, odor, taste
Microorganisms	Intake air, damp areas, network, point of use	Hygienic and microbiological risks

Source: CS-Instruments

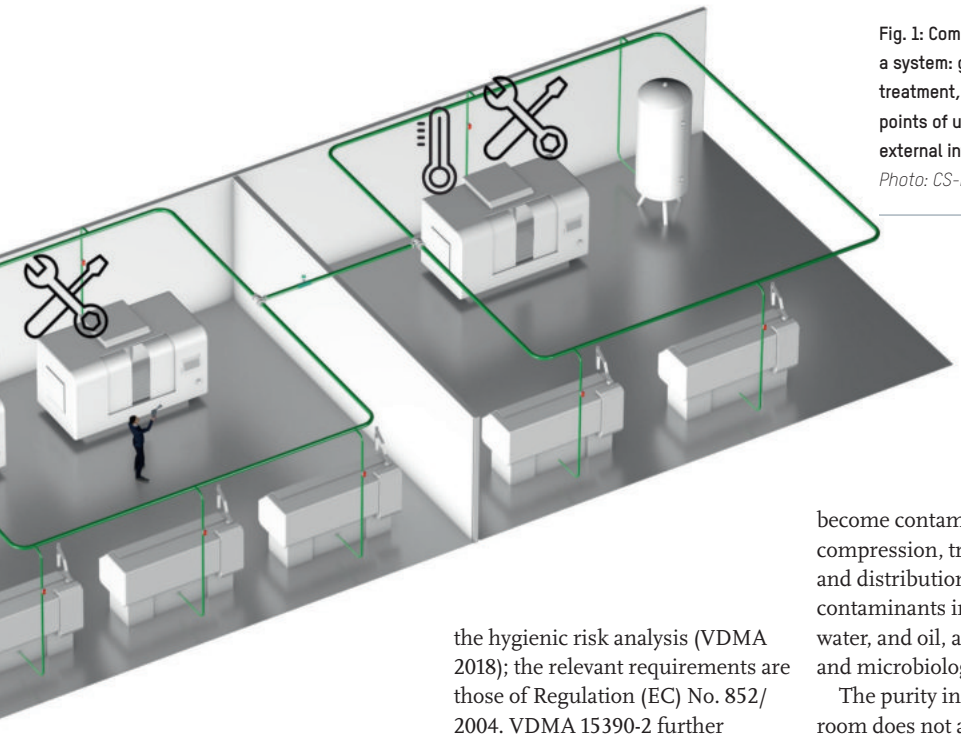


Fig. 1: Compressed air quality as a system: generation, treatment, distribution, and points of use, along with their external influencing factors. *Photo: CS-Instruments*

tection of pneumatic components, and prevention of malfunctions are the primary concerns; indirect product contact, where the air is not directed at the food, but it can affect it via airflow, airborne particles, or surfaces; and direct product contact, where the air comes into contact with meat, packaging surfaces or tools that come into contact with the product, e.g., during blowing, deboning, and trimming processes, as well as packaging applications. In this context, compressed air must be included as a process medium in the hygienic risk analysis (VDMA 2018); the relevant requirements are those of Regulation (EC) No. 852/2004. VDMA 15390-2 further distinguishes between dry products that would absorb humidity from the compressed air (e.g., additives) and non-dry products that release water. The latter predominates in meat processing. Often, the very locations where manual blow-off is used are missing from the records, since they are not part of a machine and do not appear on a plant schematic.

Contaminants, purity classes, and test methods

Compressed air can already be contaminated at the intake, or become contaminated during compression, treatment, storage, and distribution. Relevant contaminants include particles, water, and oil, as well as gaseous and microbiological contaminants.

The purity in the compressor room does not automatically translate to purity at the point of use: piping, storage tanks, filters, hoses, and extraction points can change the quality downstream. ISO 8573-1 provides a common language and defines concentration-based purity classes for particles, water or humidity, and oil. The specification is stated in this fixed order: for example [2:2:1] denotes particle class 2, dew point class 2, and oil class 1. Microbiological parameters and gases are listed but not categorized into classes.

For formal verification of compliance with the purity class, the ISO 8573 series specifies Part 2 for oil aerosols, Part 3 for humidity, Part 4 for particles, Part 5 for oil vapor, Part 6 for gaseous contaminants, Part 7 for viable microorganisms, Part 8 for particles as mass concentration, and Part 9 for liquid water.

What purity class does the meat industry need?

VDMA 15390-2 specifies typical purity classes for food and pharmaceutical facilities. The goal is to prevent contamination by particles and oil and prevent moisture promoting microbial growth. (See also BCAS 102-1.)

The classes are for guidance only and are not prescribed limit values. Each sampling point must be confirmed or adjusted based on the process, product type, and operational risk and hazard analysis (VDMA 2018).

The dew point is determined by the coldest point

The pressure dew point must be well below the lowest temperature reached by the compressed air at any point in the system. Cutting rooms are typically operated at around 10 to 12 °C; cooling and aging areas are significantly below that; and outdoor pipework sections drop below freezing in winter. Compressed air with a pressure dew point of +3 °C, such as Class 4 requires, is dry in a compressor room at 30 °C but

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Overview

Tab. 2: Purity classes according to ISO 8573-1:2010

Class	Particles 0.1–0.5 µm	0.5–1 µm	1–5 µm	Dew point	Total oil [mg/m³]
0	Requirements stricter than Class 1 (values must be specified)				
1	≤ 20,000	≤ 400	≤ 10	≤ –70 °C	≤ 0.01
2	≤ 400,000	≤ 6,000	≤ 100	≤ –40 °C	≤ 0.1
3	–	≤ 90,000	≤ 1,000	≤ –20 °C	≤ 1
4	–	–	≤ 10,000	≤ +3 °C	≤ 5
5	–	–	≤ 100,000	≤ +7 °C	–
6	–	–	–	≤ +10 °C	–

Particle counts are given as the maximum number per m³; water is defined as the pressure dew point; oil is defined as the sum of liquid oil, oil aerosol, and oil vapor.

Source: CS-Instruments FLEISCHWIRTSCHAFT international 4_2026

might condense in cold storage rooms. Furthermore, it should be noted that dry air inhibits the growth of microorganisms. Growth ceases at a pressure dew point of –26 °C or lower (BCAS 102-1). For this reason, Class 2 with a dew point of –40 °C is commonly used in practice.

Integration into the HACCP System

Compressed air quality should be an integral part of the Hazard Analysis and Critical Control Points (HACCP) system. Whether monitoring is conducted as a critical control point (CCP), as an operational preventive program, or as part of a general hygiene control program must be determined by the individual HACCP analysis. (EU Guidance 2022/C 355/01).

Technical implementation

The selected purity class must be translated into a treatment concept. This typically consists of a system comprising an intake filter, compressor, aftercooler, condensate drain, compressed air receiver, dryer, particle, coalescing, and activated carbon filters, as well as hygienically suitable points of use.

Compressed air quality is not a constant

The compressed air system is not static. It is directly connected to its environment and must cope with a multitude of changing influences. Each of these influences has implications for system design or monitoring. These include time, where treatment performance declines over the operating time, and components can fail suddenly, placing an extraordinary strain on the remaining stages of the treatment process; time of day and season, where the contaminant load in the intake-air varies with the time of day and the seasons; temperature and humidity, where as temperature rises, the water vapor content and the hydrocarbon load in the intake air increase significantly; ambient air, where traffic and local sources increase the particle and hydrocarbon load in the intake-air, while regional weather conditions cause pollution peaks (inversion layers, smog events, etc.); operating conditions of the treatment system, where adsorbers, coolers, and dryers operate in a temperature-dependent manner and their performance characteristics shift with changes in thermal conditions; and the human factor, where operation and maintenance significantly affect system performance and the introduction of contaminants, with monitoring being planned to reliably detect these influences.

Monitoring

One cannot assume that a planned system will automatically handle all possible scenarios on its own. A suitable monitoring concept to ensure compliance with the specified media purity must therefore be incorporated into the planning phase. It combines central monitoring, mobile verification measurements, and at particularly critical points continuous monitoring at the point of use.

Humidity in the Compressor Room

Humidity, or the dew point, is the most frequently measured quality parameter in compressed air supply systems. Because of the significance of humidity for the growth of microorganisms, its measurement is particularly important in the meat industry. To prevent the proliferation of microorganisms in the compressed air network, the dew point is continuously measured using dew point sensors.

Oil in the compressor room

Oil can exist in liquid, aerosol, or vaporous form. At the outlet of the compressor room, provided the treatment system is intact and the purity classes 1 or 2 recommended in the meat industry are met, it is almost entirely in vapor form. Liquid oil is not to be expected there during normal operation after treatment. However, in the meat industry where temperatures in the distribution network are significantly lower over large areas an additional risk arises. Under certain circumstances, the vapor component may condense there and accumulate over the operating time.

Oil-lubricated compressors

With an oil-lubricated compressor, a residual oil content always remains in the compressed air. Therefore, downstream treatment with filters and activated carbon is a necessity in many applications.

Typical failure sources in a treatment system include:

- Oil carryover from the compressor or failure of the separator
- improperly selected, installed, or saturated coalescing filters
- an activated carbon stage that is undersized or saturated
- Defective condensate drains, collection tanks, or bypass valves
- Dryers operated outside their design parameters
- Maintenance or operational changes that affect the treatment process

Food-grade compressor oil

One way to reduce the potential risk is to use food-grade compressor oil. However, the oil remains an industrial lubricant: A food-grade lubricant reduces the consequences of accidental contact with food, but it does not prevent oil carryover, nor does it make the compressor oil part of the recipe. The comparison to an

Applications

Tab. 3: Guideline values

Examples	Typical Quality Guidelines
Direct contact with dry products	[2:2:1]
Direct contact with dry, sterile-packed products	[1:2:1]
Direct contact with non-dry products	[2 : 2 to 3 : 1]
Direct contact with non-dry, sterile-packed products	[1 : 2 to 3 : 1]
Indirect product contact	frequent [2 : 2 to 3 : 2]

Guideline values based on VDMA 15390-2, adapted for the meat industry. These are not legally binding limits.

Source: CS-Instruments FLEISCHWIRTSCHAFT international 4_2026

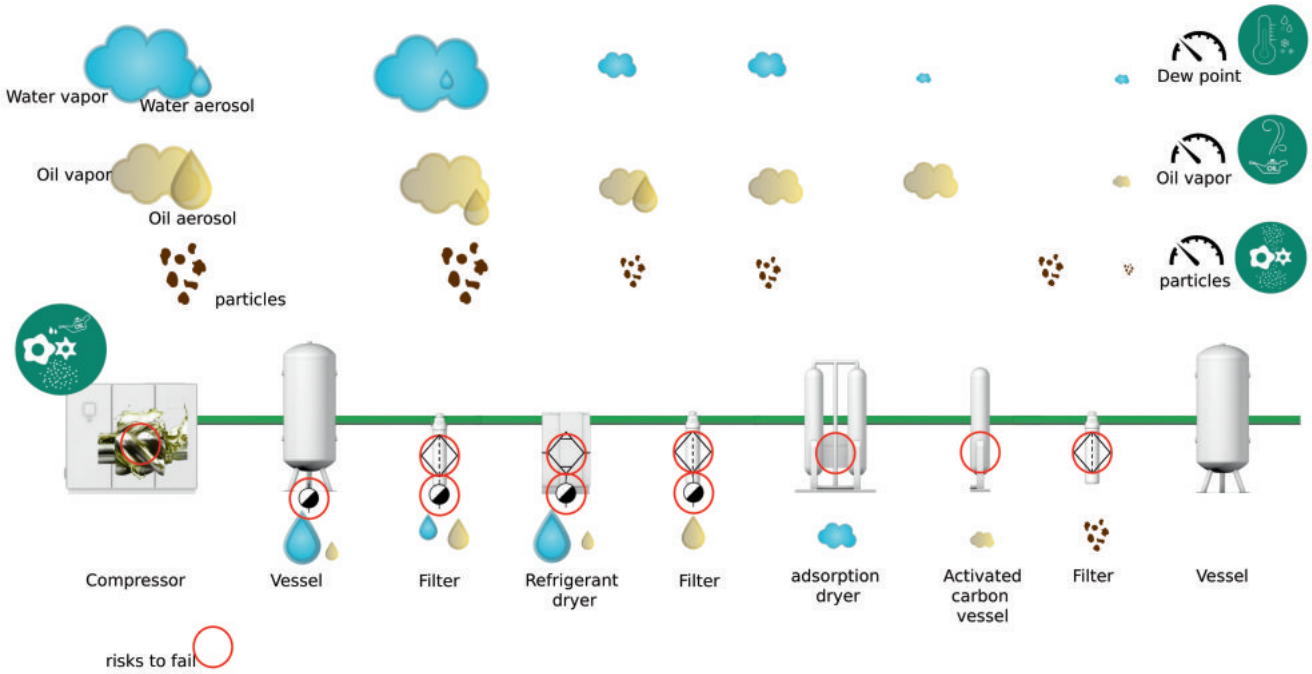

Fig. 2: Treatment chain for oil-lubricated compression (sequential drying, refrigerant, and adsorption) with examples of risk points. *Source: CS-Instruments*

airbag is apt: It mitigates the consequences if something goes wrong, but it does not prevent the event from happening. A food-grade lubricant therefore does not replace proper treatment, a specified residual oil limit, or the measurement of the supplied air.

Oil-free compression

In oil-free compression, there is no oil in the compressor chamber. This greatly reduces the risk of significant oil carryover. Nevertheless, hydrocarbons in the intake air, lubricated components in the compressor, aging seals, maintenance work, and downstream treatment systems can all affect the final air quality. After all, most oil-free compressors still contain oil in their drive system. The difference is that no oil is intentionally introduced during compression. Measurements taken on oil-free compression systems show that significant oil carryover can indeed occur. The term “oil-free” therefore refers to the compression principle, not necessarily to a measurement result at the outlet.

Typical risk areas for oil-free compressors are:

- Hydrocarbons in the compressor’s intake air
- Aging, maintenance work, or abnormal internal conditions of the compressor
- Leaks from lubricated bearings, gearboxes, seals, or auxiliary components
- Contaminants from dryers, filters, desiccants, or in the downstream system

Why oil can become a problem in a cold system

Central monitoring of the residual oil content is particularly important in meat production. The amount of oil that compressed air can absorb in vapor form depends on the temperature. In the distribution system and at the outlet points, the temperature is typically lower than in the compressor room. As a result, the risk of liquid oil forming in the distribution network increases. Liquid oil can accumulate over time. Once this happens, the necessary cleaning is not simple and is often time-consuming and costly. For the meat industry, with its consistently cooled production areas, continuous monitoring is therefore advisable.

Particles

Particles behave differently from humidity and oil: They can also originate within the compressed air system itself due to corrosion, desiccant abrasion, or filter damage. Centralized monitoring in the compressor room is therefore less important than monitoring at the point of use.

Mobile measurements and online monitoring

Mobile measurements are suitable for initial qualification, regular verification, root cause analysis, and testing after maintenance work or changes to the piping network. The risk assessment determines where measurements are taken. The advantage is the flexible examination of many sampling points; the disadvantage is that a mobile measurement essentially represents a snapshot in time. Additional continuous measurements are advisable if the risk assessment indicates a particularly high risk to product hygiene.

Types of monitoring

Tab. 4: Monitoring levels and their functions in the compressed air system

Monitoring Level	Purpose	Typical Application
Compressor room	Status of the central treatment system	Pressure dew point, residual oil content
Mobile Measurement	Qualification and verification	Multiple sampling points, commissioning, troubleshooting, particle measurement
Online at the critical point	Continuous process monitoring	Direct product contact, critical production lines
Periodic Laboratory Testing	Supplementary validation	Oil, Particles, and Microbiological Parameters

Source: CS-Instruments

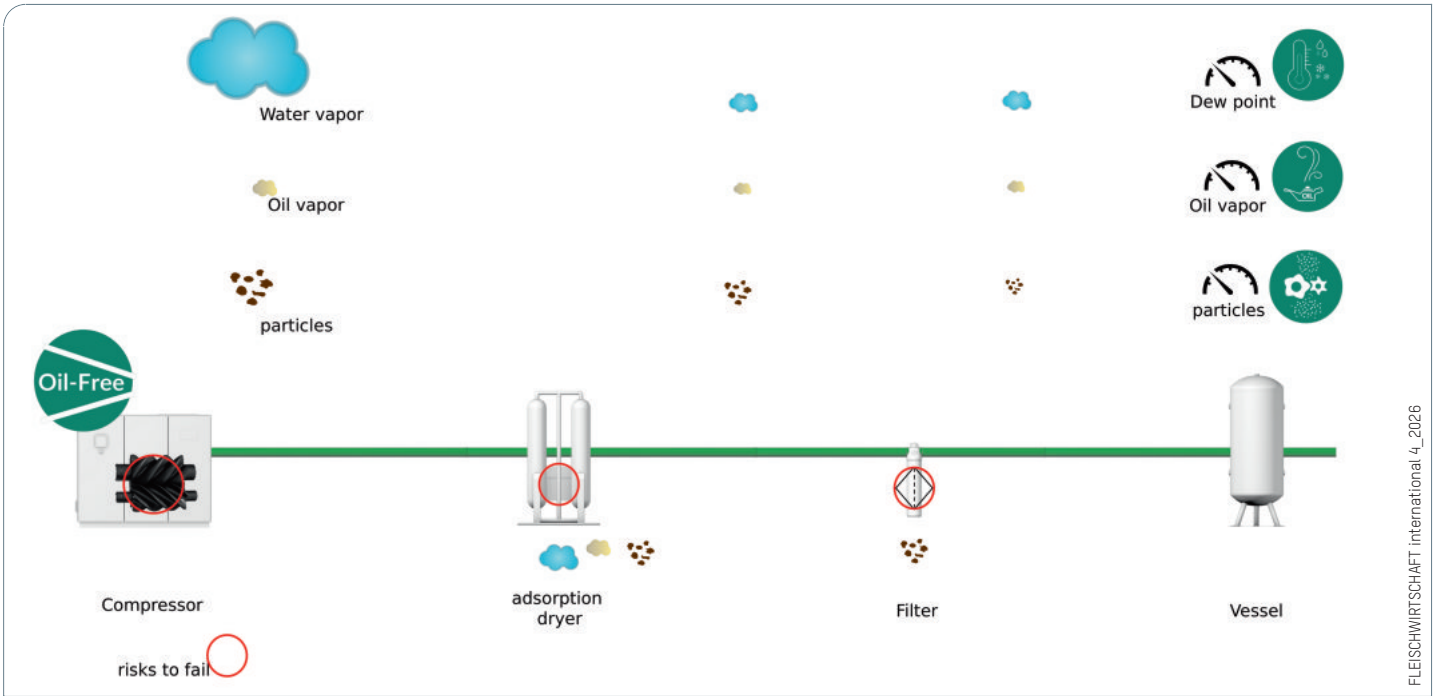

Fig. 3: Oil-free configuration in common practice, showing the main risk areas. *Source: CS-Instruments*

Combination of monitoring methods

The interplay between centralized monitoring, mobile measurements, and laboratory analyses should be taken into account as early as the planning phase. Centralized measurement provides system information, mobile measurements verify the actual quality at the point of use, and online sensors reduce the time between a deviation and its detection.

The point of use is the weakest link

If a deviation is found, the cause is, in practice, more often in the last few meters than in the compressor room. For meat processing plants, the following points are particularly relevant:

- Point-of-use filtration.
- Couplings and hose ends.
- Hoses.
- Restart after a shutdown.
- Dead ends and materials. Branch lines with no flow and sections of decommissioned machinery are reservoirs of humidity and microorganisms. In galvanized pipes and tanks, flaking and the release of particles can occur.
- Blow-off as an aerosol source. When blowing off, aerosols can form from water, product residues, cleaning agents, and microorganisms present on surfaces

Test plan and procedure for deviations

From the defined purity class and monitoring concept, a test plan is derived that can be submitted as a document. The actual frequencies must be derived from the risk assessment specific to the facility.

Just as important as the test plan is the procedure to follow when a deviation is detected. If this is not clarified until an incident occurs, time is lost and traceability is compromised. A defined sequence has proven effective:

1. Verify the plausibility of the measured value and perform a repeat measurement to rule out sensor or sampling errors.
2. Identify the affected area and time interval: Which sampling points are connected to this section, and when was the last measurement within the target range?
3. Assess the product impact: Were any unpackaged goods affected during this time interval? Document the decision regarding suspension, rework, or release.
4. Narrow down the cause, such as filters, dryers, condensate drains, end-point filters, recent maintenance, or changes to the system.
5. Implement corrective action and grant approval only after a measurement within the target range at the affected sampling point.
6. Evaluate the results with the HACCP team and determine whether the testing frequency, alarm threshold, or system design needs to be adjusted.

Conclusion

The technical requirements for compressed air in the meat industry are determined by its specific application. In cases of direct or indirect contact with unpackaged meat, it becomes an integral part of hygienic process control. ISO 8573-1 provides the framework for particles, water, and oil; the remaining parts of the series of standards specify the corresponding test methods; and VDMA 15390-2 supplements these with application-specific recommendations. However, the entire system only becomes robust through three elements that no supplier provides: specifications for each extraction point, a testing plan with a justified frequency, and a predefined procedure for handling deviations.

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M.Sc. Christian Kuhn
is a Product Manager at CS-Instruments with 20 years of experience in measurement technology and analytics.

Contact
Christian Kuhn, CS-Instruments,
Zindelsteiner Straße 15, 78052 VS-Tannheim,
c.kuhn@cs-instruments.com