

Air Cleaner

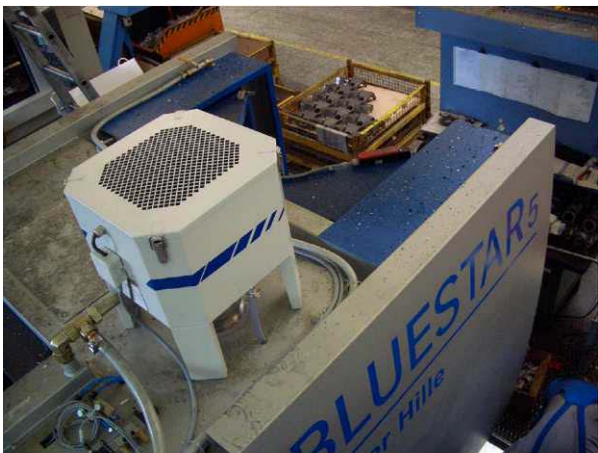
13.8	Safety engineering	3
13.8.3	Emission protection on machining tools through oil and emulsion mist separation in the micron range.....	3
13.8.3.1	Tried and testes compact separators....	3
13.8.3.2	Flexible combinations	4
13.8.3.3	Multi-stage electrostatic collectors	4
13.8.3.4	Central or de-central?	5
13.8.3.5	Special case of minimum lubrication	6
13.8.3.6	Summary	7

13.8 Safety engineering

13.8.3 Emission protection on machining tools through oil and emulsion mist separation in the micron range

Cooling lubricants are indispensable in the machining of metals. Due to the heat generated in the machining process, cooling lubricants release oil and emulsion mist as well as smoke and aerosols. At high processing rates with indexable cutters for instance, the temperature may rise to 1,000 °C. Any cooling lubricant entering the processing zone evaporates immediately.

The emitted particle range is very large and includes all sizes from droplets with a diameter of 100 µm to finest particles with a size below 0.5 µm. They do not only pollute the work environment but also threaten the health of the operators. Inhaled particles with a size below 5 µm even get into the lower respiratory tracts. Droplets smaller than 2 µm penetrate into the pulmonary alveoli. They are carried away with the blood stream and can enter all organs. If the operators are exposed to the pollutants without or with insufficient protection, this may have toxic, allergic, neural, cancer producing or genotoxic effects according to workplace health specialists. Therefore, emission protection is urgently required - not least in view of indoor hygiene requirements and structural fire protection.



III. 1: Compact separator on a processing centre

13.8.3.1 Tried and tested compact separators

The approaches to emission protection on chip removing, reshaping or eroding machines are versatile and depend on the cooling lubricants that are used, the pollutants that are emitted and the particle range of these pollutants. For smaller machine tools with a workspace of about 4 m and low fume and smoke generation, compact separators that are placed on top of the machine have proven their worth (ill. 1). The air-handling capacity varies between 400 and 800 m³/h. The cleaned air is returned to the workshop.

Modern compact separators are fitted with self-cleaning cyclone separator blades. The separation is based on purely mechanical processes dispensing with filter mats that become saturated with time and have to be replaced at regular intervals.

The compact units are often designed as rotational separators. The entire filter drum rotates and generates vibrations and noise. In modern versions, only the fan rotates not the entire drum. In addition, the fan speed and the air volume are continuously adjustable to the emissions. Engineers should consider these features.

Compact separators are often available ready for connection. They can be opened on top providing easy access to the cyclone separating elements (ill. 2). Electrostatic collectors are available as accessories. The combination of both devices is suitable for smaller grinding machines, for instance, that use pure oil for greasing and cooling.

The limits of application of compact separators are cooling lubricant pressures of about 20 bars.



III. 2: Compact separator with removable top

13.8.3.2 Flexible combinations

Larger machine tools up to a workspace of approximately 16 m with cooling lubricant pressures up to 40 bars require multi-stage separating systems. These systems have no rotational units and are composed of several succeeding cyclone separator elements (ill. 3). The separators are rack units that can be extracted and disassembled for cleaning. They are suitable for continuous reuse.

The multi-stage systems are very flexible in their application. If the machine parameters change or emulsion is used instead of oil, only the combination of separating elements needs to be changed. An example of a three-stage system: The first stage separates oil droplets with sizes of $1\ \mu\text{m}$ and more on the basis of the cyclone principle. The separated oil runs down on the vertical blades of the cyclone separator into a collecting channel (ill. 4).

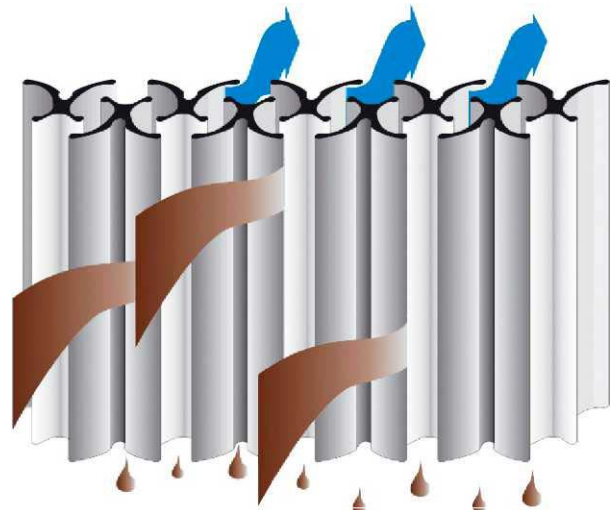
The agglomerator downstream captures fine particles below $1\ \mu\text{m}$. It consists of a multi-ply stainless steel fabric. Its surfaces are moistened with the oil separated before. This causes the agglomeration of fine aerosols, i.e. the creation of larger particles due to adhesion and cohesion forces. The agglomerated particles are reliably separated in the third stage by a second cyclone separator. Depending on the customer's requirements, up to five separating stages are cascaded this way, using a particulate air filter as a final stage, if required. In applications with extremely high cooling lubricant pressures (up to 100 bars) and/or high smoke generation, an electrostatic air filter ensures post filtering. If odours and dangerous gases have to be eliminated, activated carbon filters are a good choice for the final stage. Due to the high separating efficiency of multi-stage systems, the cleaned air can be returned to the workshop under normal conditions. In modern systems, a separating rate of 100 % can be achieved with particle sizes of $1\ \mu\text{m}$. With sizes of $0.5\ \mu\text{m}$, the rate still amounts to 95 %. It is important to inform the customer about the fractional separating rates in the quotation phase. Serious suppliers specify the separating rates of their equipment over the entire particle range. The indication of gravimetric total efficiency rates is questionable, however, because these values render a comparison to competing systems difficult and might lead to misinterpretation.

13.8.3.3 Multi-stage electrostatic collectors

Extremely high cutting speeds and increasingly tight encapsulations produce super proportional pollutant concentrations on state-of-the-art machine tools.



III. 3: Multi-stage oil mist separator



III. 4: Self-cleaning cyclone separating element



III. 5: Multi-stage electrostatic collector



III. 6:
Separators connected to a manifold exhaust air duct

They are often about a hundred times higher (!) than those of five-years-old machines. Purely mechanical oil mist separators cannot cope with these concentrations. Therefore, industry developed multi-stage electrostatic collectors that are preceded by an agglomerator or a cyclone separator. The pre-stages separate the coarse contamination. The superfine particles down to $0.01\ \mu\text{m}$ are efficiently captured in the three-stage ionization field of the electrostatic collector (ill. 5).

Some manufacturers specify the fractional separating rates in the documentation of their high-performance electrostatic equipment, such as 93 % for a particle diameter of $0.05\ \mu\text{m}$ and 98 % for a particle diameter of $0.8\ \mu\text{m}$. Due to the high separating performance, the air handling capacity and the power consumption of these devices are relatively low. In most cases, the power consumption is not taken into account when selecting oil or emulsion mist separators, even though the cost saving potential is considerable. Please note the following calculation:

10 machine tools with oil mist separators run in three-shift operation in a metal machining factory. The resulting annual operating time is 6,400 hrs p. a. If each separator has a power consumption of 1.2 kW at a price of 16 Cents/kWh, the resulting power consumption costs amount to:

$10\ \text{machines} \times 1.2\ \text{kW} \times 6,400\ \text{hrs} \times 0.16\ \text{€/kWh} = 12,280\ \text{Euros.}$

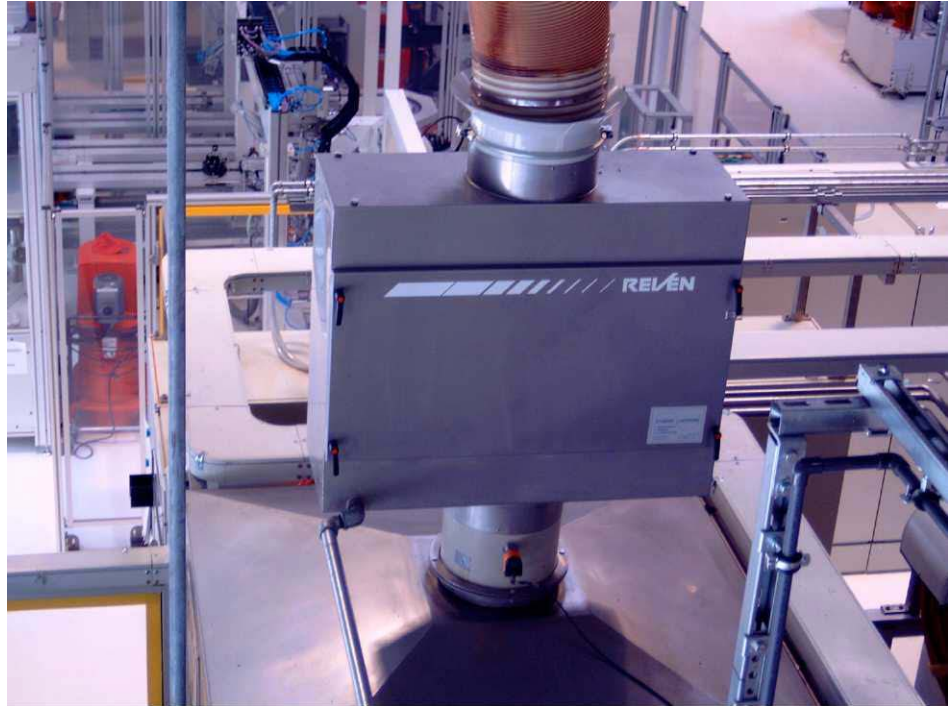
If the power consumption of each separator is only 0.4 kW, the annual power consumption costs are reduced by two thirds.

Where do these differences in consumption come from? As with cars, the air resistance has a decisive influence. The resistance value of a cyclone separator with optimized flow is in most cases only a fraction of that of a traditional mesh filter or baffle plate separator. The designers and buyers of extraction systems should therefore always consider power consumption. Particularly the afore-mentioned compact separators differ considerably in their power consumption from each other. The extra costs for a high-grade system often pay off within one and a half year. If you replace the filter cartridges in older systems by modern separating elements, the pay-off times might even be shorter. The replacement of filters with standard dimensions does not involve any problems.

13.8.3.4 Central or de-central?

In larger production facilities with a great number of machine tools, the individual oil mist separators are often connected to a common extraction system (ill 6). An alternative to this decentralized solution is a central separation with a powerful air cleaner in the exhaust air duct. In both cases, the extracted air is not returned into the shop but let out into the open. This can improve the air hygiene at the workplace. It involves a drawback, however: Oil deposits might accumulate inside the long horizontal air ducts with time, thereby increasing the fire load.

III. 7:
*Pre-separator
in the exhaust
air duct*



In the event of a fire, the air ducts act as ignitor cords. Therefore, high separating rates are required in central separating systems for reasons of structural fire protection. Fire dampers actually help to reduce the fire risk, but there is a much more efficient alternative: the pre-separation of the emissions on the individual machines.

The pre-separation with highly efficient separating elements keeps the air ducts free from oil to the greatest possible extent (ill. 7). However, it is only reasonable if the pre-separators are flame arresting. A corresponding DIN test sign establishes evidence of this property. The test is based on DIN 18869-5. The standard was published in 2007. It requires flame-arresting grease separators for industrial kitchens, because of devastating air duct fires in the past. This standard is currently the most stringent test standard for the flame-arresting capability of equipment and is increasingly adopted as a guideline by the suppliers to industry when equipping machine tools with oil mist separators.

The corresponding DIN test sign on the pre-separating equipment is a guarantee to the operator that a lubrication oil fire will not flash over into the air duct. Baffle plates, which are often used as pre-separators, do not comply with these requirements. They are flame retarding at best.

13.8.3.5 Special case of minimum lubrication

The minimum lubrication involves special requirements on emission protection because the aerosol concentration and the smoke generation are particularly high in this process. Industry developed separating systems with up to nine stages for this type of lubrication. They are particularly aligned to the machine parameters and the oil or emulsion type used for lubrication. The first stage captures the relatively coarse aerosols and dusts, the succeeding stages agglomerate and remove smallest droplets with sizes below 1 μm . Typical cases of application are high-speed grinding machines that work with thin oils and high oil pressures. The "Venturi separation system" has proven its worth in applications with minimum lubrication. The Venturi pipe supplies additional indoor air (secondary air) to the separation chamber and increases the total airflow. The additionally supplied air reduces the air inlet temperature, which causes the aerosols in the airflow to condense partially. This effect guarantees the early separation of finest particles. Particles with a diameter of 0.8 μm are separated by 99 % for instance. Thanks to adjustable Venturi nozzles, the amount of added air and the supply air temperature can be varied. Some suppliers of Venturi solutions make sure that a part of the condensed aerosols is removed before getting into the separating chamber.



Ill. 8:
Separator with
Venturi air intake

This increases the service life of the separating element considerably, by up to 2.000 operating hours in some cases. Therefore, it is reasonable to operate Venturi systems with a high portion of secondary air. The best mixing ratio is 1:1. The Venturi principle protects also the highly sophisticated electronic control system of the machine tool from heat action. The system is suitable for retrofitting because the described air intake components can easily be connected upstream of the separator (ill. 8).

Another special case is dry machining, such as cast and graphite processing without cooling lubricant. Mechanical cyclone separators have proven their worth here too. They are combined in multi-stage systems in accordance with the application. A subsequent spray system is recommended. A set of nozzles sprays water onto the stainless steel separating blades to drain off the pulverized chip particles into a collecting tank.

13.8.3.6 Summary

Workplace safety and health requirements are the main reasons why highly efficient oil and emulsion mist separators become more and more important in metal processing factories. The separation of finest particles with a diameter below $1\ \mu\text{m}$ is in the focus of attention in this regard. You cannot see these particles or detect them with traditional

manual measuring instruments. They are the greatest threat to the health of the operators.

The approaches to separating solutions are quite versatile and depend on the respective case of application. Modern separating systems have a multi-stage layout and the combination of separating elements is tailored to the particle range and the pollutant concentration. In many cases, mechanical and/or electrostatic separators without throwaway filters can solve the problem. The investor who looks for a suitable system should ask for a detailed specification of the fractional separating rates, because the total efficiency is no criterion for the separation quality.