United Air Specialists, Inc.

"Life cycle costs for industrial air filter systems for separation of cooling lubricants"

Comparison between mechanical and electrostatic collectors

SOPHISTICATED INDUSTRIAL AIR CLEANING

„Life cycle costs for industrial air filter systems for separation of cooling lubricants“

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Author: Carlo Saling, Produktmanager, UAS United Air Specialists Inc.
Publisher:
UAS United Air Specialists Inc., Branch office Germany
Otto-Hahn-Str. 6 | 65520 Bad Camberg
Phone +49 (0) 64 34 / 94 22-0 | Fax -99
www.uas-inc.de

Layout:
IHW Jörn Jacobs & Co.
Otto-Hahn-Str. 15 | 65520 Bad Camberg
www.ihw-marketing.eu

„Life cycle costs for industrial air filter systems for separation of cooling lubricants

Comparison between mechanical and electrostatic collectors“

by Carlo Saling

Globalisation as well as heavy growth of newly industrialising countries have led to considerable increase in competitive pressure on European industry in recent years. At the same time, this period has shown quite plainly that the era of “cheap” energy has passed. Given the shortage of resources, easing of resource costs – regardless whether for oil, natural gas, electricity, or industrial metals – is not foreseeable in the long run.

In the years to come, energy efficiency will become an advantage in competition for business. Furthermore, we are obliged – no matter if as employee of a company or as person – to handle natural resources in a conscientious way.

Life cycle costing provides an interesting approach. This considers the costs over the entire life cycle, i.e. starting with purchasing until final disposal. The VDMA (Verband Deutscher Maschinen- und Anlagenbau – association of German mechanical and plant engineering) has defined it as follows: Life cycle costs are the sum of all expenses required for use of a suitably designed machine or plant to the intended purpose, starting with purchasing until final disposal.[1]

Particularly the operating expense for energy- and maintenance-intensive air filter systems is a multiple of the investment costs. Figure 1 shows the different cost types that may accrue from the moment of purchasing until disposal of a filter.

Industrial air filter systems – also designated exhaust systems or filtering collectors – are designed to remove harmful and hazardous substances such as oil mist, emulsion mist, smoke, or dust from the ambient air of production – optionally directly on the machine or through a central shop exhaust system.

Separation of cooling lubricants emitted as aerosol or vapour into the air as a consequence of metal machining in machine tools is an important field of application for industrial air filter systems. Cooling lubricants among others serve

[1] VDMA – standard 34160

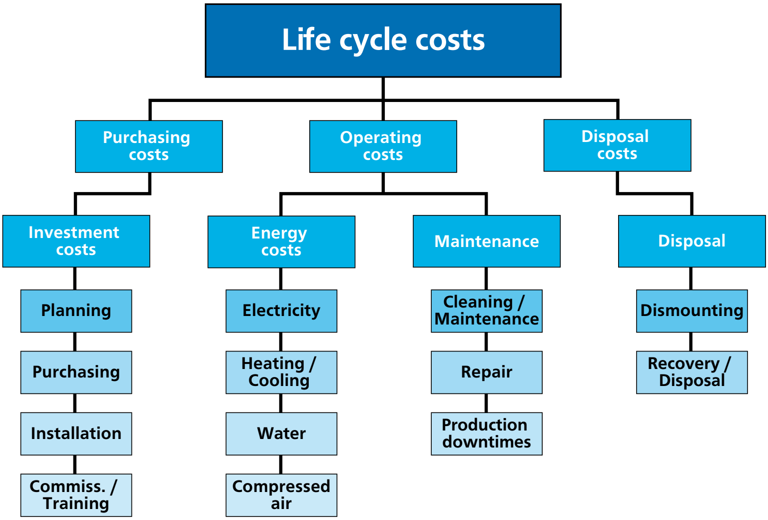

Figure1: Life cycle costs of an industrial air filter system

cooling, lubricating, and rinsing of machined parts.

The Ordinance on Hazardous Substances commits business to free the air inhaled by insurants from harmful substances (e.g. cooling lubricants). As a remedy for this issue air filter systems remove emissions directly from the ambient air. Fundamental principles of separation are:

- Mechanical collectors
- Electrostatic collectors (electrostatic filters)
- Inertial collectors (centrifugal collectors)
- Wet dust collectors (washers)

This article will not deal with the fundamentals of such principles.

Please refer to relevant literature and VDI guidelines (VDI 3677, VDI 3678, VDI 3676, VDI 3679).

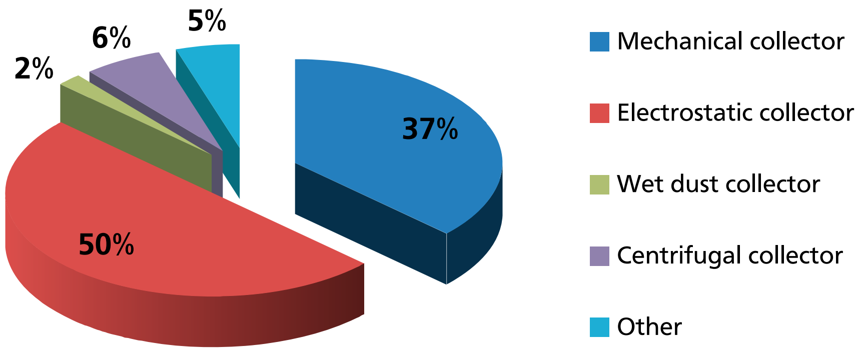

Figure 2: Conclusion of Metallberufsgenossenschaft (association of metal professions): Distribution of the filter systems actually used in companies

This article considers the life cycle costs for mechanical and electrostatic collectors, only, because in the companies' practise these collectors have a market share of 90% for exhaustion of cooling lubricants; see figure 2.[2]

Classic centrifugal collectors are suitable to only a limited extent for modern machining processes because the principle of separation is based on forces of gravity. Since the largest share of particles emitted from machine tools is < 2 µm, gravity collectors should not be used as main filters.

Measuring of BGIA has shown that the filtration efficiency in practise may even be negative due to a new emission of substances already separated.[3]

In the companies' practise, wet dust collectors are rarely used for separation of cooling lubricants. Wet dust collectors provide good separating performance; however, pressure loss of filters as well as water treatment lead to high operating expenses for the operating company. Wet dust collectors are an interesting alternative for use cases with high safety requirements (fire and explosion prevention) due to the process.

[2] Source: BIA – Report 03/1991 "Kühlschmierstoffe – Umgang, Messen, Beurteilung, Schutzmaßnahmen" (Cooling lubricants – handling, measuring, safety measures) editor Berufsgenossenschaftliches Institut für Arbeitsschutz BGIA, St. Augustin, 1993

[3] BGIA- Report 09/2006 "Absaugen und Abscheiden von Kühlschmierstoffen" (Exhaustion and separation of cooling lubricants) by W. Pfeiffer, editor Berufsgenossenschaftliches Institut für Arbeitsschutz BGIA, St. Augustin, 2006

Calculation of life cycle costs

Cost types for procurement

Investment costs are the largest share of procurement costs. The expenses for planning, installation, commissioning, and training can be neglected for a comparison of costs for mechanical and electrostatic filters, for those costs do not directly depend on the principle of filter. Costs for planning are equivalent for both principles of separation and many manufacturers of industrial filter systems provide the planner with advice.

Costs for installation heavily depend on the space available on site. Costs for commissioning and training are comparable for both principles of separation, as well. In general the space required for a mechanical filter is larger than that required for an electrostatic filter.

For this comparison, capital costs have been taken into consideration by discounting all costs with the respective cash value to time t_0. Tax advantages of investment costs that in contrast to operating costs are depreciable have been neglected for this consideration.

Cost types during operation

The operating expense for an industrial filter system for separation of cooling lubricants is primarily made up of expenses for electricity and maintenance. Normally, costs for water, cooling energy, heating energy, compressed air do not accrue. **Energy costs** considerably depend on the motor capacity of the fan. In mechanical filters, often high efficiency submicron particulate air filters (HEPA) are used as last filter stage designed to reach the requested filtration efficiency for submicron particles – particularly for recirculation air. Such deep-bed filters provide the operating company with excellent filtration efficiency; however, since harmful substances remain in the filter stage, the flow resistance of the filter stages is continuously increasing during service life.

As a consequence, pressure drops as well as power consumption of the fan increase as well. In the companies' practise, the motor capacity of a mechanical filter is often more than twice the motor capacity of an electrostatic filter required to get comparable suction pressures.[4]

[4] Suction pressure of a fan means that a comparable suction pressure is available for suction of harmful substances.

Electrostatic filters provide the advantage that the flow resistance hardly increases over the operating time because the collector plates are arranged in parallel in flow direction allowing the harmful substances to run off the smooth surfaces. Another advantage is that most of the harmful substances are removed from the air flow, thus reducing the danger of evaporation compared to a filter fabric soaked with harmful substance.

Maintenance expenses comprise the costs for spare filter or cleaning of the filter elements, respectively. The filter elements of mechanical filter systems (e.g. non-woven, fabric) have to be replaced when the fabric is saturated with harmful substances and the filter – due to an increased flow resistance – fails to suck the harmful substances.

Then, filter elements have to be disposed of as hazardous waste. The expenses for disposal have been neglected for this consideration. Only the expenses for spare parts as well as for one man-hour required for replacing a filter element have been considered.

Electrostatic filter elements (pre-filters, ionisers, and collectors of metal) can be cleaned in an ecologically minded way in ultrasonic cleaning devices and be reused subsequently. The calculation assumes that the customer will replace the filter elements autonomously. Actually, companies often proceed this way in case of single filters. For a trouble-free operation, you only shall have a spare part set of filter elements in stock. Soiled filter elements can be taken out of the filter easily via guide rails and e.g. sent to United Air Specialists Inc. for central regeneration in an ultrasonic cleaning device. UAS offers all new customers a free of charge training on this subject. Subsequently, the cleaned filter elements will be sent back to the customer for reuse. The calculation of costs includes one customer man-hour required for replacing of a filter element. Cleaning expenses (external) for the filter elements as well as disposal costs for cleaning agents have been considered in the calculation. If a company has a large number of filters, the cost-effective service by UAS or its service partners in a comprehensive network is reasonable.

Furthermore, the calculation includes expenses for wear and tear amounting to 3% p.a. for both separation principles.

Cost types for disposal

Disposal costs comprise dismounting of the system as well as disposal of the material. Since the expenses for both separation types are similar, we have neglected such expenses or used identical values, respectively.

Calculation of life cycle costs

We have taken an example (air flow 2,000 m³/h) for calculation of the life cycle costs of industrial filter systems for separation of cooling lubricants. We have considered different cost scenarios to get a representative view.

Assumptions for calculation

Parameters	**Mechanical filter**		**Electrostatic filter**	
Scenarios	Minimum	Maximum	Minimum	Maximum
Number of filters	1 piece		1 piece	
List price	2,500 €	5,500 €	3,500 €	7,000 €
Costs: commissioning / training	600 €		600 €	
Number of filter stages	2	3	2	3
	Pre-filter, main filter, possibly HEPA		Pre-filter, 1 - 2 main filter(s) (collectors)	
Operating time	8.000 h per year		8.000 h per year	
Pressure loss of filter	250 Pa	800 Pa	120 Pa	200 Pa
Suction pressure	350-450 Pa		350-450 Pa	
Motor capacity	1.5 kW	2.2 kW	0.75 kW	0.85 kW
ø–load intake	60%		60%	
Air recirculation	Yes		Yes	
Ø-service life	3,000 h	9,000 h	1,500 h	2,500 h
Maintenance Ø-costs per spare filter element	200 €	350 €	–	–
Maintenance; Ø-costs for cleaning of all filter elements	–	–	70 €	90 €
Costs for working time	45 € per hour		45 € per hour	
Expenditure of human labour for replacing of a filter element	1 hour		1 hour	
Electricity tariff Cents/kWh	10 Cent	15 Cent	10 Cent	15 Cent
Capital costs, interest rate	5%		5%	
Wear and tear	3% per year		3% per year	
Operating life	10 years		10 years	
Disposal costs for filter and material	1,250 €		1,250 €	

Figure 3: Single-position exhaustion of cooling lubricants (air flow: 2,000 m³/h)

Calculation results

General expense	Mechanical Minimum [5]	Mechanical Maxi-mum	Electrostatic Minimum [5]	Electrostatic Maxi-mum
Supplier	Example		United Air Specialists	
Manufacturer's type	Example		SH Modular	
Number of filters	1 unit			
Investment costs [€]				
Purchase price per filter	2,500.-	5,500.-	3,500.-	7,000.-
Piping and fittings	0.-	0.-	0.-	0.-
Installation	0.-	0.-	0.-	0.-
Commissioning	500.-	500.-	500.-	500.-
Training	100.-	100.-	100.-	100.-
Others	0.-	0.-	0.-	0.-
Total [€]	***3,100.-***	***6,100.-***	***4,100.-***	***7,600.-***
Operating costs [€]				
Electricity costs	720.-	1.584.-	360.-	612.-
Maintenance costs	471.-	3.085.-	473.-	930.-
Total [€]	***1,.191.-***	***4.669.-***	***833.-***	***1.542.-***
Disposal costs [€]				
Disassembly	1,000.-	1,000.-	1,000.-	1,000.-
Disposal	250.-	250.-	250.-	250.-
Other costs	0.-	0.-	0.-	0.-
Total [€]	***1,250.-***	***1,250.-***	***1,250.-***	***1,250.-***
CO_2 emission in tons per year [6]	4.3	6.3	2.2	2.4

Figure 4: Table with results

[5] Calculation of min. costs with min. investment costs, min. number of filter elements, min. motor capacity of fan, min. electrical costs, min. spare parts costs or min. cleaning costs, respectively, and longest service life

[6] Based on motor capacity of fan

Results

Normally, the list price for an electrostatic collector is above the price for a mechanical collector. Since the prices depend heavily on the number of filter stages as well as on optional features, we have defined a wide range of costs for both filter systems covering the spectrum of market prices.

Investment costs for a mechanical filter range between 2,500 and 5,500 € for an operational volumetric flow range[7] of 2,000 m³/h, whereas electrostatic collectors range between 3,500 and 7,000 €. This difference induces many companies to opt for an investment in mechanical filter systems. For commissioning and training, we have assessed expenses amounting each to 600 € per day.

A view on the **operating costs** shows different results. The motor capacity of the mechanical example representing the experiences gained in companies' practise corresponds to 1.5 – 2.2 kW. The motor capacity of an electrostatic collector amounts to only 750 – 850 W. Both filter systems of the example provide a suction pressure of about 350 – 450 Pa. Whilst power consumption of a fan in electrostatic collectors is comparatively constant, power consumption of the fans in mechanical filters heavily depends on the load of harmful substances in the individual filter elements. In the beginning, pressure loss ranges from about 250 to 300 Pa, however, it may increase up to 800 Pa during operation when the filter elements are saturated with harmful substances.

Should the crude gas load on the filter inlet be high, double-stage electrostatic filters with mist eliminators are a suitable solution. The double-stage solution is of advantage because it increases the filter service life and the separating performance during short-term flashovers, which might occur in case of cooling lubricants with a high proportion of water, will not be affected considerably. Such flashovers are popular reason to opt against electrostatic filters; however, such flashovers can almost be excluded by clever monitoring of the high-voltage range as well as selective design modifications. Only pressure sensors of sufficient accuracy may detect filter fractures and defective spots in the fabric of a mechanical collector.

In both cases, power consumption (load) of the fans averages to 60%. Based upon these data and upon an assumed electricity tariff of 10 – 15 Cents per kWh (VAT excluded), the electricity costs for mechanical filters are 720 – 1,584 € (7,200 – 10,500 kWh) per filter and for an electrostatic collector 360 – 612 € (3,600 – 4,800 kWh). Apart from the economic point of view, such

[7] Do not mistake the operational volumetric flow rate for the idling capacity of the fan!

economy of electricity of about 50% corresponds to a CO_2 equivalent[8] of at least 2 t CO_2 per year emitted less into the atmosphere.

Maintenance costs (servicing and cleaning) for the mechanical filter have been limited to replacing of filter elements. We have assumed one man-hour for replacing of one filter element (in-company hourly rate: 45 €). The top reference value for the service life of a mechanical filter is based on specifications made by a competitor who assures his customers of a service life of up to 9,000 h for a mechanical filter element. An operating time of 8,000 h per year would result in less than 1 exchange per year. Usual prices on the market for spare filter elements are 200 - 350 € per element. Disposal costs for mechanical filter elements saturated with cooling lubricant (hazardous substance) have not been taken into consideration for this calculation.

The service life of an electrostatic filter element has been specified with 1,500 – 2,500 h. This assumption is based on the experiences gained by the services of United Air Specialists Inc. and represents a **conservative** approach. For replacing of filter elements, we have again considered one man-hour per exchange. The filter elements of the electrostatic filter (pre-filters, ionisers, collectors) can be cleaned and reused, e.g. in the ultrasonic cleaning systems of UAS. Disposal of filter elements is not required. Cleaning of filter elements is normally charged with 70 – 90 €.

Therefore, maintenance costs for a mechanical filter amount to 471 – 3,085 € and those for an electrostatic filter to 473 – 930 € (each incl. 3% for wear and tear per year). Below the line, the maintenance costs for an electrostatic filter will usually be less, despite the assumption of a multiple service life of mechanical filters.

In total, the operating expenses for a mechanical filter range between 1,191 and 4,699 €, whereas the running expenses for an electrostatic collector only range between 833 and 1,542 € per year.

Disposal costs for both collectors have been set to 1,250 €. Just as the costs for installation, such costs heavily depend on the space available on site.

[8] Information by ifeu (Institut für Energie- und Umweltforschung Heidelberg – Institute for Energy and Environmental Research in Heidelberg, Germany) on a CO_2 equivalent of the German electricity mix of 0.6 kg per kWh, survey on behalf of Federal Environmental Agency.

Conclusion

The calculation example compares life cycle costs for mechanical and electrostatic air filter systems of a suction capacity of 2,000 m³/h. The calculations consider different scenarios (minimum and maximum) concerning investment costs, service life of filter elements, number of filter stages and their maintenance costs, as well as electricity costs.

Adding and discounting investment, operating, and disposal costs leads to figure 5.

This figure impressively proves that opting for an investment in electrostatic collectors in many cases is advantageous. Despite the higher investment costs, electrostatic collectors will break even after a short time of operation already.

In order to approach reality, we have taken different scenarios into consideration.

It is important to discount capital costs – here assumed with 5% – over the procurement period to take into account the higher purchasing costs for electrostatic filters.

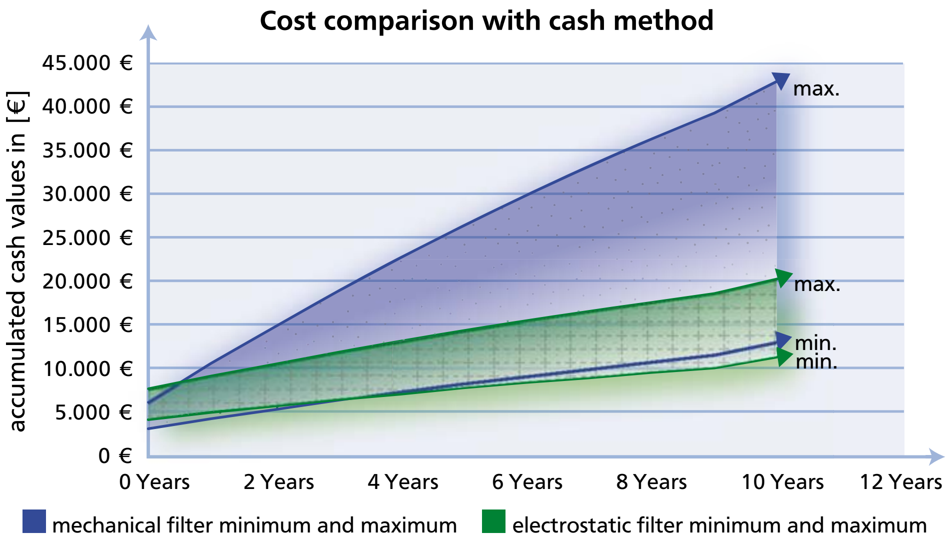

Figure 5:
Comparison of life cycle costs between mechanical and electrostatic collectors

After an operation of 10 years, cost differentials of up to 25,000 € per filter will result – without impairment of air quality. On the contrary: The economy of electricity will reduce CO_2 emissions by at least 2 tons CO_2 per year.

The example shows that a comparison of life cycle costs as basis for decision-making of companies pays off and at the same time preserves resources. Less investment costs for mechanical collector systems seem to be more favourable on the surface, only.

This example is even based on a multiple service life of mechanical filters compared to electrostatic filters.

Furthermore, the filter elements of the electrostatic filter can be cleaned in an ecologically minded way to be reused subsequently. No hazardous waste result! Disposal costs have not been considered in the calculation.

The difference in life cycle costs in case of higher volume flow even increases. This is the reason why power station technology prefers electrostatic filters with low pressure loss for air purification.

The results show: A comparison of costs is profitable!

Seemingly less expensive may become expensive for companies!

Branch office Germany:
Otto-Hahn-Str. 6 | 65520 Bad Camberg
Phone +49 (0) 64 34 / 94 22-0 | Fax -99 | info@uas-inc.de | www.uas-inc.de

Office North:
Neuenlander Straße 5 | 27299 Langwedel
Phone +49 (0) 42 35 / 9 29 94 | Fax 9 29 96

Office Nordrhein-Westfalen:
Auf dem Eigen 2 | 42349 Wuppertal
Phone +49 (0) 2 02 / 2 47 81 40 | Fax 2 47 81 66

Office Central:
Dehrner Straße 12a | 65554 Limburg
Phone +49 (0) 64 33 / 70 06 36 | Fax 81 33 3

Office Sachsen:
Daubaer Straße 20 | 01847 Lohmen
Phone +49 (0) 35 01 / 58 83 44 | Fax 58 81 97

Office Baden-Württemberg / Bayern:
Büchel GmbH | Breite Str. 27 | 89168 Niederstotzingen
Tel. +49 (0) 73 25 / 96 05 0 | Fax 96 05 80

Office Austria:
Hallestraße 29 | 4030 Linz | Phone +43 (0)7 32 / 31 38 13 | Fax 30 44 89