September 2005

RECOMMENDATION

concerning

CALCULATING OF LIFE CYCLE COST FOR AIR FILTERS

Purpose

Air ventilation systems often account for the lion's share of a building's energy consumption and the pressure drop in air filters accounts for a larger portion of the total pressure drop in a ventilation system. Thus from the viewpoint of increasing energy efficiency, there are strong reasons for optimizing the choice of air filters without compromising filtration requirements.

A life cycle cost can be made in different ways depending on application and purpose of the air filters. This Recommendation prepared by the Eurovent WG 4B "Air Filters" gives a guideline, for calculating life cycle cost of air filters and a tool to minimize the running costs of an air handling installation.

Method

The annual energy and power costs (electricity) during the useful life or utilization time of the filters are converted to a present value. A corresponding procedure is adopted for future maintenance costs and also for the disposal or environmental costs.

The reason to use air filters is to clean the air and the most important property is the filter efficiency. Before any LCC calculations are made, the right filter quality (efficiency or filter class) together with other requirements shall be chosen according to the Eurovent / Cecomaf Recommendation "Air Filters for better IAQ" (ref 1).

It is also important to maintain a high efficiency during the operation of the filters. The discharge efficiency according to the European Test Norm EN 779 indicates the minimum life efficiency (MLE) of a filter and should not decrease substantial from the new filter. A decrease of 10% units or more will probably give a corresponding lower filter class in real life compared to the filter class measured in laboratory. The MLE could be verified or certified by life time tests through and independent laboratory.

Calculation

The life cycle cost (LCC) could be defined as follows

Life cycle cost (**LCC**) = **I**nvestment + $\mathbf{LCC_{Energy}}$ + $\mathbf{LCC_{Maintenance}}$ + $\mathbf{LCC_{Disposal}}$

- **I**nvestment: Capital costs of the filter installation when the new ventilation system was first installed (filters + frame + labour). The capital cost could also include the building volume for filters.

- $\mathbf{LCC_{Energy}}$: Present total cost of energy (electricity to power the fan) for the filters.

  Except the energy price and operation time, the energy cost depends on the filter pressure drop, the air flow and the fan characteristics.

  The energy cost is, in most cases, based on the filter(s) average pressure drop and the mean value between initial pressure loss and final pressure loss at nominal air flow is normally used. Many installations have fans with rotational speed and the air flow will be higher than the nominal air flow with clean filters and lower than nominal with dust loaded filters. But an assumption based on nominal air flow will be good enough for comparison and approximation of costs. With the lower energy requirement, more and more systems are being designed for constant nominal flow, and average pressure loss is the integrated value of the pressure drop vs. operational time.

  In some applications, part of the “filter” energy reduces the heating consumption. In other applications this “filter” energy needs extra cooling capacity. If known, these effects could be included in the calculation.

- $\mathbf{LCC_{Maintenance}}$: Present total cost of replacement, including filters and labour costs for replacing the filters.

  The maintenance cost could be calculated according to the filter lifetime or from a certain time of operation (one per year, for instance). In the first case, the filter lifetime has to be estimated at a given final pressure drop. In the other case, the final pressure drop has to be estimated after a certain period of time. These estimations are sometimes difficult to make and are normally made by the filter manufacturer or better by an independent laboratory. These estimations must be based on experience from filter operation in real life, results from laboratory tests according to EN 779 can not be used.

- $\mathbf{LCC_{Disposal}}$: Present total cost for the disposal of an air filter. By incinerating some energy could be gained.

Present Cost:
Money spent some time in future is worth less than equivalent amount spent today. The present cost of a cost paid after ”n” years can be calculated with the following correction factor:

$[1 + (i-p)]^{-n}$ where
n = number of years
p = price increase
i = interest rate

The correction factor for each year or period is calculated and the sum of these gives the total sum factor.

Example 1:
Assume that an installation has a lifetime of ten years.
The filter’s price, EURO 50, will not increase during the ten-year period (p=0) and the interest rate is 6% (i = 0.06).
The correction factor for each year will be:

Beginning of year	No of years	Factor
2	1	0.9434
3	2	0.8900
4	3	0.8396
5	4	0.7921
6	5	0.7473
7	6	0.7050
8	7	0.6651
9	8	0.6274
10	9	0.5919
	Total sum factor	6.8018

The cost for future replacement will be the sum of the correction factors multiplied by the present price = 6.80 * 50 = EURO 340.

The installation, energy and disposal costs have to be added to calculate the total cost for the ten-year period.

Example 2:
Make a ten years LCC calculation with the following assumptions

Interest rate: 6 %.
Air flow: 1 m^3/s (3600 m^3/h)(constant)
Running time 8760 hours per year
Fan efficiency: $\eta = 0.5$
Energy cost : EURO 0.05/kWh, Increasing 2 % per year.

Filter:

- Installation cost: Filter, Frame and labour cost: EURO 80
- Replacement cost of filter: EURO 55:- (including labour cost)
- Filter price: Fixed for the ten-year period
- Lifetime of filter: 7 filter replacements in 10 years (the filter has a lifetime of 1.43 years)
- Average pressure drop: 200 Pa
- Disposal cost EURO 1.50

Investment: EURO 80
Present Cost of Energy:
Energy cost per year is calculated by:

$$\frac{q.\Delta p}{\eta} \text{ x T x } \frac{\text{c}}{1000}$$

with:

q air flow
Δp average pressure drop
T running time
η fan efficiency
c cost of energy in Euro per kWh

Energy cost per year:

$$\frac{1x200}{0.5} \text{ x } 8760 \text{ x } \frac{0.05}{1000} = 175.20 \text{ Euro}$$

The present cost for energy over the ten-year period can be calculated with the following correction factors, assuming that the cost is paid at the end of each year. Price increase 2%
(p =0.02) and interest rate 6% (i = 0.06).

No of years	1	2	3	4	5	6	7	8	9	10
Factor	0.9615	0.9246	0.8890	0.8548	0.8219	0.7903	0.7599	0.7307	0.7026	0.6756

Total sum factor: 8.1109

The energy cost for the ten-year period will be 8.11 * 175.20 = EURO 1421

Present Cost of Maintenance:
Seven filter replacements in ten years means a lifetime for each filter of 1.43 years. The last filter is changed after 8.6 years and will last to the end of the ten-year period. The present cost of maintenance (with p = 0 and i = 0,06) can be calculated with the following correction factors.

Filter change	No of years	Factor
	0	
1	1.43	0.9201
2	2.86	0.8466
3	4.29	0.7790
4	5.71	0.7168
5	7.14	0.6595
6	8.57	0.6069
	10.0	
	Total sum factor	4.5290

The total maintenance cost for ten years will thus be 4.53 * 55 = EURO 249.

Present Cost of Disposal:
The disposal cost for a filter is EURO 1.5 and could be included in the maintenance cost for LCC analysis, but assume that the price increase is 3% per year (p=0.03) and the interest rate still 6% (i=0.06). The present cost for future disposal cost will be

Filter no	year	factor
1	1.43	0.9587
2	2.86	0.9190
3	4.29	0.8810
4	5.71	0.8446
5	7.14	0.8097
6	8.57	0.7762
7	10.0	0.7441
	sum	5.933

The cost for future replacement will be the sum of the factors, 5.09, multiplied by the present price.

The cost for the disposal will then be
5.93 * 1.5 or ca EURO 9:-

By incineration there is a possibility to earn some energy or money, EURO 0.50, corresponding to one liter of oil, which could be included in the total $LCC_{Disposal}$. This ”reduction of cost” could be reduced from the disposal cost.

Total Life Cycle Cost (LCC):
The total LCC cost could be calculated as the sum of all individual costs

Investment	80	
LCC_{Energy}	1 421	
$LCC_{Maintenance}$	249	
$LCC_{Disposal}$	9	
LCC	1 759	EURO

In this case with 200 Pa average pressure loss the main cost is the energy cost. A user has to consider lowering that cost by running the filter to a lower final pressure loss. The filter will then have a shorter life time and the cost for maintenance will increase. At the same time he has to consider changes in performances of the filter. The classification system of air filters is based on high final pressure losses (450 Pa for F-filters and 250 Pa for G-filters).
The disposal cost is in this case small and will not influence on the LCC analysis.

References

1. *Air Filters for better Indoor Air Quality*. Eurovent/Cecomaf Recommendation, Jan 1999.
2. CEN EN 779:2002, *Particulate air filters for general ventilation – Determination of the filtration performance.*
3. VDI 6022:1998, Part 1*, Hygienic standards for ventilation and air conditioning systems. Offices and assembly rooms.*
4. *Filters Application Guide*. AG 8/97, BSRIA 1997

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For more information contact
Sule BECIRSPAHIC
Eurovent/Cecomaf Technical Secretariat
62 bld de Sébastopol, 75003 PARIS
Tel 33 1 49 96 69 80 / Fax 33 1 49 96 45 10