ANNEX 27
DOMESTIC VENTIL.

developing tools for evaluating performance of ventilation systems

VENTILATION AND COOLING

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System Safety Analyses of the Performance of Mechanical Ventilation Systems - the quantitative approach

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1 Synopsis

A method for estimating the reliability of mechanical ventilation systems in dwellings has been developed. The analysis is based on component level reliability models interconnected by so called fault-tree schemes. A simplified model for maintenance is included. The analysis procedure is applied on an central exhaust ventilation system and on a central supply and exhaust ventilation system with heat recovery. For each system, three different quality standards have been defined and combined with three levels of maintenance. Work has also been done on collecting relevant input data, e.g. expected life-time values for ventilation components. The result of an analysis can be presented as a figure showing the reliability of the total system as a function of time. The result can also be presented in a compressed form giving the mean and minimum reliability values for a certain time period. Finally, a classification routine is proposed. This will transform the resulting mean and minimum values into a five graded classification scale.

2 Introduction

At the 1996 AIVC Conference, the basic principles of a method for estimating the reliability of mechanical ventilation systems was outlined (Kronvall, 1996). The concept of the analysis was based on general methods for system safety analysis, e.g. Rau, 1992 and Salem et al., 1976. However, no qualitative data were presented and the principles were shown only for a simple mechanical exhaust ventilation system. During the last year, extensive work has been done, not least in order to come up with quantitative data and an evaluation procedure for assessing the performance of different mechanical ventilation systems in terms of reliability.

The paper forms part of the Swedish contribution to the work of IEA-Annex 27 "Evaluation and Demonstration of Domestic Ventilation Systems".

3 Model for Reliability

What is reliability ?

definitive scale

in ISO norm

3.1 Reliability on Component Level

The following model assumes that the life time of each component in a system has a normal distribution, i.e. it can be given a mean life time (*m*) and a standard deviation (*s*). Inserted into the general model of reliability this means that the reliability of the component (*R*) over time (t) can be expressed as follows, (Råde & Westergren, 1995):

if $t<m$ *then;* $$R(t,m,s)=\frac{1}{\left(1+\exp^{-p(t,m,s)}\right)}$$

else $(t \geq s);$ $$R(t,m,s)=1-\frac{1}{\left(1+\exp^{-p(t,m,s)}\right)}$$

Reliability = a probability (which is time depending)

T = lifetime of a component

where; $$p(t,m,s) = \frac{|t-m|}{s} \cdot \left[1{,}5976 + 0{,}070566 \cdot \left(\frac{t-m}{s} \right)^2 \right]$$

Depending on the type of component and its operational conditions, different values of *m* and *s* may be set. Figure 1 shows an example on how the reliability as a function of time depends on these values.

For reliability studies over time, the use of the so called Weibull distribution is more or less the standard procedure. In this work however, the normal distribution is used; the reason for that being that the input parameters for this model, mean life time and standard deviation, were assumed to be easier to understand and interpret for the practitioners than the more sophisticated parameters used for the Weibull model.

In this kind of component reliability analysis, ***reliability*** means ***the probability that the component performs in such a way that the design flow rate within a certain interval is maintained.***

A simplified model for describing the influence of maintenance has also been incorporated into each component model. It assumes that after each maintenance interval the component is "as good as new". However, this is not shown in figure 1, but in figure 5.

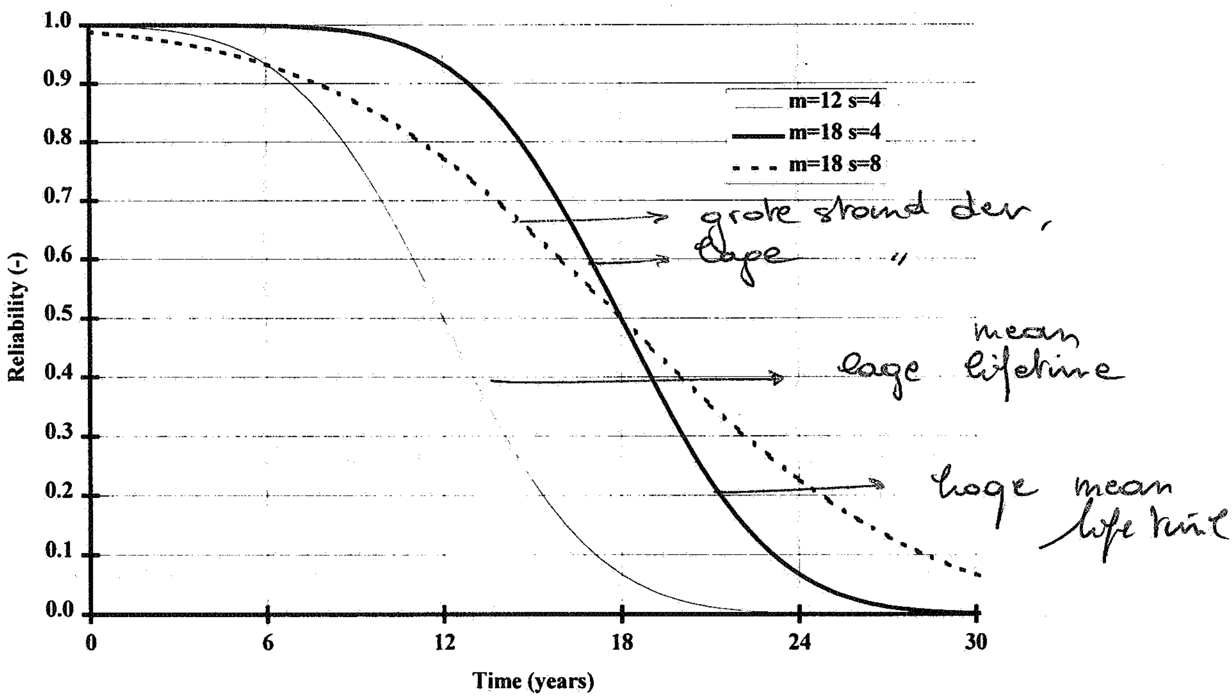

Figure 1 Reliability as a function of mean life time (m) and standard deviation (s).

‖

50 % reliability

+ moorten probab. elektriciteit fan f(t, maint.)... AAN of AF

3.2 Application on System Level

By connecting component models in a fault-tree scheme the analysis can be extended to a system level (Kronvall, 1996). This has in the present work been done on both an exhaust ventilation system and on a supply and exhaust ventilation system. The latter system including a heat exchanger is schematically shown in figure 2.

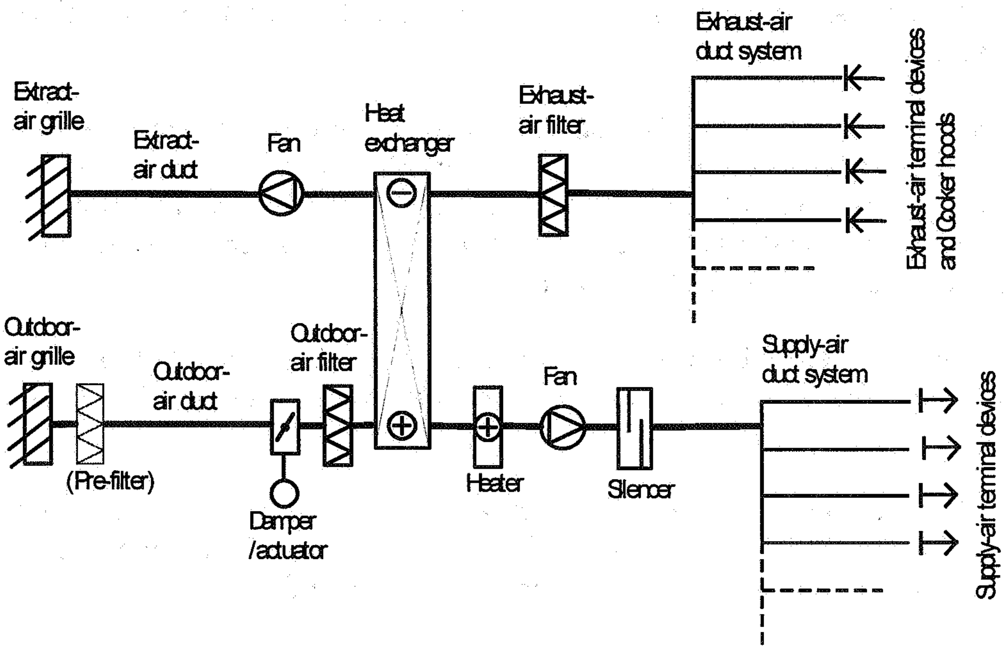

Figure 2 Central mechanical supply and exhaust ventilation system - Multi family house

The more simple exhaust ventilation system is schematically shown in figure 3.

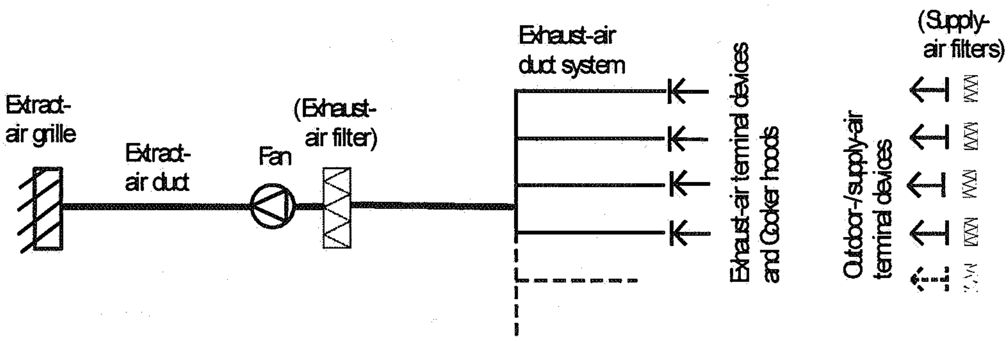

Figure 3 Central mechanical exhaust ventilation system - Multi family house

The fault-tree scheme for the exhaust system is shown in figure 4. The fault-tree for the supply ~~and exhaust~~ system, not shown, is more complex but built up in a similar way.

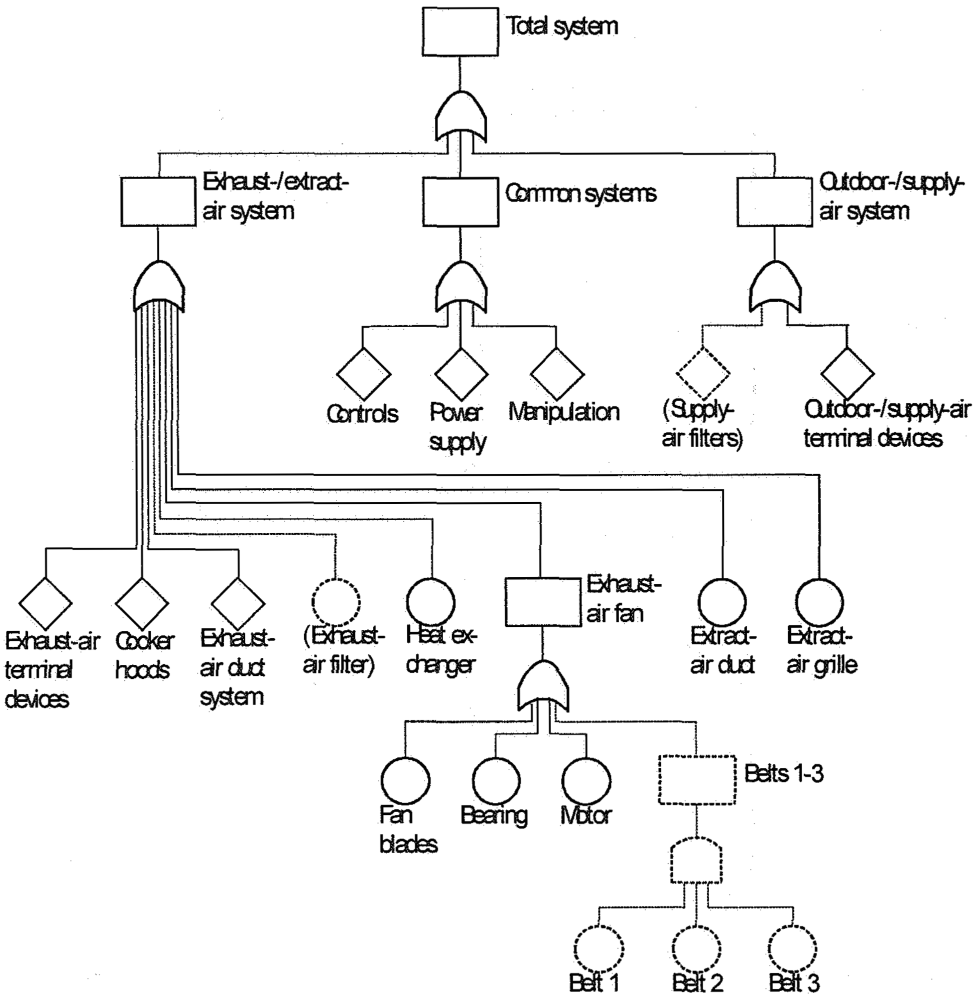

Figure 4 Fault three - Central mechanical exhaust ventilation system

MODEL in EXCEL

Alles wordt verwerkt in EXCEL sheet

Bel!

For each type of system, three different quality standards have then been defined and combined with three different levels of maintenance intensity. This means a matrix with a total of nine different combinations for each ventilation system. An example of input data used for the exhaust system in this present work is shown in table 1. Relevant data have been collected from published and orally transferred empirical experiences from maintenance people and other researchers working with reliability or related matters, e.g. Myrefelt, 1996 and Gröninger & van Paassen, 1997. Certain basic data regarding maintenance origin from a Dutch investigation, (Op't Velt, 1997).

Table 1 Central mechanical exhaust ventilation system - Multi family house

Average system	* Mean life time (years)	Standard deviation (years)	** Maintenance intensity Interval (years)		
			High	Medium	Low
<u>*Outdoor-/supply-air components*</u>					
Outdoor-/supply-air devices	3	0.6	0.25	0.5	1
Outdoor-/supply-air filter	Not installed !				
<u>*Exhaust-/extract-air components*</u>					
Exhaust-air terminal devices	2	0.6	0.25	0.5	1
Cooker hoods	2	0.6	0.25	0.5	1
Exhaust-air duct system	10	2	4	6	8
Exhaust-air filter	Not installed !				
Fan blades	6	1.5	2	3	4
Bearing	18	3	8	12	16
Belt	8	2	4	6	8
Motor	20	4	8	12	16
Extract-air duct	20	4	8	12	16
Extract-air grille	20	4	8	12	16
<u>*Controls*</u>	12	2	4	6	8
<u>*Manipulation*</u>	50	20	4	8	16
<u>*Power supply*</u>	R=	0.999			

* If no maintenance is performed

** After each maintenance interval, the component is assumed to be ”as good as new”.

4 Results of application

The result of each combination in the matrixes can be presented in a figure showing the estimated reliability for the system as a function of time. An example of such a presentation is shown for the average system combined with medium maintenance in Figure 5.

The result is further evaluated by calculating the mean value and minimum value of the reliability for a time span of thirty years. The result for each system can be summarised in a matrix. The resulting matrixes for the two systems studied in this present work is shown in table 2 and table 3.

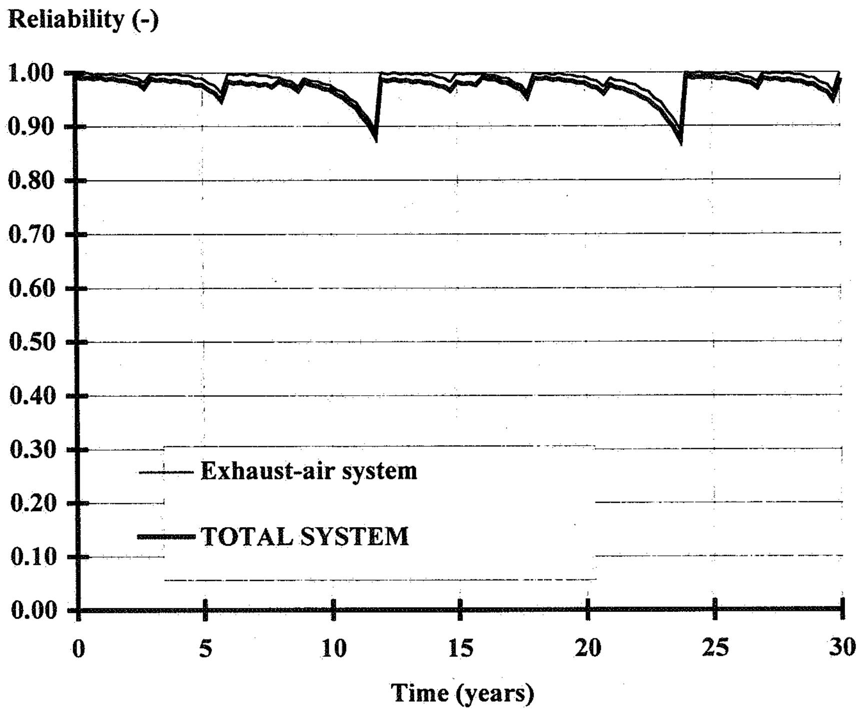

Figure 5 Exhaust ventilation - Average system - Medium maintenance

Lifetime of components vary

Table 2 Summary - System reliability. Exhaust ventilation system

Type of system	Reliability	Maintenance intensity		
		High	Medium	Low
Poor system	Mean	0.98	0.89	0.65
	Minimum	0.92	0.42	0.01
Average system	Mean	0.99	0.97	0.89
	Minimum	0.98	0.87	0.32
Best practice	Mean	0.99	0.99	0.96
	Minimum	0.99	0.97	0.76

Reliability mean & minimum

Table 3 Summary - System reliability. Supply and exhaust ventilation system

Type of system	Reliability	Maintenance intensity		
		High	Medium	Low
Poor system	Mean	0.93	0.70	0.46
	Minimum	0.61	0.13	0.00
Average system	Mean	0.98	0.92	0.73
	Minimum	0.93	0.70	0.07
Best practice	Mean	0.99	0.97	0.91
	Minimum	0.98	0.90	0.48

5 Discussion

The resulting mean and minimum values (of the reliability for a time span of thirty years) given in the matrixes may then finally be evaluated and transferred into a single classification system. A routine for such a classification is proposed in table 4. This means that each cell in the system matrix is given a reliability classification in a five graded scale, from very poor (- -) to very good (+ +). The result of such a classification is given in table 5a-b for the two systems studied in this present work.

Table 4 Proposed classification for reliability of ventilation systems

	Minimum reliability									
Mean reliability	0.90-1.00	0.80-0.89	0.70-0.79	0.60-0.69	0.50-0.59	0.40-0.49	0.30-0.39	0.20-0.29	0.10-0.19	0.00-0.09
0.90-1.00	++	++	+	+	+/-	+/-	-	-	- -	- -
0.80-0.89		+	+	+/-	+/-	-	-	- -	- -	- -
0.70-0.79			+/-	+/-	-	-	- -	- -	- -	- -
0.60-0.69				-	-	- -	- -	- -	- -	- -
0.50-0.59					- -	- -	- -	- -	- -	- -
0.40-0.49						- -	- -	- -	- -	- -
0.30-0.39							- -	- -	- -	- -
0.20-0.29								- -	- -	- -
0.10-0.19									- -	- -
0.00-0.09										- -

Table 5a-b Results of proposed classification for the studied systems

a: Central exhaust ventilation			
Type of system	Maintenance intensity		
	High	Medium	Low
Poor system	+ +	-	- -
Average system	+ +	+ +	-
Best practice	+ +	+ +	+

b: Central supply and exhaust ventilation			
Type of system	Maintenance intensity		
	High	Medium	Low
Poor system	+	- -	- -
Average system	+ +	+	- -
Best practice	+ +	+ +	+/-

data from DUTCH ventilat. industry

6 Conclusions

From the work performed hitherto, the following conclusions can be drawn:

- The general concept of system safety analyses can be used in order to assess the performance over time for mechanical ventilation systems.
  weinig data
- There is a great lack of knowledge on basic reliability data for ventilation system components, e.g. life-times; only more or less "best guesses" can be used with the present knowledge.
  veel
- The reliability of a mechanical ventilation system is determined both by the technical quality of the system and the maintenance intensity.

uit analyse blijkt

deze zeer belangrijk

invloeden

7 Acknowledgements

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8 References

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