Ergänzung zum vfdb Artikel XXXX

von

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List of Abbrevations

EU United Europe

FTA Fault Tree Analysis

Chapter 1

Appendix

Input reliability values

Lay fire extinguisher

Time begin fighting	Fire extinguisher	Beginning and spread phase	Full fire phase	Literature	Quality
1 min	Portable	$5.0 * 10^{-2}$	not possible	[Fac15]	+++
3 min	Portable	$1.0 * 10^{-1}$	not possible	[Fac15]	+++
5 min	Portable	$3.0 * 10^{-1}$	not possible	[Fac15]	+++
10 min	Portable	$8.0 * 10^{-1}$	not possible	[Fac15]	+++
>10 min	Portable	$9.5 * 10^{-1}$	not possible	[Fac15]	+++
no define	Wall hydrant	$1.9 * 10^{-4}$ to $7.4 * 10^{-3}$		[Fac15]	+++

Table 1.1: The values only refer to development and spread phase. Minutes in the first column describe the time between detection the fire and begin to fire frighting with fire extinguisher. The input values for wall hydrant are the same for beginning and full fire phase.

Non-detection failure rate

Fire detection by	Fire beginning and spread phase	Full fire phase	Literature	Quality
Human: always present	$1.0 * 10^{-1}$	$1.0 * 10^{-3}$	[BM79]	+++
Human: mostly present	$8.0 * 10^{-1}$	$2.0 * 10^{-2}$	[BM79]	+++
Human: 1/3 time present	$9.9 * 10^{-1}$	$2.0 * 10^{-3}$	[BM79]	+++
Human: rarely present	1.0	$5.0 * 10^{-1}$	[BM79]	+++
Automatically*	$2.0 - 10^{-2}$	$2.0 - 10^{-1}$	[Fac15]	+++
Indirectly with errors	not possible	$6.0 * 10^{-2}$	[Fac15]	+++

Table 1.2: The table shows the unavailability per requirement in case of fire for the fire beginning and full fire phase. The human fire detection data is based on US studies. *In case of automatic fire detection, are detection by only single smoke detector per room. If there are more smoke detectors per room, the total value per room must be calculated.

Fire alarm system reliability

Door type	$5\% - \mathcal{Q}$	$50\% - \mathcal{Q}$	$95\% - \mathcal{Q}$	Mean	σ	Literature	Quality
Central G.II	1.1^{-9}	1.5^{-7}	2.0^{-6}	4.8^{-7}	9.1^{-7}	[FE16]	+++
Central G.III	3.3^{-9}	4.5^{-7}	6.1^{-6}	1.4^{-6}	2.7^{-6}	[FE16]	+++
Sub-system G.II	2.8^{-10}	3.8^{-8}	5.1^{-7}	1.2^{-7}	2.3^{-7}	[FE16]	+++
Sub-system G.II	9.4^{-10}	1.3^{-7}	1.7^{-6}	4.1^{-7}	7.8^{-7}	[FE16]	+++
Insertion G.II	3.5^{-11}	4.8^{-9}	6.5^{-8}	1.5^{-8}	2.9^{-8}	[FE16]	+++
Insertion G.III	2.4^{-10}	3.2^{-8}	4.4^{-7}	1.0^{-7}	2.0^{-7}	[FE16]	+++
Det. line G.II	4.9^{-12}	6.3^{-10}	9.0^{-9}	2.1^{-9}	4.1^{-9}	[FE16]	+++
Det. line G.III	6.4^{-12}	8.8^{-10}	1.2^{-8}	2.8^{-9}	4.3^{-9}	[FE16]	+++
More criteria G.IV A	1.2^{-11}	1.6^{-9}	2.2^{-8}	5.2^{-9}	1.0^{-8}	[FE16]	+++
More criteria G.IV B	4.2^{-11}	5.8^{-9}	7.8^{-8}	1.8^{-8}	3.5^{-8}	[FE16]	+++
Opt. det. G.II A	2.4^{-12}	3.3^{-10}	4.5^{-9}	1.0^{-9}	2.0^{-9}	[FE16]	+++
Opt. det. G.III A	1.3^{-10}	1.8^{-8}	2.4^{-7}	5.6^{-8}	1.1^{-7}	[FE16]	+++
Flam. det. G.III A	3.1^{-9}	3.6^{-8}	2.1^{-7}	6.2^{-8}	7.8^{-8}	[FE16]	+++
Head diff. G. II A	7.2^{-11}	9.8^{-9}	1.3^{-7}	3.1^{-8}	6.0^{-8}	[FE16]	+++
Ion. smoke G. II A	4.3^{-10}	3.4^{-9}	1.6^{-8}	5.2^{-9}	5.7^{-9}	[FE16]	+++
Ion. smoke G. II B	3.1^{-9}	2.5^{-8}	1.2^{-7}	3.8^{-8}	4.1^{-8}	[FE16]	+++
Smoke suck in G. I	7.3^{-8}	6.9^{-7}	2.6^{-6}	1.0^{-6}	1.6^{-6}	[FE16]	+++
Smoke suck in G. II	8.7^{-9}	5.7^{-7}	1.4^{-5}	9.0^{-6}	6.1^{-5}	[FE16]	+++
Push button alarm	2.4^{-10}	1.4^{-7}	3.5^{-6}	7.0^{-7}	1.2^{-6}	[FE16]	+++

Table 1.3: All probability are in unit $1/h$. The data are based on results in nuclear reactors. The type of the fire detecor are split in Type A (technical direct release) and Typ B (technical indirectly release). Furthermore there are four different generations of fire alarm system. Generation I have no address to report (almost no longer in use), Generation II are intelligence report wiht trigger detector, Generation III intelligence report with more criterion detector and Generation IV same as Generation III, with a new software version. Variable in the header are $\mathcal{Q}$ calls quartiles and σ calls the standard deviation.

Stationary extinguishing system

Technical system	Fire beginning and spread phase	Full fire phase	Literature	Quality
Water fire pump	$8.5 * 10^{-4}$ to $3.5 * 10^{-2}$*		[Fac15]	+++
CO_2-gas extinguisher	$9.2 * 10^{-3}$ to $8.1 * 10^{-2}$*		[Ges01]	+++
INERTING gas extinguisher	$5.8 * 10^{-2}$*		[Ges01]	+++
Water spray system general	$2.0 * 10^{-2}$*		[Fac15]	+++
with remote and total failure	$2.2 * 10^{-4}$ to $3.9 * 10^{-3}$*		[Fac15]	+++
failure remote control	$3.2 * 10^{-4}$*		[Fac15]	+++
with alarm check valve	$3.2 - 10^{-4}$*		[Fac15]	+++

Table 1.4: Technical failure probability for fire fighting systems. The data refer to the whole function of the system, if no further information is described. For partial functions example given remote switch the data are specified separately. *Same probability for beginning spread phase and full fire phase and development and spread phase.

Occupancy sprinkler reliability

Occupancy	Reliability	Effectiveness of suppression	Probability of success	Literature	Quality
Apartment	98	98	96	[XH13]	++
Health care	96	100	96	[XH13]	++
1 or 2 family dwelling	94	100	94	[XH13]	++
Educational	92	100	92	[XH13]	++
Hotel	97	94	91	[XH13]	++
Stores and offices	92	97	90	[XH13]	++
Manufacturing	93	94	87	[XH13]	++
Public assembly	90	89	81	[XH13]	++
Storage	85	90	77	[XH13]	++

Table 1.5: The table shows the proportion of reliability, effectiveness and probability of sprinkler system performance. All values are in units % of the hole data frame. The data are based on a study in China with over four years of full survey. The statistical mass is 562,235 fires over 4 years. It must be checked whether the results can also be transferred to the United Europe (EU).

Fire door reliability

Door type	$5\% - \mathcal{Q}$	$50\% - \mathcal{Q}$	$95\% - \mathcal{Q}$	Mean	σ	Literature	Quality
Self closing	2.5^{-7}	1.0^{-6}	2.8^{-6}	1.2^{-6}	7.9^{-7}	[FE16]	+++
Self lock	1.1^{-7}	8.3^{-7}	3.2^{-6}	1.2^{-6}	1.5^{-6}	[FE16]	+++
Closing sequence	9.4^{-7}	2.0^{-6}	4.1^{-6}	2.2^{-6}	6.7^{-7}	[FE16]	+++
Barrier function	2.1^{-7}	4.8^{-8}	4.3^{-7}	1.6^{-7}	6.4^{-7}	[FE16]	+++
Fixed function	3.3^{-7}	8.3^{-7}	5.0^{-6}	1.4^{-6}	1.1^{-6}	[FE16]	+++

Table 1.6: All probability are in unit $1/h$. The data are based on results in nuclear reactors. The doors were checked every three months for several decades and errors recorded. This corresponds to a very high safety standard, since the errors were also corrected during the check. Non included are the deliberate stopping by wedges or other objects. There are only technical failure rates. Variable in the header are $\mathcal{Q}$ calls quartiles and σ calls the standard deviation.

Bulkhead failure rate

Bulkhead type	$5\% - \mathcal{Q}$	$50\% - \mathcal{Q}$	$95\% - \mathcal{Q}$	Mean	σ	Literature	Quality
Melting lot trigger system							
Variant 0	4.4^{-9}	9.4^{-8}	4.9^{-7}	2.0^{-7}	5.6^{-7}	[Fac15]	+++
all Bulkhead	1.5^{-9}	2.1^{-7}	2.0^{-6}	4.8^{-7}	5.9^{-7}	[Fac15]	+++
With remote function							
Variant 1	2.9^{-9}	4.8^{-7}	6.1^{-6}	1.7^{-6}	4.8^{-6}	[Fac15]	+++
Variant 2	3.7^{-7}	2.0^{-6}	6.0^{-6}	2.4^{-6}	1.8^{-6}	[Fac15]	+++
Variant 3	3.8^{-8}	5.6^{-7}	2.7^{-6}	8.2^{-7}	5.8^{-7}	[Fac15]	+++
Variant 4	9.1^{-9}	7.5^{-7}	8.0^{-6}	4.8^{-6}	3.0^{-5}	[Fac15]	+++
Closing and barrier function							
Variant 0	7.4^{-10}	2.7^{-7}	5.3^{-6}	1.7^{-6}	7.1^{-6}	[Fac15]	+++
Variant 1	2.5^{-8}	1.9^{-7}	5.9^{-7}	2.5^{-7}	2.8^{-7}	[Fac15]	+++
Variant 2	8.8^{-8}	4.8^{-7}	1.5^{-6}	5.9^{-7}	4.6^{-7}	[Fac15]	+++
Variant 3	9.1^{-8}	2.6^{-7}	6.7^{-7}	3.0^{-7}	1.6^{-7}	[Fac15]	+++
Variant 4	1.4^{-8}	8.7^{-7}	8.5^{-6}	4.3^{-6}	2.4^{-5}	[Fac15]	+++
all Bulkhead	9.1^{-9}	2.1^{-7}	6.1^{-7}	2.5^{-7}	8.9^{-8}	[Fac15]	+++
Smoke and heat discharge bulkhead							
Bypass, smoke	3.9^{-8}	1.2^{-6}	6.6^{-6}	1.9^{-6}	1.4^{-6}	[Fac15]	+++
Light dome	4.0^{-7}	2.4^{-6}	6.4^{-6}	2.8^{-6}	2.4^{-6}	[Fac15]	+++
Flap in-wall	9.5^{-8}	2.0^{-6}	1.5^{-5}	5.2^{-6}	1.6^{-5}	[Fac15]	+++

Table 1.7: Variant 0: only melting lot, no remote function, variant 1: electrically-pneumatic trigger, variant 2: electrically-magnetic trigger with opening help, variant 3: electrically-magnetic trigger without opening help, variant 4: detection-magnet. All probability are in unit $1/h$. The data are based on results in nuclear reactors. The bulkhead were checked one time per year for several decades and errors recorded. This corresponds to a very high safety standard, since the errors were also corrected during the check. Variable in the header are $\mathcal{Q}$ calls quartiles and σ calls the standard deviation.

Fire fighting technical equipment

Equipment	$5\% - \mathcal{Q}$	$50\% - \mathcal{Q}$	$95\% - \mathcal{Q}$	Mean	σ	Literature	Quality
Extinguish water supply							
Pump begin	5.7^{-8}	1.7^{-6}	1.0^{-5}	2.8^{-6}	2.4^{-6}	[Ges01]	+++
Pump go on	4.2^{-8}	2.3^{-6}	1.6^{-5}	4.3^{-6}	4.4^{-6}	[Ges01]	+++
Hydrant outside	6.7^{-9}	4.0^{-7}	3.3^{-6}	8.4^{-7}	9.4^{-7}	[Ges01]	+++
Hydrant wall	8.3^{-10}	4.5^{-8}	3.9^{-7}	9.9^{-8}	1.2^{-7}	[Ges01]	+++
Foam mix syst.	2.1^{-7}	2.0^{-6}	8.4^{-6}	2.8^{-6}	2.4^{-6}	[Ges01]	+++
Deluge water system							
Remote exting.	6.4^{-8}	2.6^{-6}	1.7^{-5}	5.0^{-6}	7.5^{-6}	[Ges01]	+++
Gas extinguishing system							
CO^2	2.2^{-9}	2.5^{-6}	2.3^{-4}	1.6^{-3}	2.8^{-2}	[Ges01]	+++
INERGEN exting.	3.3^{-8}	4.5^{-6}	6.1^{-5}	1.4^{-5}	2.7^{-5}	[Ges01]	+++

Table 1.8: All probability are in unit $1/h$. The data are based on results in nuclear reactors. It is only with the probability of failure of the technical system. Human mistakes are not included. Components are also described as part of an overall system. Variable in the header are $\mathcal{Q}$ calls quartiles and σ calls the standard deviation.

Fire brigade performance

Fire fighting by	Additional Information	Value	Literature	Quality
Public fire brigade	t.t.p. <15 min	0.2	[Beu15]	+
Public fire brigade	t.t.p. >20 min	0.5	[Beu15]	+
Factory fire brigade*	t.t.p. >10 min (24 fire fighter)	0.02	[Beu15]	+
Factory fire brigade*	t.t.p. >10 min (12 fire fighter)	0.05	[Beu15]	+

Table 1.9: The values of the probability of failure rate to fire fighting per alarm to performance in the describe time. Abbreviation t.t.p. calls time to performance the are including the alarm time + support time. Between the t.t.p. it is possible to interpolate linearly between the two times. *In case of factory fire brigade it is assumed that are a automatically fire detector alarm.

Fire causes Germany

Fire influence	Causes 2018	Causes 2002 - 2018	Literature	Quality
Electricity	31 %	32 %	[Ins18]	++
Other and unknown	22 %	21 %	[Ins18]	++
Human misconduct	20 %	17 %	[Ins18]	++
Fire raising	9 %	9 %	[Ins18]	++
Overhead	8 %	9 %	[Ins18]	++
Flammable work	3 %	3 %	[Ins18]	++
Explosion	2 %	2 %	[Ins18]	++
Open fire	2 %	3 %	[Ins18]	++
Spontaneous self fire	2 %	2 %	[Ins18]	++
Lightning strike	0.5 %	0.3 %	[Ins18]	++

Table 1.10: The information on the distribution of causes of fire relates exclusively to Germany and is always rounded to the full percent. The basis for the period from 2002 to 2018 is a total of 1,600 fires, which were recorded by a professional fire cause agent from insurance companies. The statistics only included fires that were reported to the insurance company.

Fire per unit of use

$O =$ Occupancy	$p_{approx}(O) =$ Housing unit per year (1/a)	$a =$ Basic value per $1/(m^2 * a)^{-1}$	$b =$ Exponent for split units	Literature	Quality
Residential	3.0^{-3}	4.8^{-5}	0.9	[Beu15]	++
Office	$6,2^{-3}$	5.8^{-5}	0.9	[Beu15]	++
Hospital, Nursing	3.0^{-1}	7.0^{-4}	0.75	[Beu15]	++
Hotel	3.7^{-2}	8.0^{-5}	1.0	[Beu15]	++
School, University	4.0^{-2}	2.0^{-4}	0.75	[Beu15]	++
Shopping mall	8.4^{-3}	6.6^{-5}	1.0	[Beu15]	++
Theater, Cinema	2.0^{-2}	9.7^{-5}	0.75	[Beu15]	++
Discotheque	1.2^{-1}	9.7^{-5}	1.0	[Beu15]	++

Table 1.11: The probability for arise a fire in the occupancy $p_{approx}(O)$ see the second column per unit of use. It is possible to calculate the Fault Tree Analysis (FTA) with this values, but its conservative assumption. Alternative calculate exact $p_{exact}(O) = a * A^b$ with $A = m^2 area$. Also $p_{approx}(O) \approx a * A^b$.

Probability of spread and death

Occupancy per	p_{st} (year)	p_{de} (fire)	p_{sp} (fire)	$r_f * 10^{-4}$ (year)	$r_{sp} * 10^{-4}$ (year)	Literature	Quality
Resid.-Other	0.067	0.123	0.06	82	40	[HNGT02]	++
Resid.-Institut.	0.021	0.090	0.03	19	6	[HNGT02]	++
Entertainment	0.0038	-	-	-	-	[HNGT02]	++
Industr. & Storage	0.0035	0.078	0.16	3	6	[HNGT02]	++
Assembly.	0.0077	0.042	0.10	3	8	[HNGT02]	++
Shop & Commercial	0.0030	0.077	0.12	2	4	[HNGT02]	++
Office	0.0017	0.063	0.08	1	2	[HNGT02]	++

Table 1.12: The table shows a summary of the probability (p) the fire occurring and the consequences of fire in terms of casualty rate per fire and spread rate beyond the room of origin per fire for each of the purpose groups. Entertainment is excluded from analysis because small amount of data. Index: st = start, de = death. Data from London fire department.

Number of spread and fire

Source of ignition	Fire	Resc.	Inju.	Death	Casu.	% spread room	Literature	Quality
Naked flammes	1,687	449	117	12	0.076	13.3	[HNGT02]	++
Cooking appl.	435	7	27	0	0.062	8.3	[HNGT02]	++
Domestic appl. and equipment	340	6	15	0	0.044	5.0	[HNGT02]	++
Electrical sup.	318	8	15	0	0.047	9.1	[HNGT02]	++
Industrial equi.	316	1	44	0	0.139	7.0	[HNGT02]	++
Water heating equipment	211	0	8	0	0.038	5.2	[HNGT02]	++
Unspecified source	203	26	95	3	0.483	16.3	[HNGT02]	++
Lighting and office equi.	195	3	9	0	0.046	4.6	[HNGT02]	++
Not specified	90	4	15	1	0.178	4.4	[HNGT02]	++
Vehicular source	24	3	4	0	0.167	25.0	[HNGT02]	++

Table 1.13: Table shows the number of fires, rescues, injuries, death and percentage of fire spreading beyond the room of origin, for each of the general source of ignition categories for fire occurring in commercial premises. Data of London fire department.

Incident of death and number

Number of death per incident	Number of incident	Total number of deaths	Literature	Quality
1	244	244	[HNG03]	++
2	12	24	[HNG03]	++
3	2	6	[HNG03]	++
4	-	-	[HNG03]	++
5	1	5	[HNG03]	++

Table 1.14: Table shows the number of deaths per incident and number of incidents. there were no 4 at the same time in a fire. Data form London fire brigade of the year 2002.

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