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Brief introduction into complex properties of HVAC-R products within the CAE-FM sector

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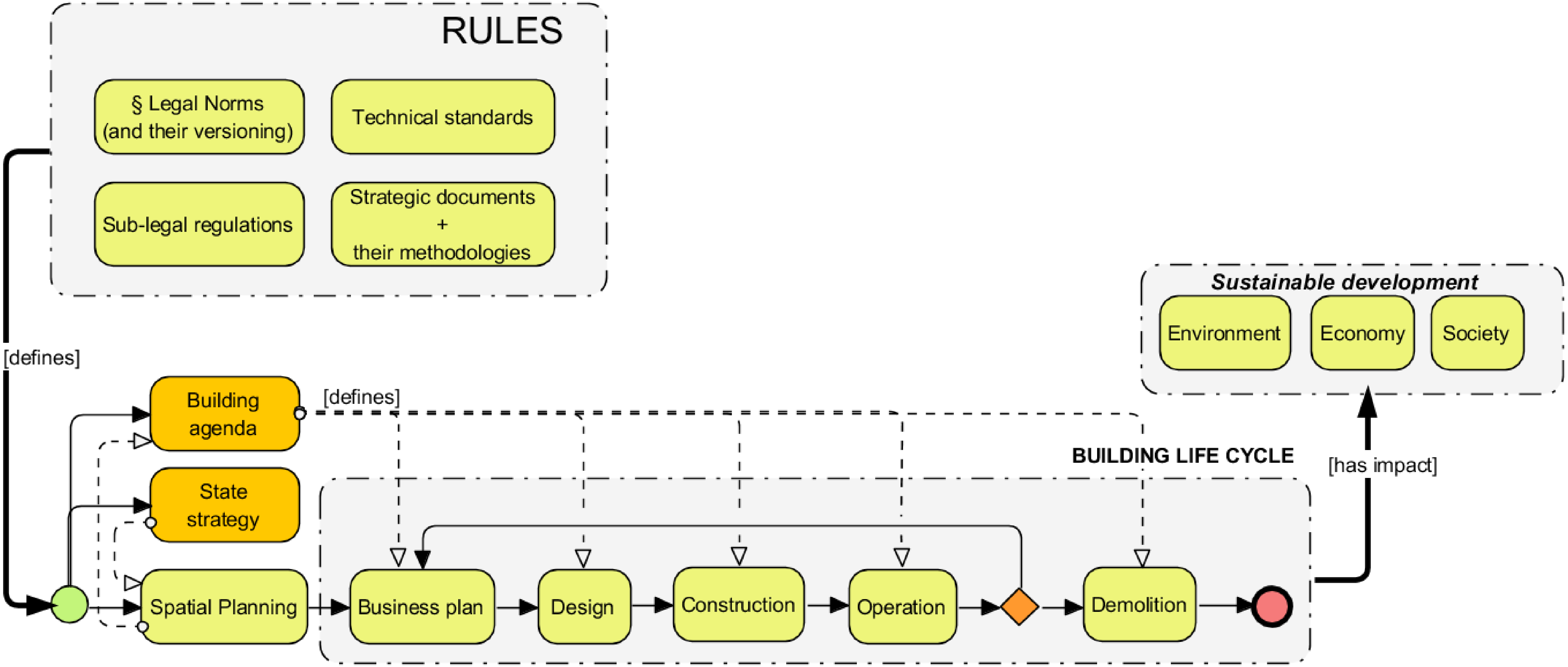
- **LIFE CYCLE OF A BUILDING AND WHERE ARE WE ?**



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Workflow is simple

Designer finds out how much cooling and heating energy and ventilated air building needs

→

Designer define building systems (topology, capacities…)

↓

Designer looks for products

↓

And looks for product parameters

↓

Aligns products and parameters to particular system design

←

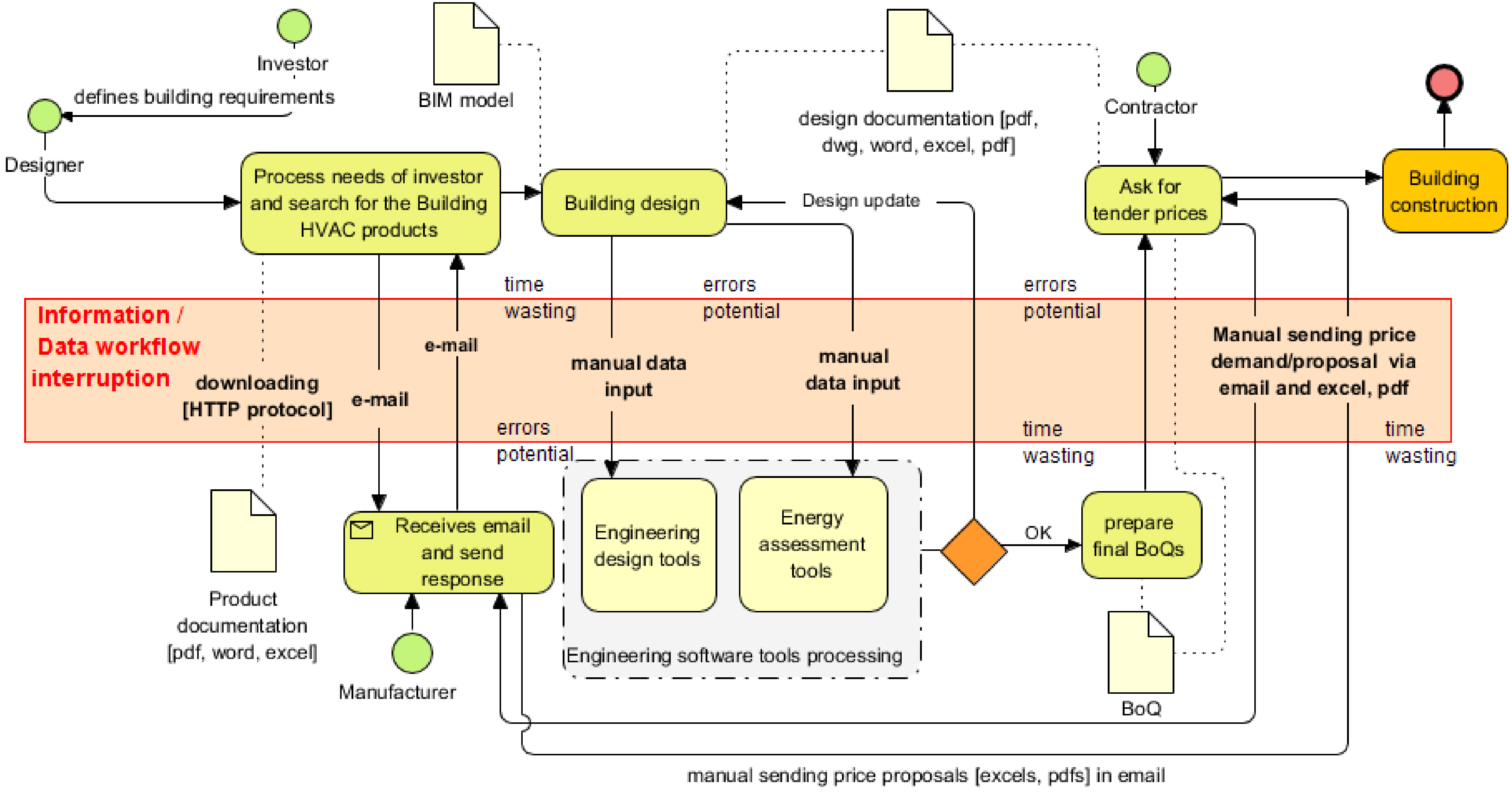
Maybe he estimates energy consumptions

Workflow is also Hard ...

WHY DO WE CARE ?

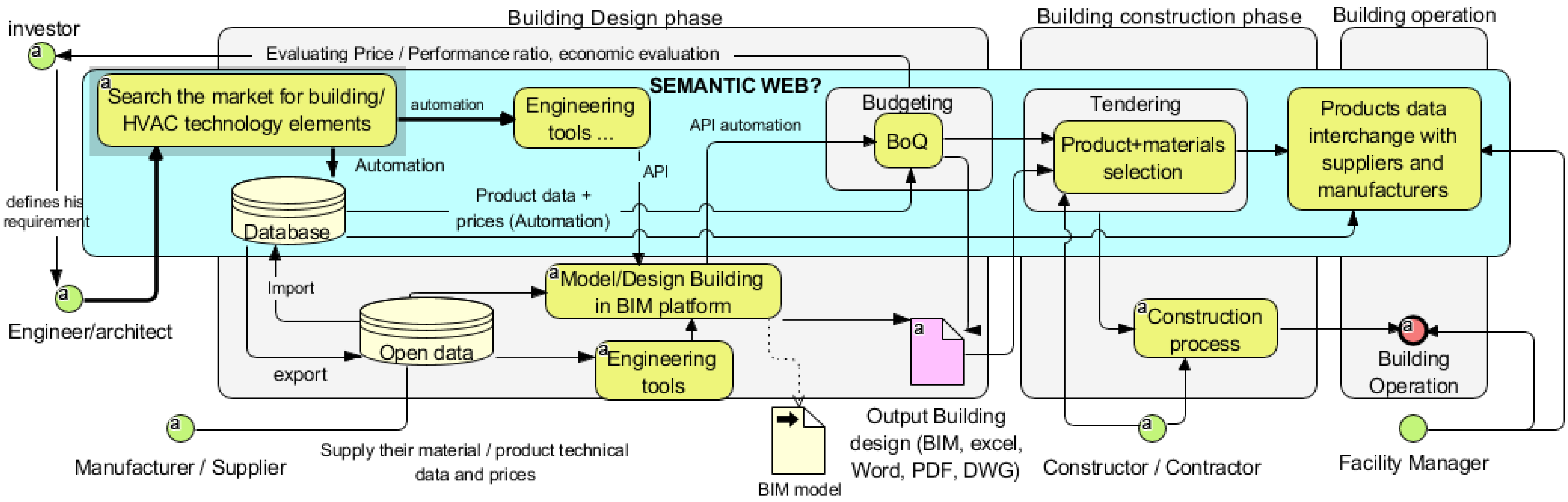
BECAUSE WE NEED TO DESCRIBE THINGS BETTER TO COMPUTERS

(WE ARE NOT DOING THIS TODAY)



THIS COULD LOOK BETTER, YES ?

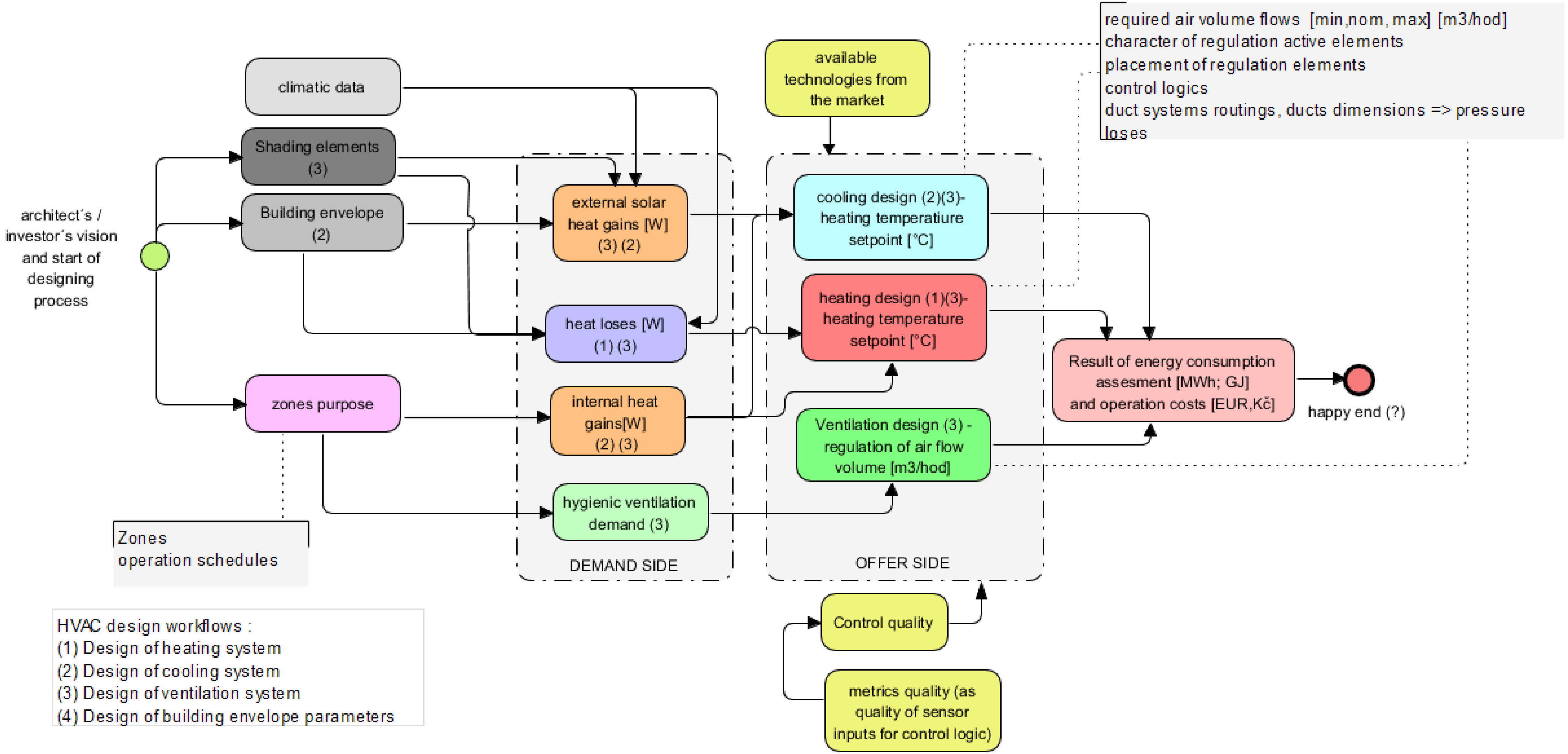
BUT WE NEED TO KNOW HOW TO EXPLAIN THINGS (PROPERTIES) TO COMPUTERS..



- **There are properties, which are required to define for BoQ´s and tendering**
- **There are properties for Design (of the maximum-worst characteristics)**
- **There are properties for LCC / energy consumption / economic assessment**

- **There are differences between them**

HVAC Designer´s worklow from the life-cycle assessment&design approach



HVAC product properties for DESIGN

Why we do need to know particular product properties ?

Purpose of HVAC ?
To bring or remove thermal energy into/from building.
(we call it heating and cooling energy acc. Its purpose)
To bring fresh air into building (hygienic ventilation)

HOW ?
To move heat-exchange medium by ducts and pipes

Mediums:

FLUIDS !
- air
- water
- mixture of water and ..
- refrigerants

Purposes:
- To ventilate
- To heat
- To cool

air	water	Water mixtures	refrigerants

We need to change of their temperature, and move it from place A to B , and back, from B to A ..

PROPERTY MODELLING

Example: pressure

Whose property is it ?

- baloon´s property ?
- Boy´s property ?
- Property of Boy´s wish to blow a baloon ?
- Baloon´s and boys property ?

Fig:1
World A: only atmospheric pressure exists

Fig:2
World B: there exist pressure higher than atm. Why? How ?

Fig:3
Many time snapshots of the World (or many worlds)
Conditional change of property of something…
If (boy knows how to blow baloon, AND he wants to blow baloon):
then: pressure inside baloon wil rise from moment to next moment
else: probably nothing happens (no pressure in ballon will change)

Lets differenciate some properties groups
WHY ?
Because of building Operation parameters ...

We need to be able to define

1/ „static properties and individuals“ which are still existing no matter world

- rigid properties of endurants in the terminology of Unified-Foundational-Ontology

2/ some kind of dynamic properties and individuals which may exist in certain world and time

- non-rigid properties of endurants in the terminology of Unified-Foundational-Ontology

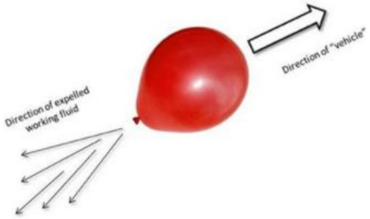
Remember the baloon ?

baloon → snapshot_In_Time; baloon → static parameters

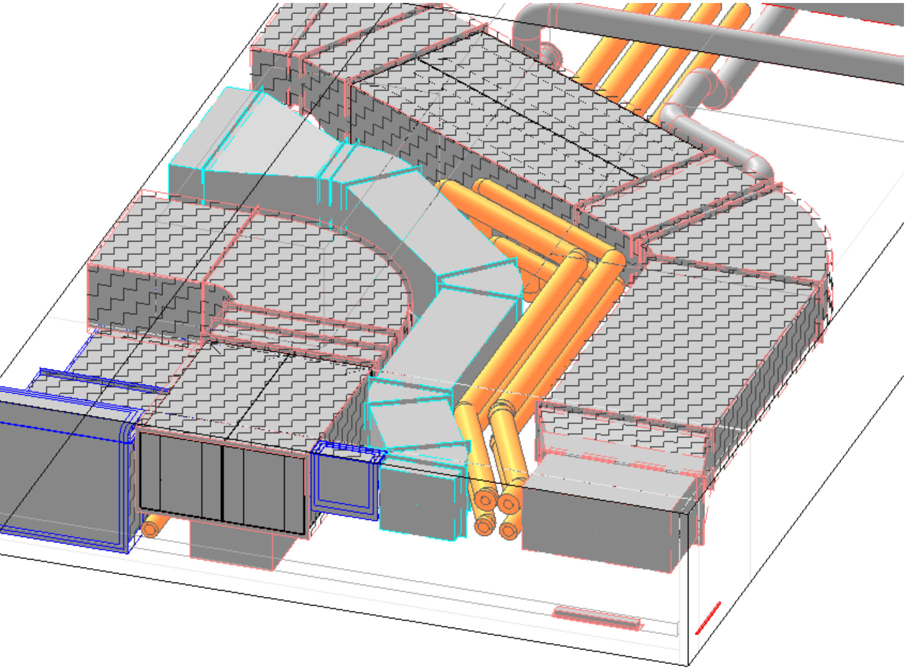
snapshot_In_Time			
snapshotName	nothing happened	blown by boy	released by the boy
TIMEDATE	26.01.2021-22:29:55	26.01.2021-22:30:01	26.01.2021-22:30:16
has_trigger		boy	boy
mediumType		air	air
medium_flowDirection		inside	outside
medium_temperature	25	30	29
medium_massFlow		0.2	0.2
medium_flowRate		0.12	16
medium_Rhumidity	55	55	55
medium_pressure	atm	65	15
medium_flowspeed	0	2	20

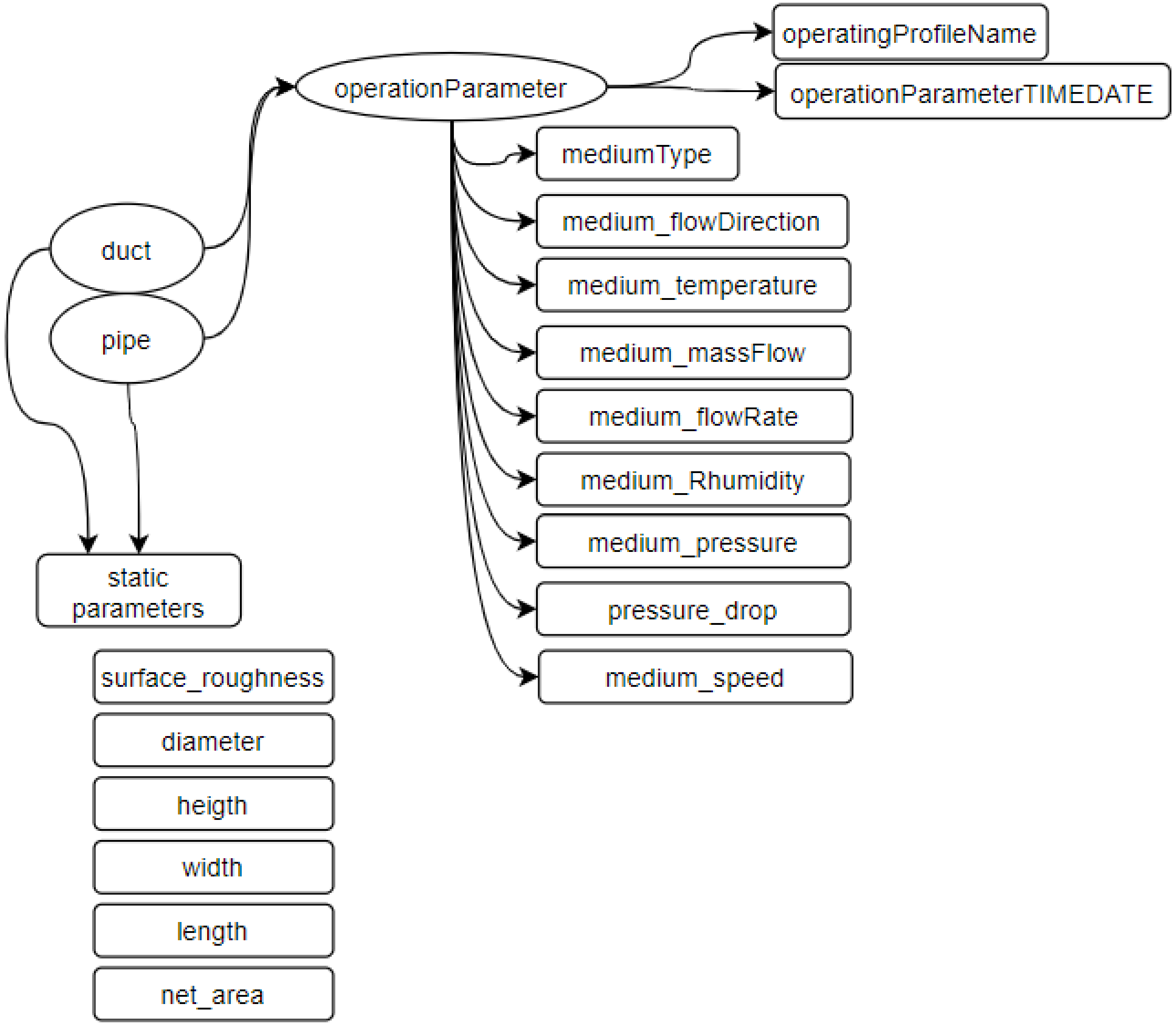
static parameters

- surface_roughness
- diameter
- heigth
- width
- length
- net_area



Ducts/pipes
variable (non-rigid) properties





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We need to be able to model:

Complex properties and properties connections in the meaning of

tabular data, and analytical descriptions of curves and 3Dshapes

Processes, triggers and moments

Well , we need to be prepared for ~~thousdands instances of properties~~..

MIRIADS instances of properties !!!

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PRODUCTS

Basic product categories :

Heat / cool energy sources

... and their characteristics

Action elements and Control elements

... and their characteristics

End Appliances

Last but not least - operation (control) logics
Building automation systems - BAS

Is there only one speed of fluid all the time ? NO .

Is there only one set of temperatures all the time ? NO .

Is it exact and wise to estimate energy consuptions with trivial properties

such COP / EER <u>as one number</u>? NO .

such SCOP / ESEER <u>as one number</u> ? Well, not really :)

Constant flow systems and operation

- same volumeflows during min/max

Constant pressure operation

- same water-pressure all the time

Variable flow systems and operation

-different volumeflows during min/max

Variable pressure operation

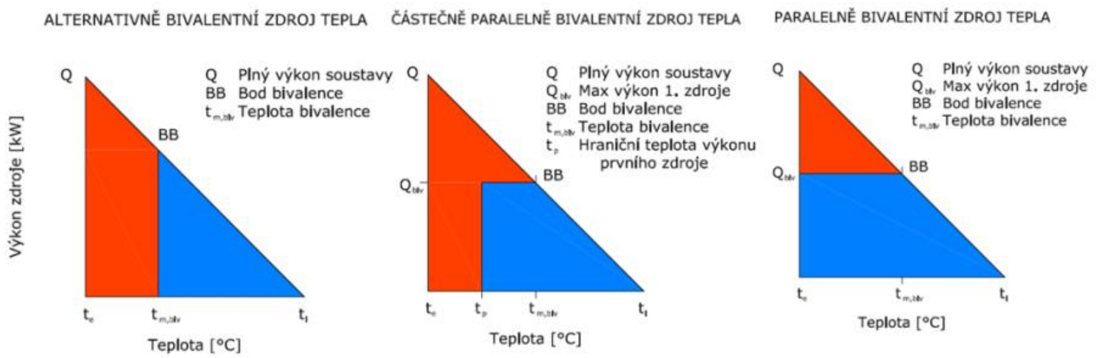
-water-pressure changes during min/max

Impact e.g. On procedures on EN 15459-1
Economic evaluation procedure for energy systems in buildings - Part 1: Calculation procedures, Module M1-14

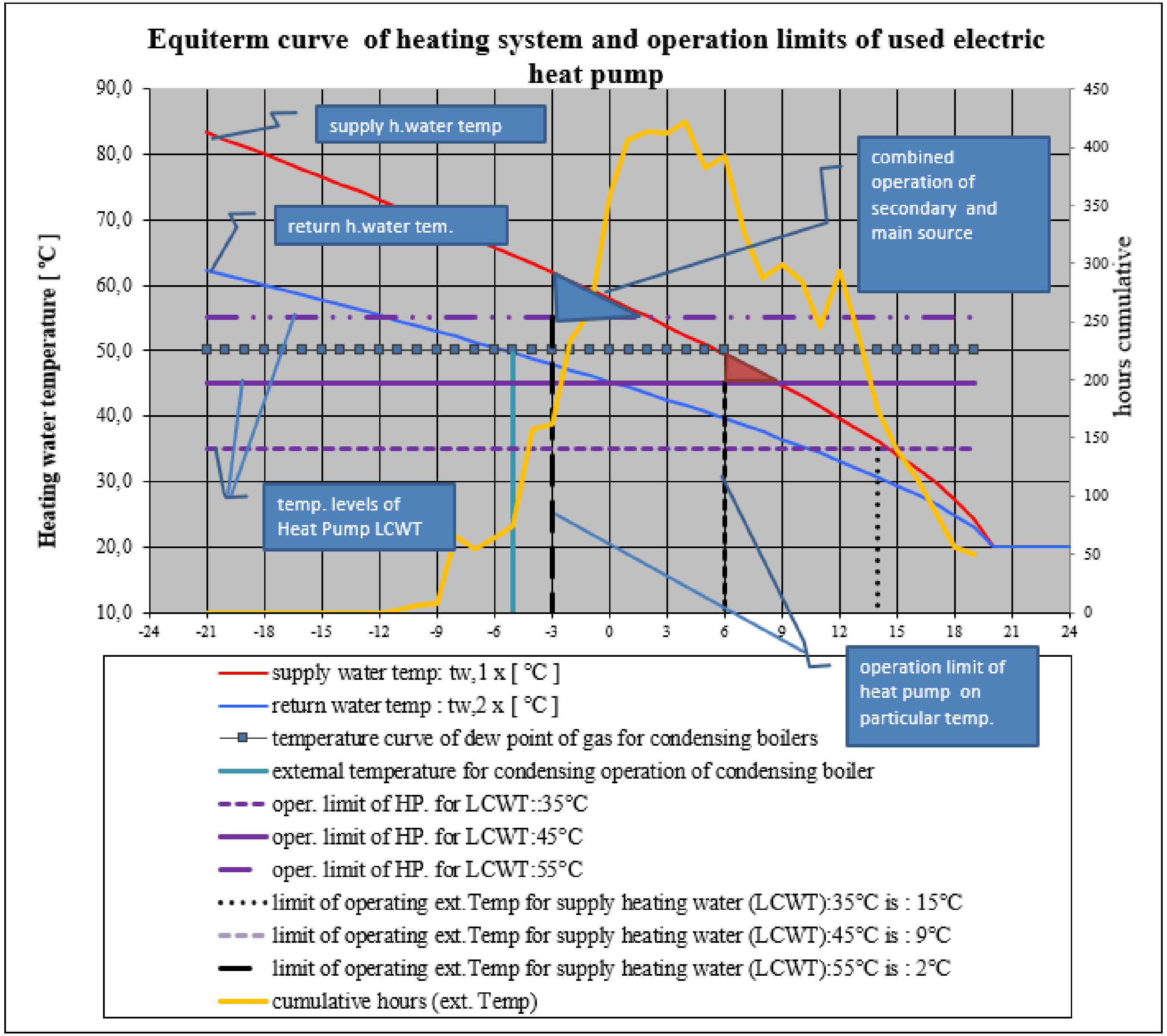
Better look on operation logics in BAS

-> many parameters changes over year-time, day-time ...

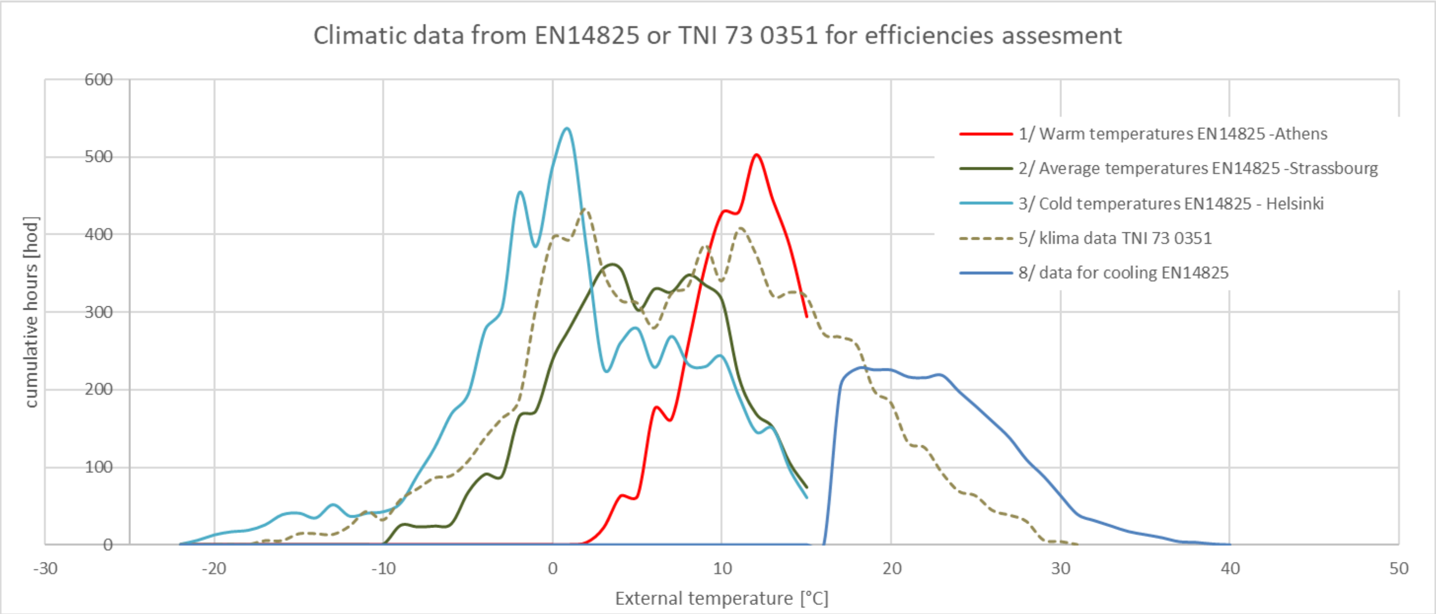
CONTROL LOGIC

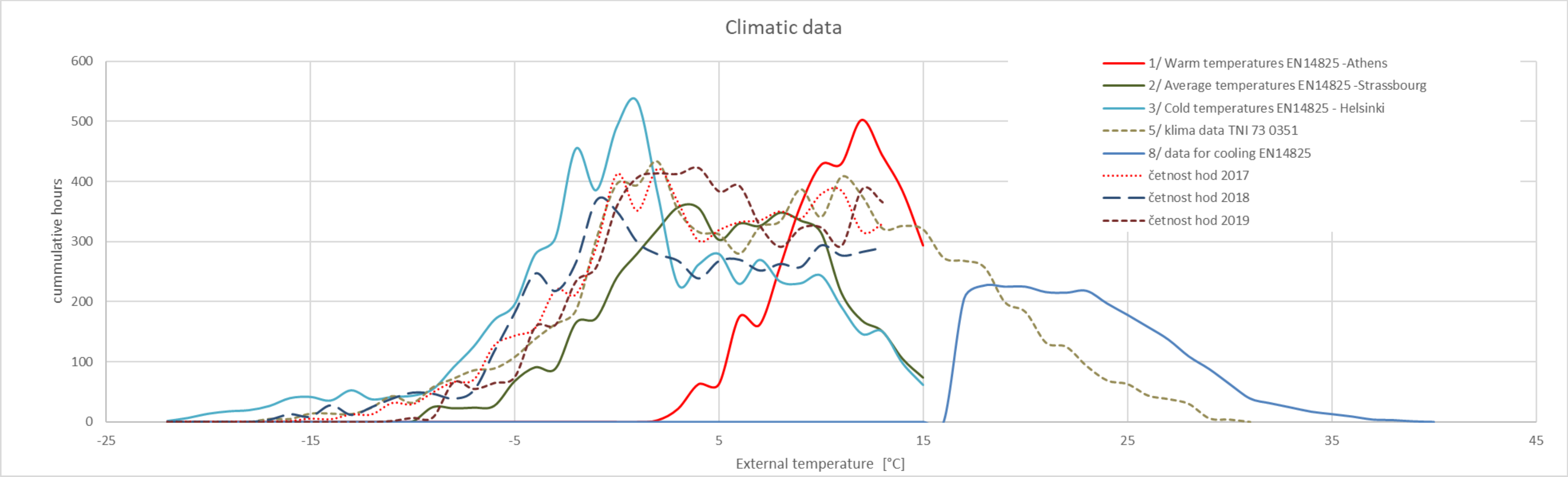


Primary heat source –blue
Secondary heat source - red



CLIMATIC DATA – INPUT PARAMETER





MAIN IDEAS OF THIS PRESENTATION

TABULAR DATA, CURVES AND 3D SHAPES as PROPERTIES in daily practice...

Properties description needs mathematical background for their description

- **if some ontologies for mathematic formulas exists, it needs to be implemented**

It is essential to sort out presenting and processing of the :

: **tabular data of product props.. (numerical representation of properties)**

: **analytical representations (if exists) of properties**

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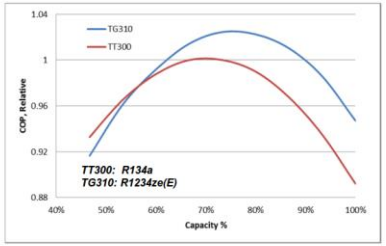
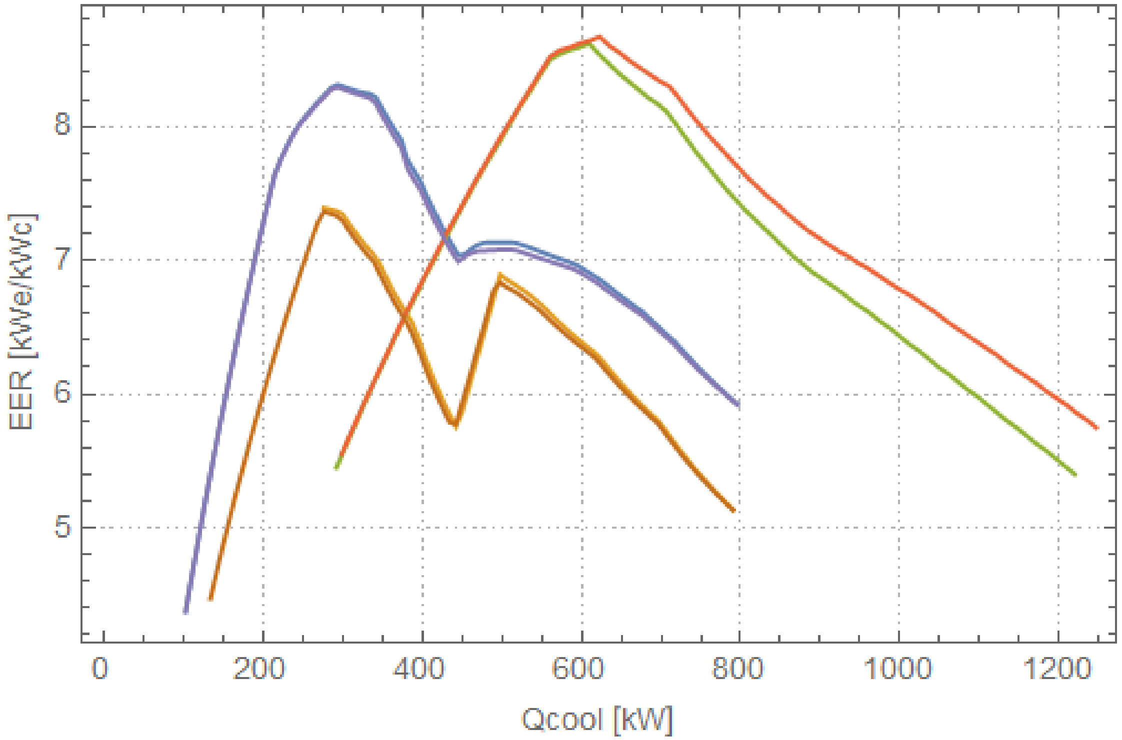
EXAMPLE 1 COMPRESSORS

Example:
You have large building with heat load of 6400 kW .
You have available to select from chillers with efficiencies similar acc patterns visible on graph.

Which and how many chillers would you select and which control logics would you define for minimizing energy consumption?





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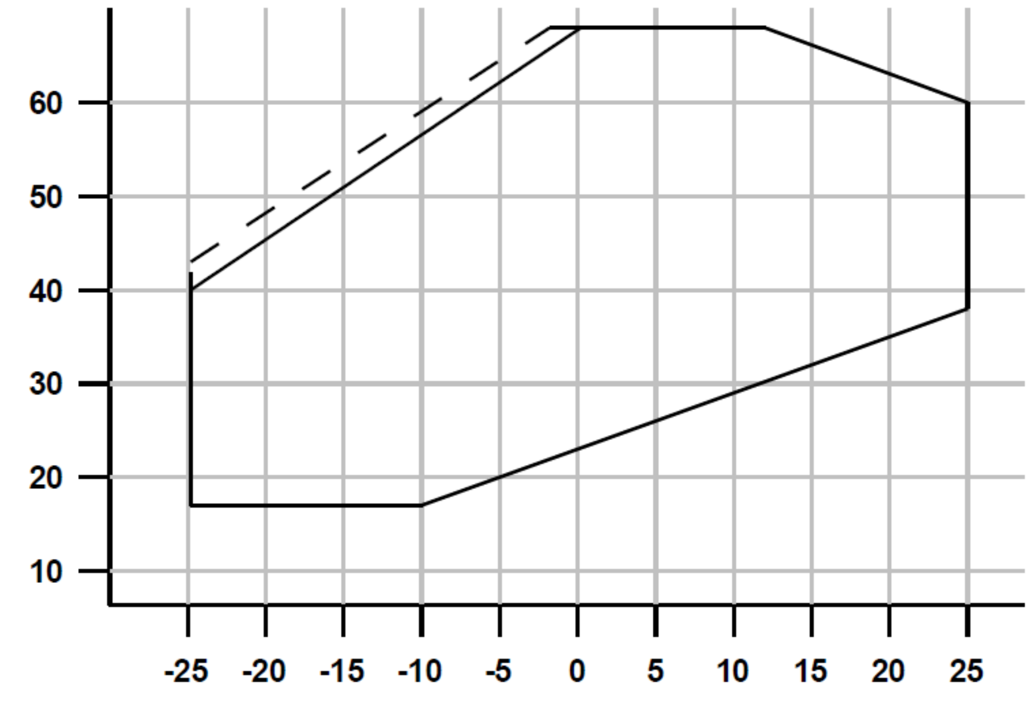
EXAMPLE 1 COMPRESSORS

- **Working area**
- **(example of scroll compressor w.a.)**

ZH05K1P-TFM



Gas overheating 5°K **Evaporating temperature [°C]** **Subcooling 4 °K**

Heating capacity [kW]

kond °C	-25	-20	-15	-10	-5	0	5	7	10	12,5	15	20	25
17	3,23	3,82	4,50	5,31									
20	3,18	3,76	4,44	5,23	6,15								
30	3,01	3,59	4,25	4,99	5,85	6,84	7,97	8,47	9,27				
40	2,86	3,43	4,06	4,76	5,56	6,47	7,50	7,96	8,69	9,34	10,05	11,60	13,30
50			3,89	4,55	5,28	6,11	7,05	7,46	8,12	8,71	9,33	10,70	12,30
55				4,44	5,15	5,94	6,83	7,21	7,84	8,39	8,99	10,30	11,80
60					5,02	5,77	6,61	6,98	7,56	8,09	8,65	9,88	11,30
65						5,61	6,40	6,75	7,30	7,79	8,32		
68						5,52	6,29	6,62	7,15				

Input power [kW]

kond °C	-25	-20	-15	-10	-5	0	5	7	10	12,5	15	20	25
17	0,89	0,90	0,90	0,90									
20	0,94	0,96	0,96	0,96	0,95								
30	1,11	1,14	1,16	1,17	1,16	1,15	1,14	1,14	1,13				
40	1,29	1,36	1,40	1,43	1,43	1,43	1,42	1,41	1,41	1,40	1,39	1,39	1,39
50			1,69	1,74	1,77	1,79	1,79	1,78	1,78	1,77	1,76	1,75	1,74
55				1,92	1,97	1,99	2,01	2,01	2,00	2,00	1,99	1,98	1,97
60					2,18	2,23	2,25	2,25	2,26	2,26	2,25	2,24	2,23
65						2,48	2,52	2,53	2,54	2,54	2,54		
68						2,64	2,69	2,70	2,72				

Mass flow [g/s]

	-25	-20	-15	-10	-5	0	5	7	10	12,5	15	20	25
17	12,10	14,90	18,20	22,00									
20	11,90	14,80	18,10	21,90	26,30								
30	11,20	14,10	17,50	21,40	25,90	31,00	36,90	39,50	43,60				
40	10,30	13,40	16,80	20,80	25,30	30,40	36,30	38,90	43,00	46,70	50,60	59,20	68,90
50			15,90	19,90	24,40	29,60	35,50	38,10	42,20	45,90	49,90	58,60	68,40
55				19,30	23,90	29,00	35,00	37,60	41,70	45,50	49,40	58,20	68,10
60					23,30	28,50	34,40	37,10	41,30	45,00	49,00	57,90	68,00
65						28,00	34,00	36,70	40,90	44,80	48,90		
68						27,80	34,00	36,70	41,00				

Compressor Selectors: e.g.
Copeland-Select, Bitzer, Danfoss

Heat-pumps tabular parameters

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Cooling capacity		evaporator				condenser				Input power	efficiency
		EEWT	LEWT	flow	Pressure drop	ECWT	LCWT	flow	Pressure drop	kW	EER
%	kW	°C	°C	l/s	kPa	°C	°C	l/s	kPa		
100	931,8	12	6	37,1	73,8	28	34	42,4	21,5	154,8	6,03
90	838,6	12	6	33,3	57,3	28	33,4	42,4	21,6	132,6	6,32
80	745,5	12	6	29,6	46,3	28	32,8	42,4	21,7	115,1	6,47
70	652,3	12	6	25,9	36,3	28	32,2	42,4	21,7	98,4	6,62
60	559,1	12	6	22,2	27,3	28	31,6	42,4	21,7	83,6	6,69
50	465,9	12	6	18,5	19,3	28	31	42,4	21,7	72,1	6,46
40	372,7	11,2	6	17	17,5	28	30,4	42,4	21,8	61,1	6,09
30	279,5	9,9	6	17	17,5	28	29,9	42,4	21,8	48,7	5,73
20	186,4	8,6	6	17	17,5	28	29.3	42.4	21,8	38,8	4,81
20	200	8,6	6	18,3	19	18	19,3	42,4	21,8	20	10

Source: Ing.Matejicek, Ideal operation of cooling Systems, www.ingmatejicek.cz

EN 14825:2018 (E)

Table K.2 – Calculation Bin for SCOPon

Bin	Outdoor temperature (dry bulb)	Hours	Heating load	Heating load covered by heat pump	$COP_{bin}(T_j)$	Fossil boiler heating	Annual heating demand	Annual energy consumption of heat pump + fossil boiler
j	T_j	h_j	$P_h(T_j)$			$P_{sup}(T_j)$	$h_j \times P_h(T_j)$	Formula *
-	°C	-	kW	kW	-	kW	kWh	kWh
21	-10	1	16,00	0,00	-	16,00	16	7
22	-9	25	15,38	0,00	-	15,38	385	162
23	-8	23	14,77	0,00	-	14,77	340	143
24	-7	24	14,15	0,00	-	14,15	340	143
25	-6	27	13,54	0,00	-	13,54	366	154
26	-5	68	12,92	0,00	-	12,92	879	370
27	-4	91	12,31	0,00	-	12,31	1 120	471
28	-3	89	11,69	0,00	-	11,69	1 041	438
29	-2	165	11,08	0,00	-	11,08	1 828	769
30	-1	173	10,46	0,00	-	10,46	1 810	762
31	0	240	9,85	2,50	3,00	7,35	2 363	942
32	1	280	9,23	2,75	3,30	6,48	2 585	997
33	2	320	8,62	3,00	3,60	5,62	2 757	1 023
34	3	357	8,00	3,51	3,68	4,49	2 856	1 015
35	4	356	7,38	4,02	3,76	3,37	2 629	885
36	5	303	6,77	4,52	3,84	2,25	2 051	643
37	6	330	6,15	5,03	3,92	1,12	2 031	579
38	7	326	5,54	5,54	4,00	0,00	1 806	451
39	8	348	4,92	4,92	4,40	0,00	1 713	389
40	9	335	4,31	4,31	4,80	0,00	1 443	301
41	10	315	3,69	3,69	5,20	0,00	1 163	224
42	11	215	3,08	3,08	5,60	0,00	662	118
43	12	169	2,46	2,46	6,00	0,00	416	69
44	13	151	1,85	1,84	6,40	0,00	279	44
45	14	105	1,23	1,23	6,80	0,00	129	19
46	15	74	0,62	0,61	7,20	0,00	46	6
						Σ →	33 050	11 125
							$SCOP_{on}$	2,97

Source: EN 14825:2018 - Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance (actually, valid is the 2020 version)

thermophysical properties of Refrigerants

EXAMPLE 1 COMPRESSORS

refrigerants
R11
R12
R22
R23
R32
R124
R125
R134A
R143A
R161
R717
R744
R1234yf
R410A
R407C
R507A
R404A

- **Isoentropic efficiency (overal efficiency) of compressor**

$$P = \dot{m} \cdot (h_v - h_s) + Q_z = \dot{m} \cdot \left(h_s + \frac{h_{ie} - h_s}{\eta_k} - h_s \right) = \dot{m} \cdot \frac{h_{ie} - h_s}{\eta_k}$$

kde je P **compressor input power [W]**

h_v **enthalpy on the pressure discharge side of compressor [J.kg^{-1}]**

h_s **enthalpy on the suction side [J.kg^{-1}]**

h_{ie} **enthalpy after isoentropic compression [J.kg^{-1}]**

η_k **overal effcienc z of compressor [-]**

- $\eta_k = f(n, \sigma, t_k, t_v, geometrie)$

Refrigerant libraries:

- **Refprop**
- **Coolprop https://github.com/CoolProp/CoolProp**
- **Solkane**

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EXAMPLE 1 COMPRESSORS

WE MAY HAVE JUST RESULTS OF SUCH COMPUTATIONS (THROUGH PRODUCT DATA FROM MANUFACTURER

- **For describing heating/cooling capacity, input power, COP/EER, may be used analytical form : polynomial expression**

$$\boxed{Y = A + B \cdot x + C \cdot y + D \cdot x^2 + E \cdot x \cdot y + F \cdot y^2 + G \cdot x^3 + H \cdot x^2 \cdot y + I \cdot x \cdot y^2 + J \cdot y^3}$$

- **Extractable from numerical data by linear regression for finding the constants of regression curves**
- **Or created by manufacturers on their own**

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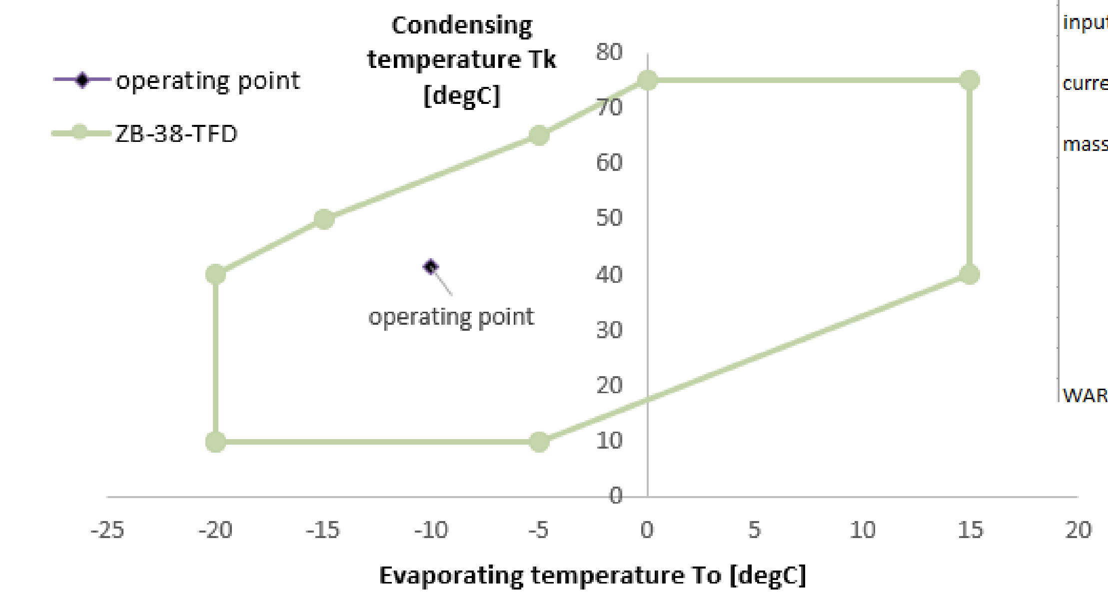
EXAMPLE 1 COMPRESSORS

Working envelope of compressor

ZB-38-TFD R134a 10K Superheat



ZB38KCE-TFD R134a
verze 7.13 / 42648 (10/16)

selekce!D3

evap	S =	-20	°C
kond	D =	25	°C

subcooling 0.00000000000000E+0000
voltage 4.00000000000000E+0002
voltage 380/420V - 3~ - 50Hz
suction temperature 1.83333339691162E+0001

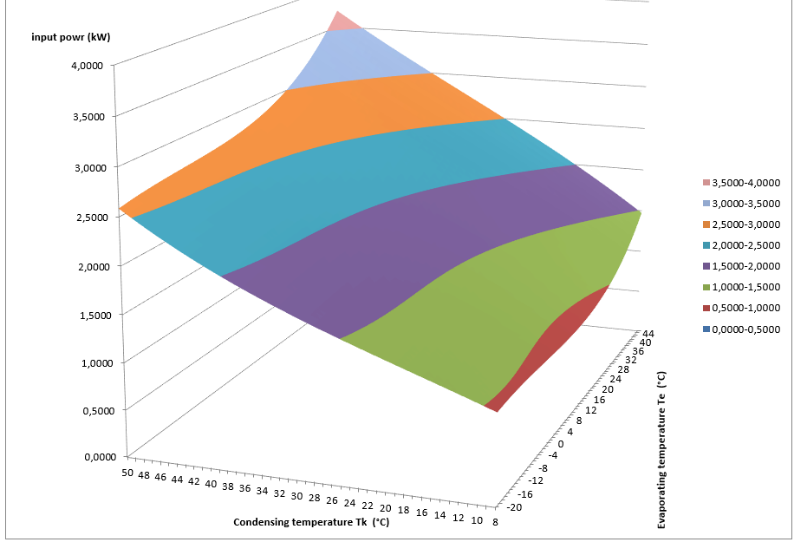
	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	output	řádek	
capacity	1,18E+01	4,60E-01	-9,75E-02	7,30E-03	-2,91E-03	3,89E-04	4,95E-05	-5,70E-05	-7,78E-06	-4,28E-06	3,81	1	kW
input powr	5,64E-01	-7,75E-03	4,81E-02	2,25E-05	5,30E-04	-5,09E-04	7,29E-06	1,16E-06	-5,88E-06	7,97E-06	1,50	2	kW
current	6,41E+00	-9,38E-03	-9,82E-02	4,75E-04	2,55E-04	1,95E-03	1,52E-05	-1,38E-05	5,35E-07	-3,65E-06	5,10	3	A
massflow	5,50E+01	2,19E+00	-1,59E-01	3,91E-02	-4,59E-04	3,43E-03	4,38E-04	-4,33E-05	-3,91E-06	-3,49E-05	20,71	4	g/s

X = C0 + C1*S + C2*D + C3*S^2 + C4*S*D + C5*D^2 + C6*S^3 + C7*D*S^2 +C8*S*D^2 + C9*D^3

X = Capacity kW; / input power kW; / current A; / mass flow g/s
S = evaporating temp, °C
D = condensing temp., °C

WARNING - Data from coefficients valid only within operating range

Source of compressor data: Copeland Select Software, compressor selection software
https://climate.emerson.com/en-gb/tools-resources/copeland-select-software



		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-20	10
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-20	40
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-15	50
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-5	65
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	0	75
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	15	75
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	15	40
		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-5	10
124		ZB	38	KCE	TFD	ZB-38-TFD	ZB-38-TFD	R134a	)K Superhe	-20	10

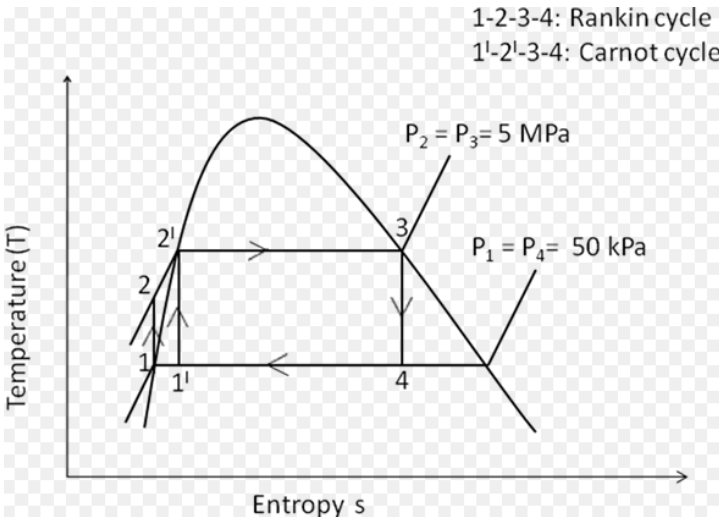
EXAMPLE 1 COMPRESSORS

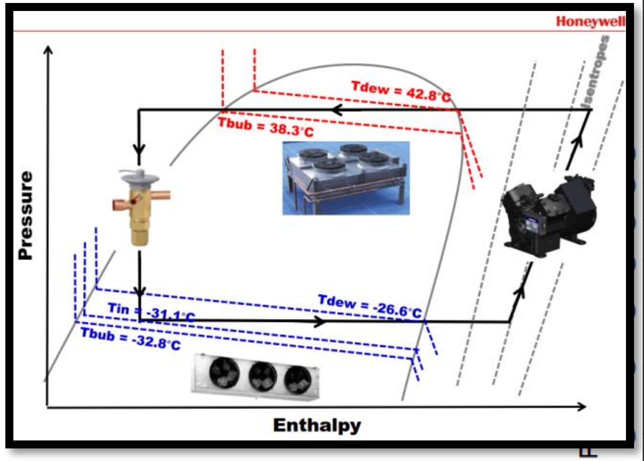
CoolProp
library parameters for refrigerant state description in the rankin/carnot cycle

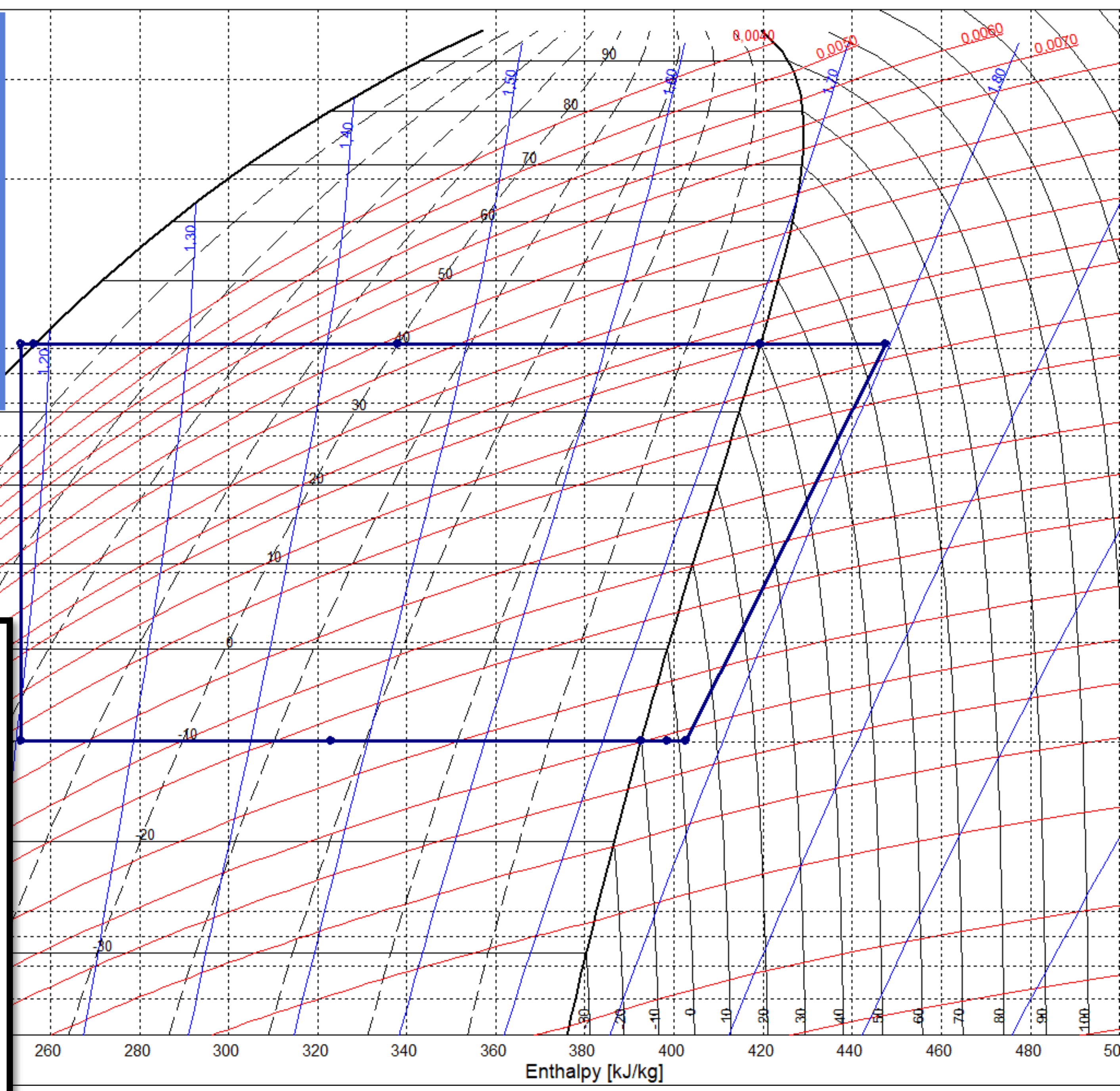
Outputs	Unit	Název
Q	-	Dryness
T	K	Temperature
P	kPa	Pressure
D	kg/m3	Density
C0	kJ/kgK	Specific heat capacity of an ideal gas in an isobaric process
C	kJ/kgK	Specific heat capacity of the isobaric process
O	kJ/kgK	Specific heat capacity of isochoric process
U	kJ/kg	Internal energy (specific)
H	kJ/kg	Enthalpy (specific)
S	kJ/K	Entropy (specific)
A	m/s	velocity
G	kJ/kg	Gibbs energy
V	Pa.s	Dynamic viscosity
L	kW/mK	Thermal conductivity
I	N/m	Surface tension

constants>:

Výstupy	Jednotka	Název
Tcrit	K	Critical temperature
pcrit	Pa	Critical pressure
rhocrit	kg/m^3	Critical density
molemass	kg/kmol	Molecular weight
Ttriple	K	Triple point temperature
ptriple	Pa	Triple point pressure
GWP100	-	Global Warming Potentian in 100 yrs
ODP	-	Ozone Depletion Potential

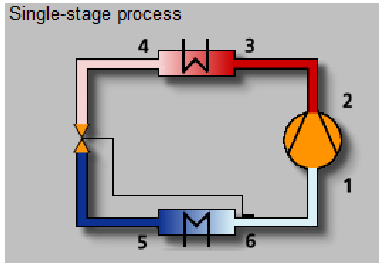






Example of cooling circuit computation

Zadání		
Condensing temp	40	°C
Evaporating temp	-10	°C
isoentropic efficiency	0,8	-
transportation coefficient	0,9	-
refrigerant	R134a	-
superheating	5	K
subcooling	2	K
flow volume of compressor	10	m3/h



		Teplota	Tlak [kPa]	Entalpie [kJ/kg]	Entropie [kJ/kg]	Hustota [kg/m3]
Operating point		fluid temp	fluid pressure	Enthalpy [kJ/kg]	Entrophy [kJ/kg]	density [kg/m3]
end of evaporating	6	-10	200 603	392 665		
behind evaporator	6´	-5	200 603	396 927	1749,394729	9,798481054
after isoentrhopic compression	2	51	1 352 083	431 643		
after compression	2´	59	1 016 593	440 321		
condensing	3	40	1 016 593	419 429		
behind condenser	4	38	1 016 593	418 549		
after expansion	5	-10	200 603	418 549		

3D shapes as descriptors of fluid properties

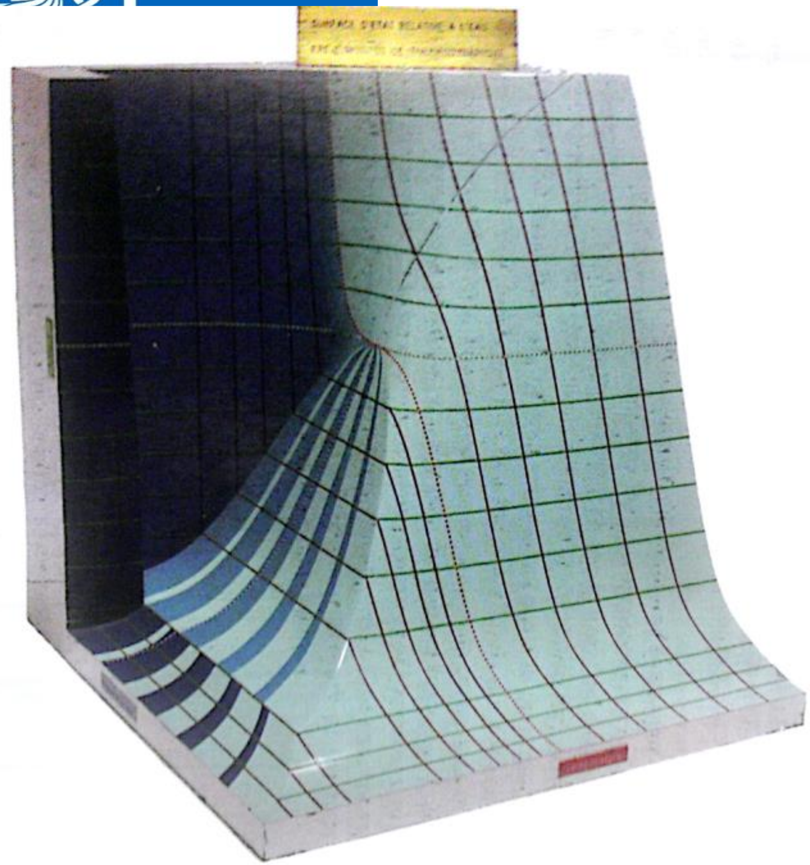


Fig. 5.19(b) A mock-up showing the state surface relative to water and to a certain number of special bodies (Ge, Bi, G

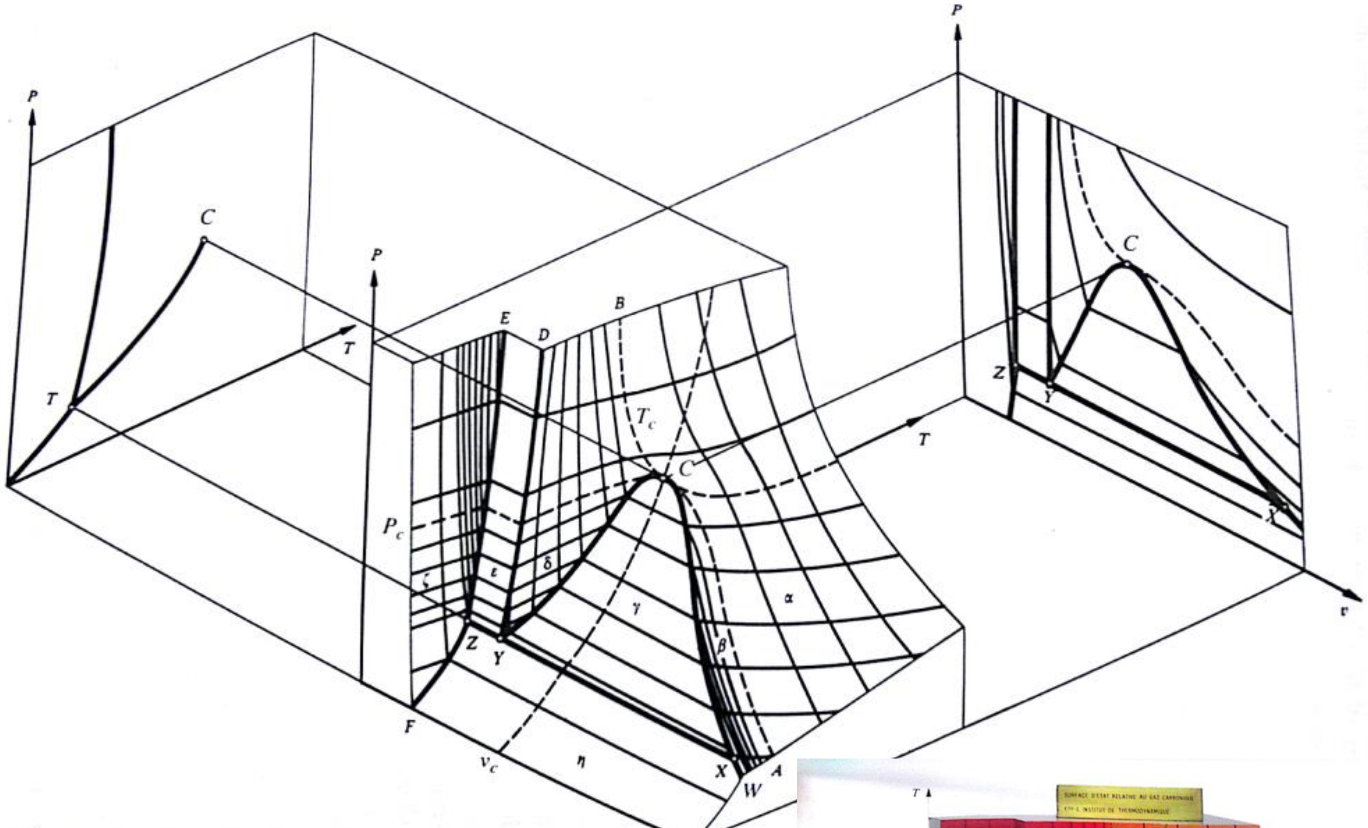


Fig. 5.18 (a) The spatial representation of the state surface relative to a real body (excluding the bodies dealt with in Figures 5.19(a) and (b))

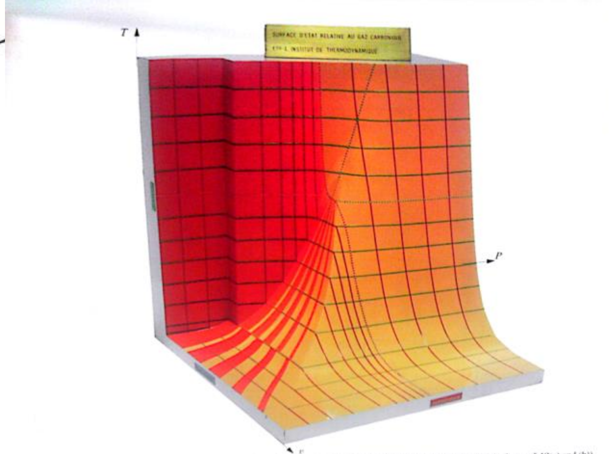


Fig. 5.18 (b) A mock-up showing the state surface relative to a real body (excluding the bodies dealt with in figures 5.19(a) and (b)).

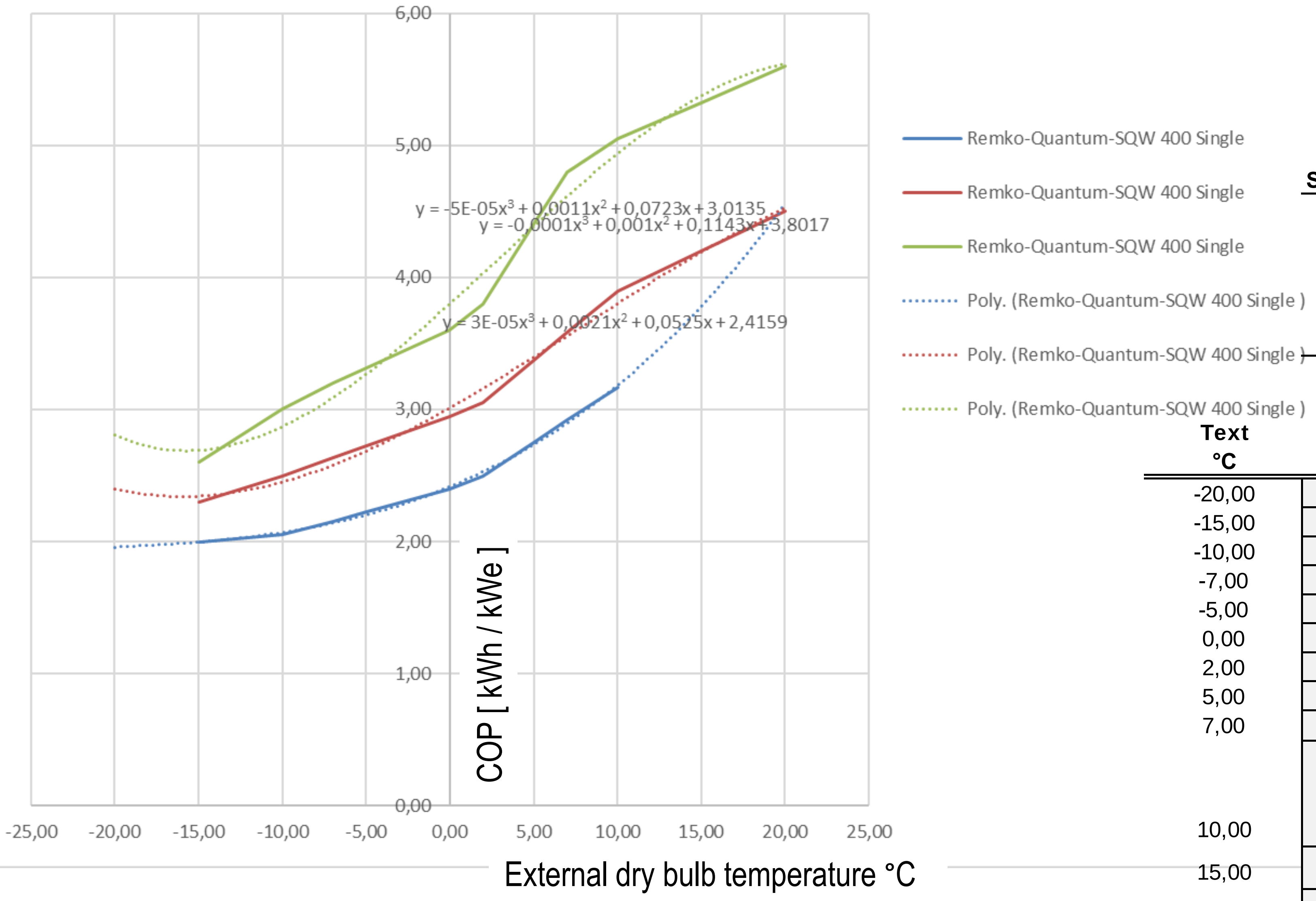
Source: some ASHRAE fundamentals book (forgot to write down)

EXAMPLE 1 COMPRESSORS

CTU CZECH TECHNICAL

Electric heat pumps efficiencies described in numerical and analytical form

COP profile of electric heat-pump (Remko Quantum)



LCWT – leaving condenser water temperature

SESTAVA ZDROJŮ TEPLA				LCWT 55 °C	LCWT 45 °C	LCWT 35 °C
	1	2	3	COP-LCWT:	COP-LCW	COP-LCW
	Remko-Quantum-SQW 400 Single	Remko-Quantum-SQW 400 Single	Remko-Quantum-SQW 400 Single	Remko-Quantum-SQW 400 Single	Remko-Quantum-SQW 400 Single	Remko-Quantum-SQW 400 Single
Text °C	Qtop kW	Qtop kW	Qtop kW	COP kWt/kWe	COP kWt/kWe	COP kWt/kWe
-20,00	0,00	0,00	0,00	0,00	0,00	0,00
-15,00	26,00	26,00	24,00	2,00	2,30	2,60
-10,00	28,00	28,00	25,00	2,05	2,50	3,00
-7,00	0,00	0,00	27,30	0,00	0,00	3,20
-5,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	32,50	32,50	30,00	2,40	2,95	3,60
2,00	34,00	34,00	31,00	2,50	3,05	3,80
5,00	0,00	0,00	0,00	0,00	0,00	0,00
7,00	0,00	0,00	40,00	0,00	0,00	4,80
10,00	45,00	46,00	43,00	3,17	3,90	5,05
15,00	0,00	0,00	0,00	0,00	0,00	0,00
20,00	64,00	68,00	68,00	0,00	4,50	5,60

EXAMPLE 1 COMPRESSORS

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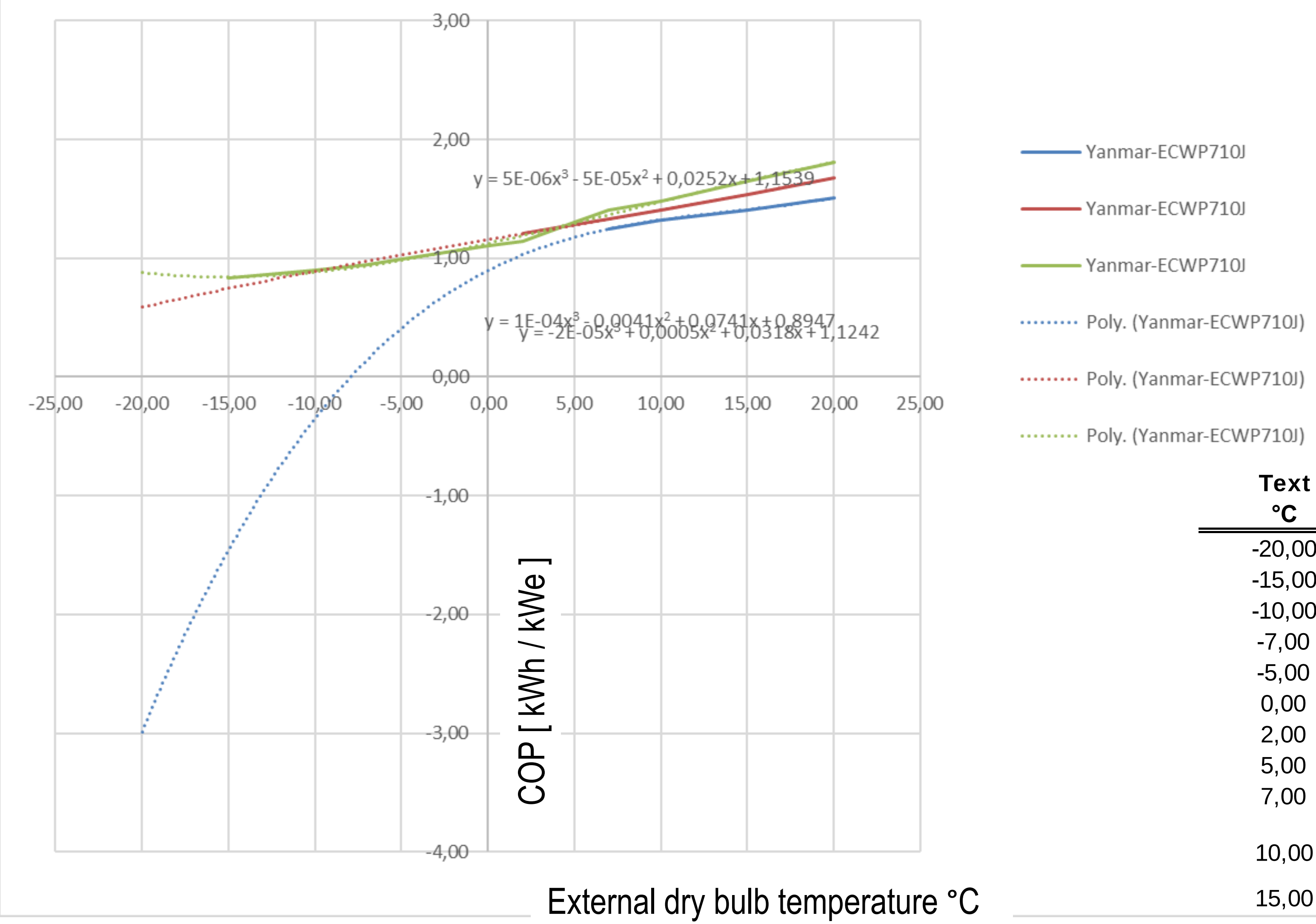
Gas heat pumps efficiencies described in numerical and analytical form

LCWT – leaving condenser water temperature

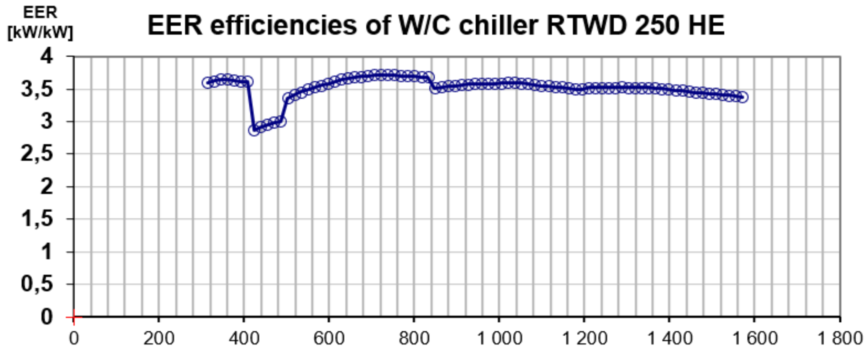
COP profile of gas heat-pump (Yanmar)



				LCWT 55 °C	LCWT 50 °C	LCWT 45 °C
SESTAVA ZDROJŮ TEPLA				8	8	8
	1	2	3	COP-LCWT:	COP-LCW	COP-LCW
	Yanmar-ECWP710J	Yanmar-ECWP710J	Yanmar-ECWP710J	Yanmar-ECWP710J	Yanmar-ECWP710J	Yanmar-ECWP710J
Text °C	Qtop kW kW	Qtop kW kW	Qtop kW kW	COP kWt/kWe	COP kWt/kWe	COP kWt/kWe
-20,00	0,00	0,00	0,00	0,00	0,00	0,00
-15,00	0,00	0,00	61,60	0,00	0,00	0,83
-10,00	0,00	0,00	67,40	0,00	0,00	0,90
-7,00	0,00	0,00	70,90	0,00	0,00	0,95
-5,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00
2,00	0,00	68,10	86,30	0,00	1,20	1,14
5,00	0,00	0,00	0,00	0,00	0,00	0,00
7,00	62,60	71,30	80,00	1,25	1,33	1,40
10,00	65,70	74,80	83,90	1,32	1,41	1,48
15,00	66,00	78,10	90,30	1,41	1,54	1,65
20,00	66,30	81,50	96,80	1,51	1,68	1,80

example of complicated product parameters:
compressor efficiency

HEAT-PUMPS



2	EER$_{max}$ = 3,72	% $_{EERmax}$ = 55,0%								
		chlazení 7 / 12								3,60
% load	Capacity cooling		LWT evap	EWT evap	Flow evap	WPD evap	WPD evap	EWT cond	Power	COP
1	2	3	4	5	6	7	8	9	14	16
%	kW		°C	°C	L / s	kPa	ft H20	°C	Kw	kWc/kWe
100,00	1571,00	1571,00	7,00	12,00	74,90	62,20	62,20	32,00	464,90	3,38
99,00	1555,50	1555,50	7,00	12,00	74,10	58,30	58,30	32,00	458,60	3,39
98,00	1539,80	1539,80	7,00	12,00	73,40	57,20	57,20	32,00	452,90	3,40
97,00	1524,00	1524,00	7,00	12,00	72,60	56,20	56,20	32,00	447,00	3,41
96,00	1508,30	1508,30	7,00	12,00	71,90	55,10	55,10	32,00	441,10	3,42
00	1492,60	1492,60	7,00	12,00	71,10	54,10	54,10	32,00	435,30	3,43
00	1476,90	1476,90	7,00	12,00	70,40	53,00	53,00	32,00	429,40	3,44
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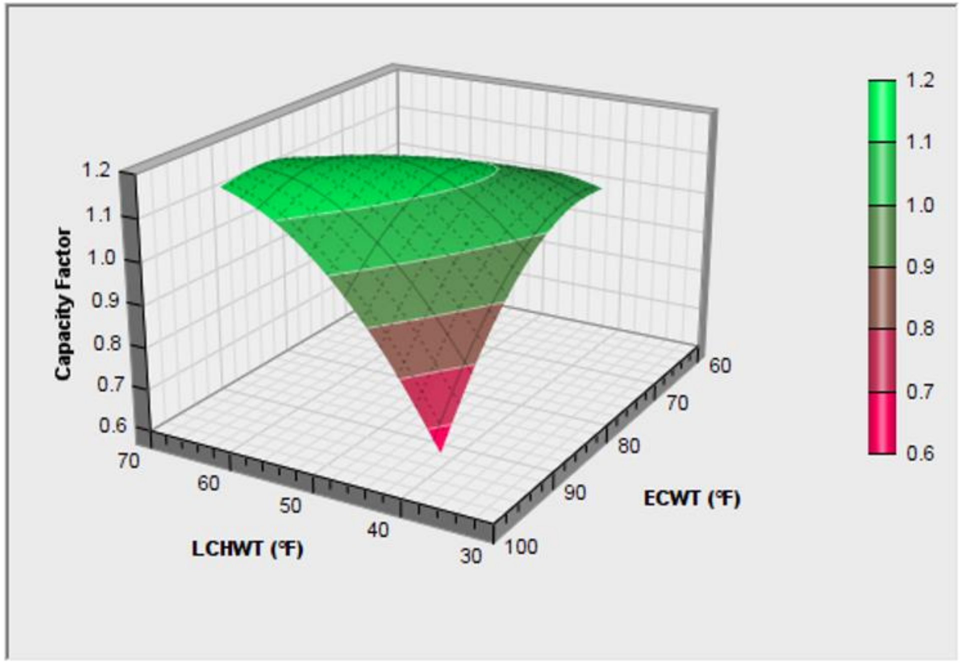
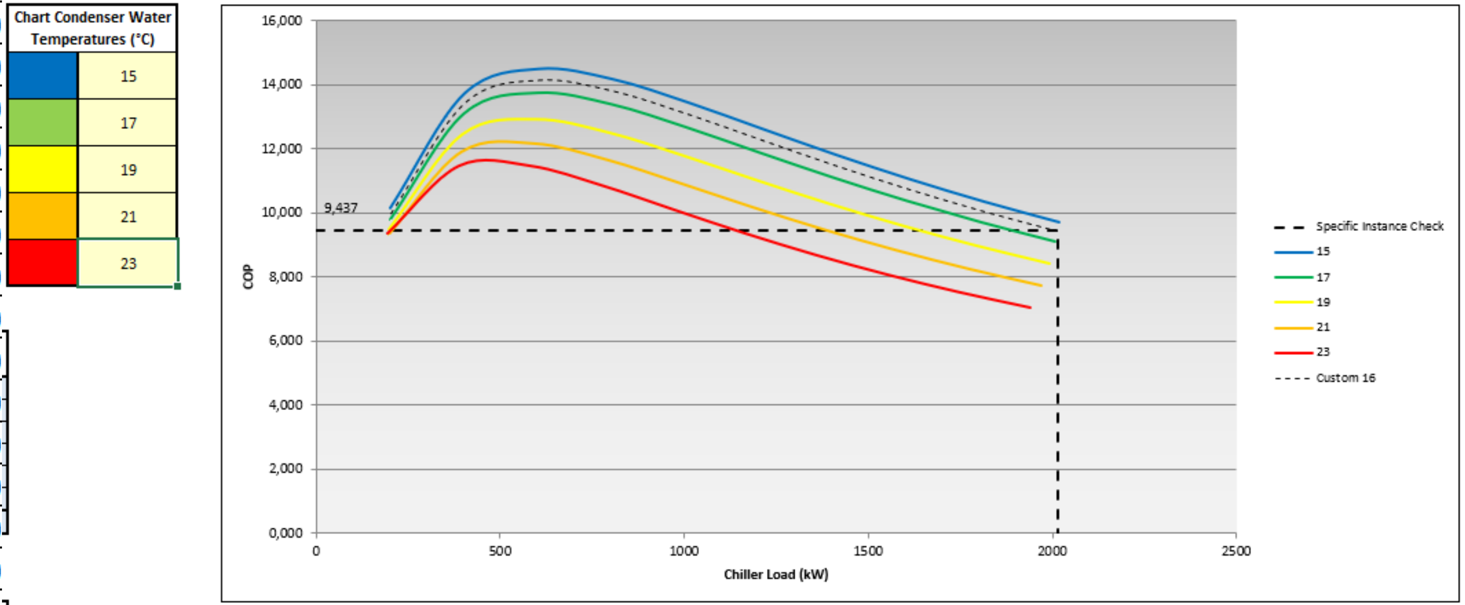
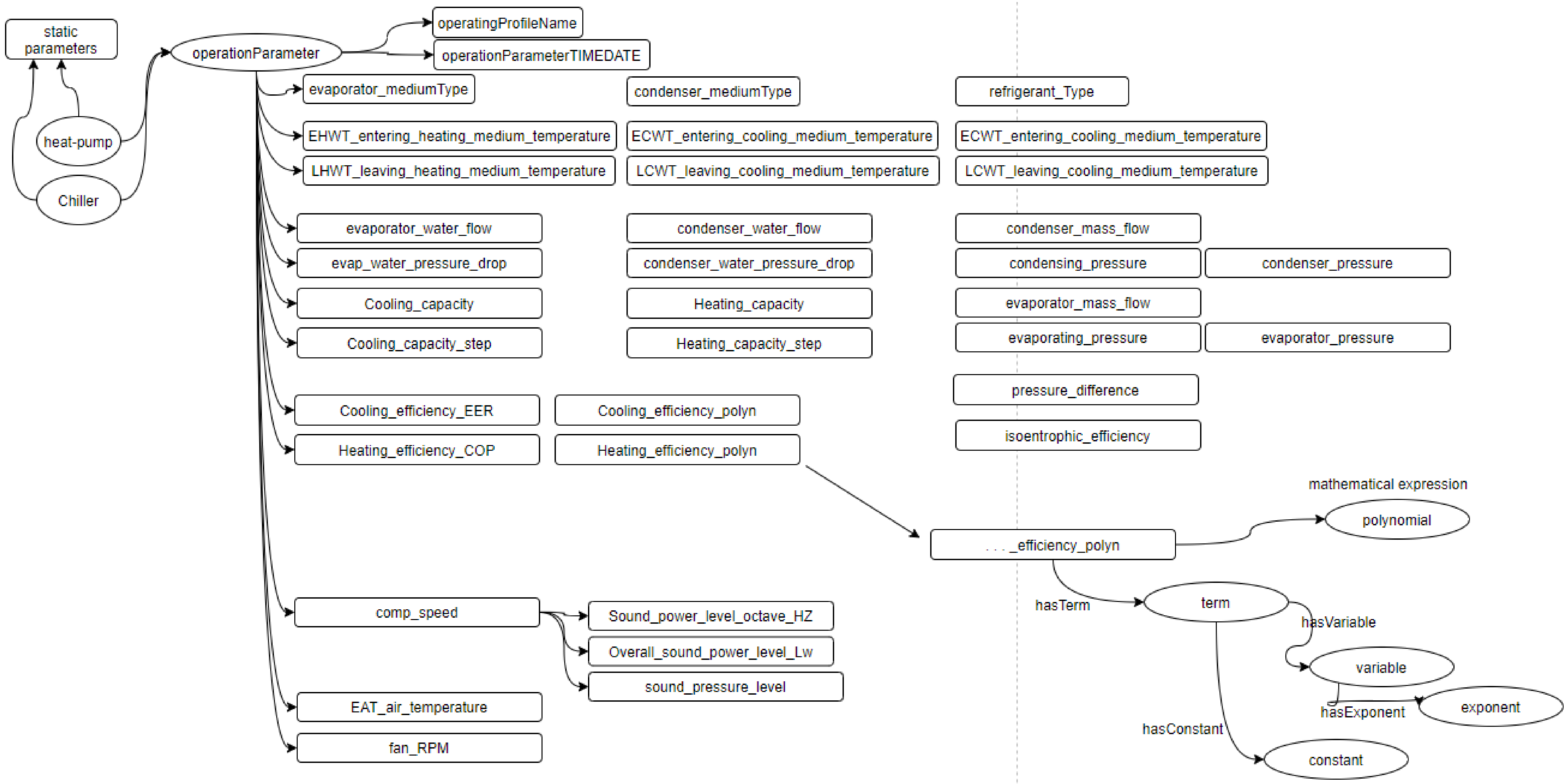




Operation properties of products with Rankine-carnot cycle circuits
Electrict heat pumps and chillers



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EXAMPLE 2 OPERATION PARAMS.

What properties do they need to have common ?

They work with the same medium properties

- temperatures
- fluid movements in ducts/pipes
  - direction
  - volume flow
  - friction (pressure drop)
  - pressure

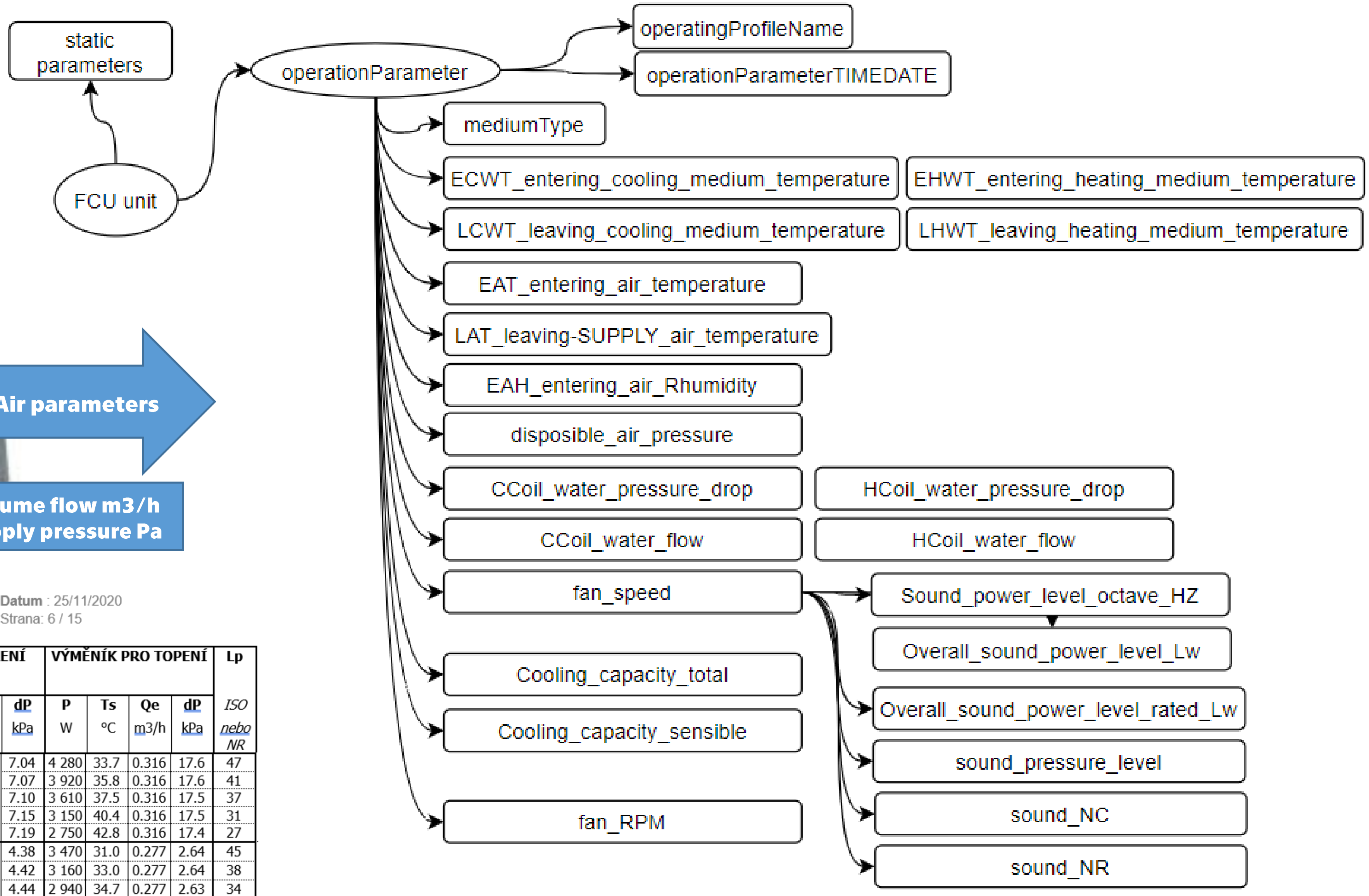
Example :

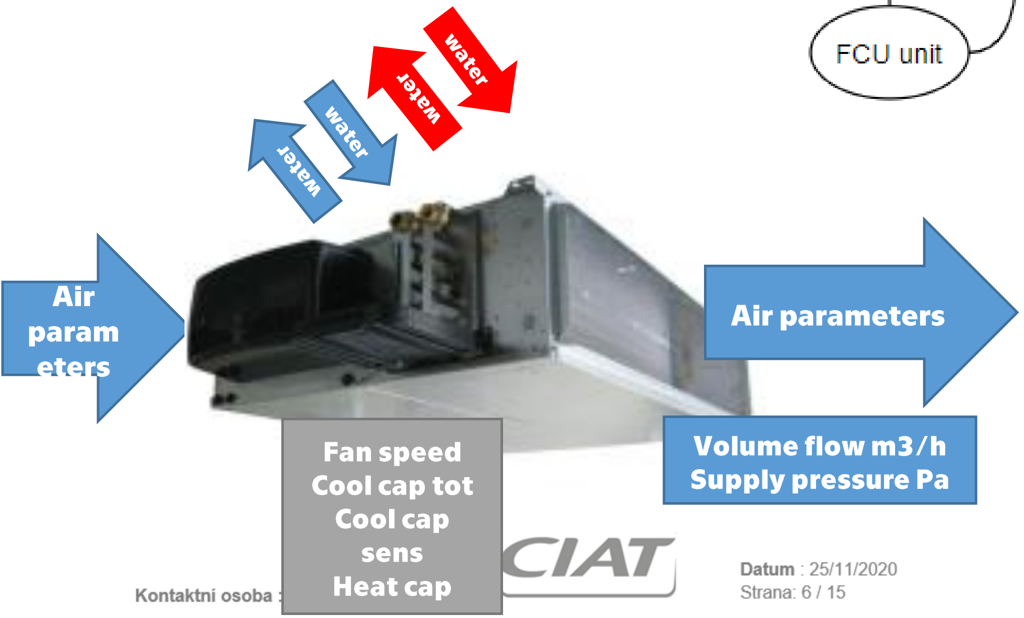
Example : FCU unit

EXAMPLE 2 OPERATION PARAMS.

Basic (static) parameters: weight, name, connection diameters, dimensions of FCU , Dimensions of service space…

But operational parameters : (in DESIGN and OPERATION afterwards)





Kontaktní osoba :

Datum : 25/11/2020
Strana: 6 / 15

							VÝMĚNÍK PRO CHLAZENÍ					VÝMĚNÍK PRO TOPENÍ				Lp
TYP **Velikost**	**R#**	**U** Volt	**N** ot/min	**OP** Pa	**Pabs** W	**Qa** m3/h	**Pt** W	**Ps** W	**Ts** °C	**Qe** m3/h	**dP** kPa	**P** W	**Ts** °C	**Qe** m3/h	**dP** kPa	*ISO nebo NR*
CFLINE	V5	8.2	1250	31	109	1120	2 340	2 340	18.0	0.320	7.04	4 280	33.7	0.316	17.6	47
34D	V4	6.5	1000	18	52	865	2 160	2 160	16.6	0.320	7.07	3 920	35.8	0.316	17.6	41
HEE	V3	5.4	840	12	30	705	2 010	2 010	15.5	0.320	7.10	3 610	37.5	0.316	17.5	37
	V2	4.1	665	6	16	520	1 790	1 700	14.2	0.320	7.15	3 150	40.4	0.316	17.5	31
	V1	3.3	550	4	10	400	1 600	1 480	12.8	0.320	7.19	2 750	42.8	0.316	17.4	27
CFLINE	V5	7.7	1170	23	102	1190	2 450	2 450	18.0	0.353	4.38	3 470	31.0	0.277	2.64	45
44C	V4	5.7	895	12	42	870	2 220	2 220	16.5	0.353	4.42	3 160	33.0	0.277	2.64	38
HEE	V3	4.7	745	8	25	705	2 050	2 050	15.3	0.353	4.44	2 940	34.7	0.277	2.63	34
	V2	3.6	595	4	13	525	1 820	1 820	13.6	0.353	4.48	2 610	37.0	0.277	2.62	29

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TBV-CM

Combined control & balancing valves for small terminal units

For modulating control

IMI Hydronic Engineering

Source:
manual TBV-CM__EN__MAIN

Technical description

Application:

Heating and cooling systems.

Functions:

Control

Balancing

Pre-setting

Measuring

Shut-off

(for isolation during system maintenance)

Dimensions:

DN 15-25

Pressure class:

PN 16

Temperature:

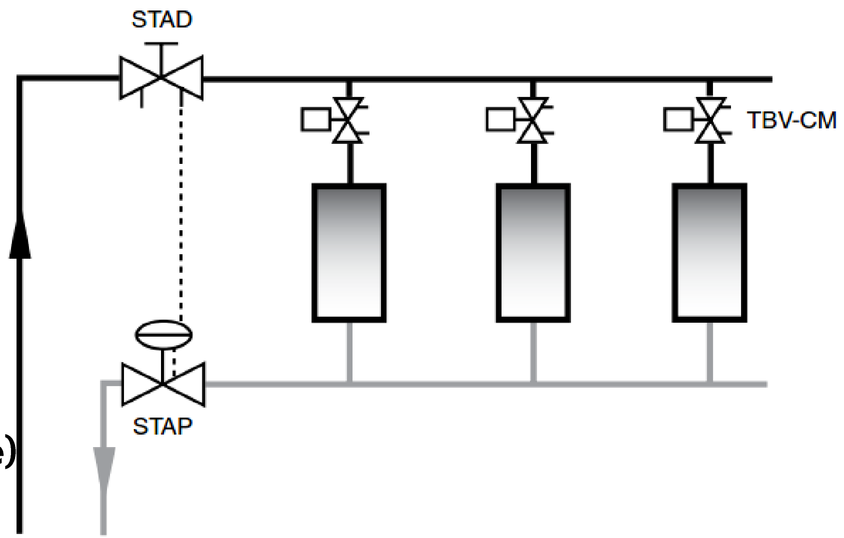
Max. working temperature: 120°C

Min. working temperature: -20°C

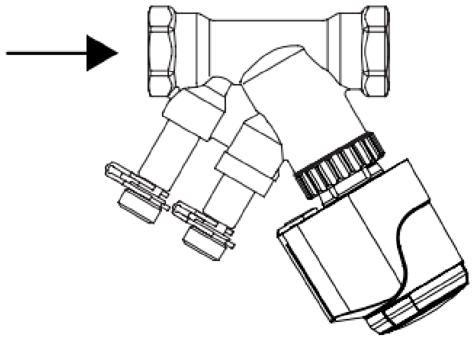
Media:

Water or neutral fluids, water-glycol mixtures (0-57%).

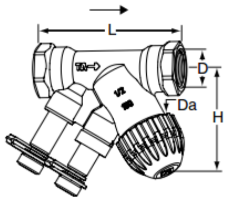
Application example



Flow direction



Articles



Female thread

DN	D	Da*	L	H	Kvs	Kg	EAN	Article No
TBV-CM LF, low flow								
15	G1/2	M30x1,5	81	58	0,40	0,34	7318793950703	52 143-115
TBV-CM NF, normal flow								
15	G1/2	M30x1,5	81	58	1,0	0,34	7318793950505	52 144-115
20	G3/4	M30x1,5	91	57	2,0	0,40	7318793951403	52 144-120
25	G1	M30x1,5	111	64	4,0	0,73	7318793977502	52 144-125

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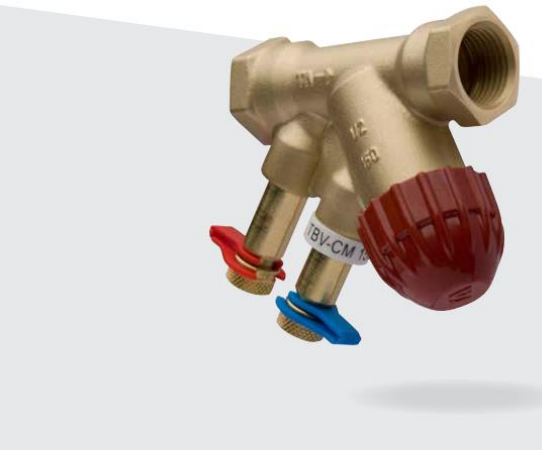
TBV-CM



Combined control & balancing valves for small terminal units
For modulating control

Source:
manual TBV-CM_EN_MAIN

IMI Hydronic Engineering

Sizing

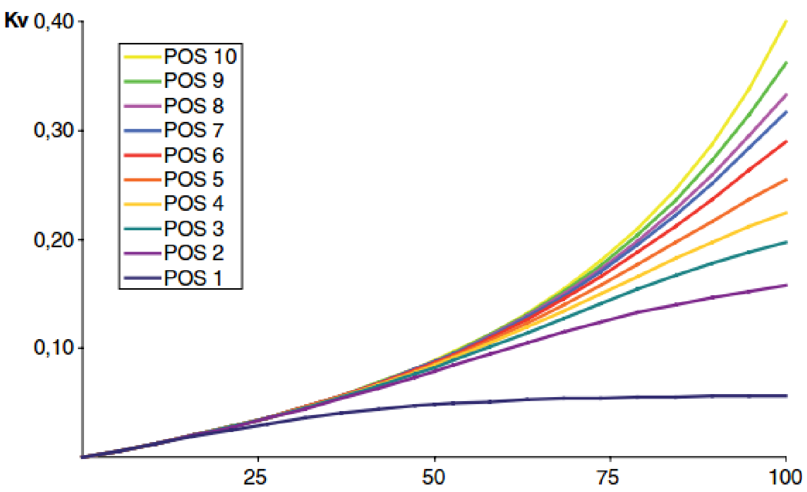
When Δp and the design flow are known, use the formula to calculate the Kv-value.

$$Kv = 0{,}01 \frac{q}{\sqrt{\Delta p}} \quad q \text{ l/h, } \Delta p \text{ kPa}$$

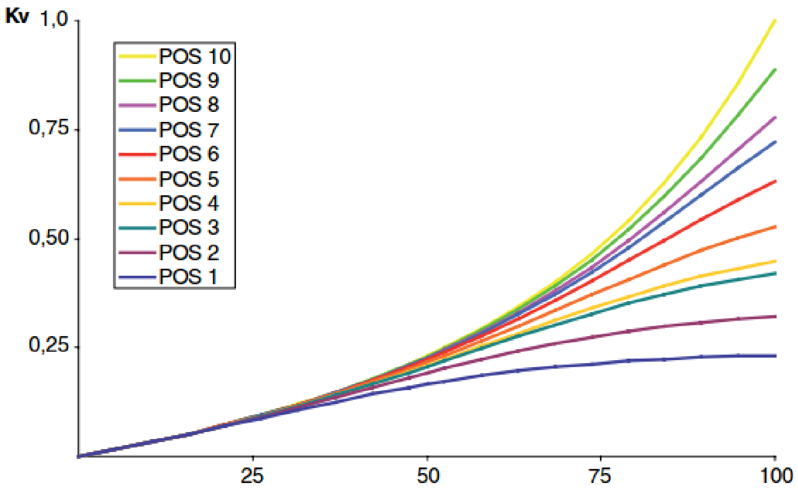
$$Kv = 36 \frac{q}{\sqrt{\Delta p}} \quad q \text{ l/s, } \Delta p \text{ kPa}$$

Valve characteristics

TBV-CM LF, DN 15, Kvs 0,40

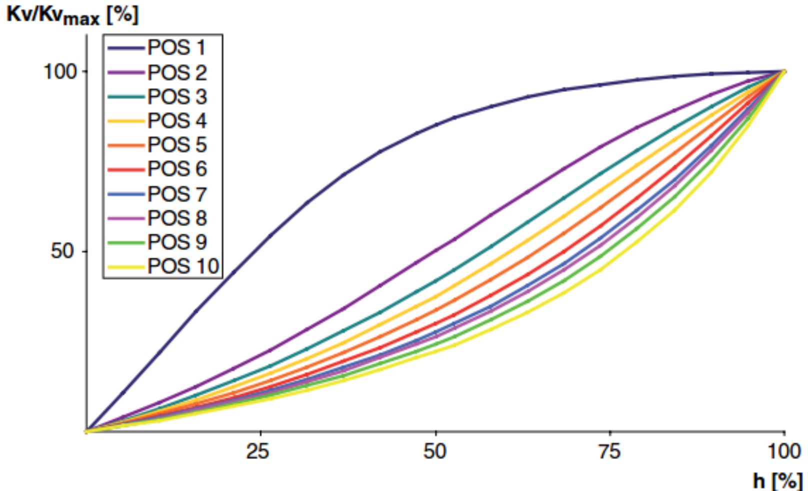


TBV-CM NF, DN 15, Kvs 1,0

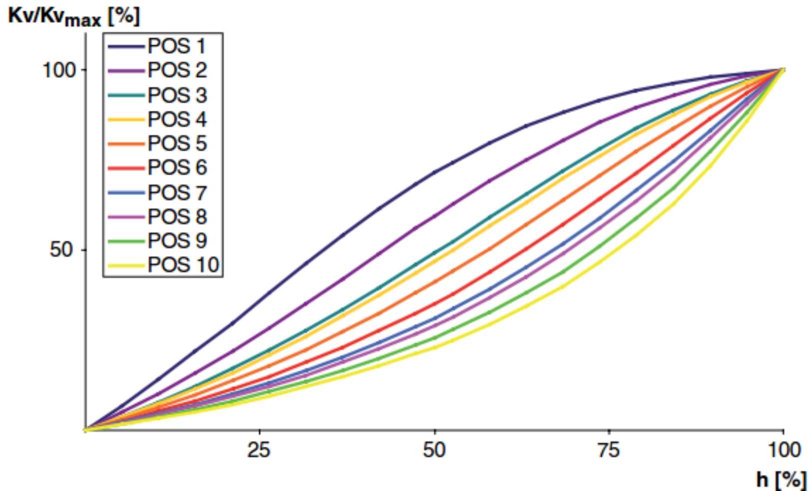


Standardised valve characteristic

TBV-CM LF, DN 15, Kvs 0,40



TBV-CM NF, DN 15, Kvs 1,0



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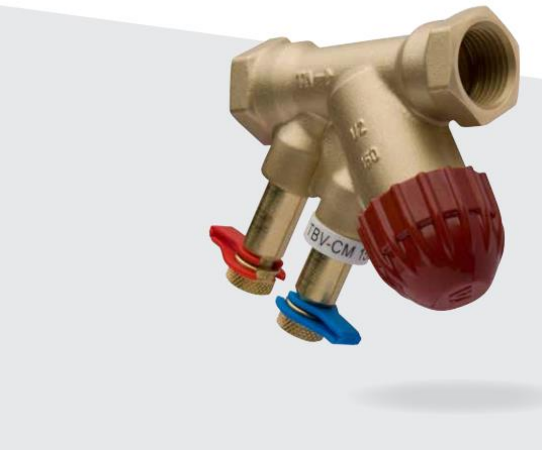
TBV-CM



Combined control & balancing valves for small terminal units
For modulating control

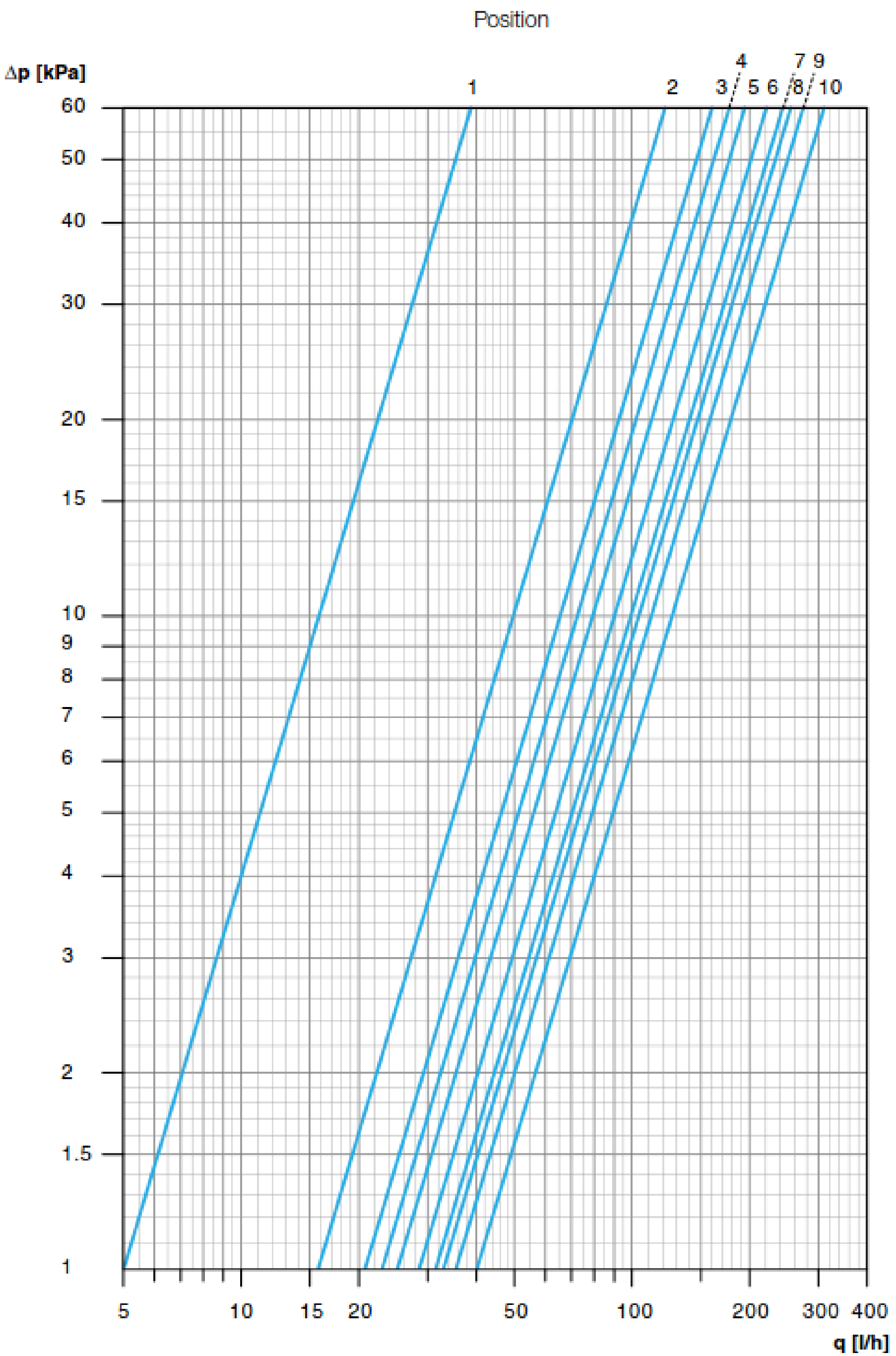
Position	1	2	3	4	5	6	7	8	9	10
Kv_{max}	0,05	0,16	0,21	0,23	0,25	0,29	0,31	0,33	0,35	0,40

Kv_{max} = m³/h at a pressure drop of 1 bar at each pre-setting and fully open valve plug.

Source:
manual TBV-CM_EN_MAIN

IMI Hydronic Engineering

Diagram TBV-CM LF, DN 15

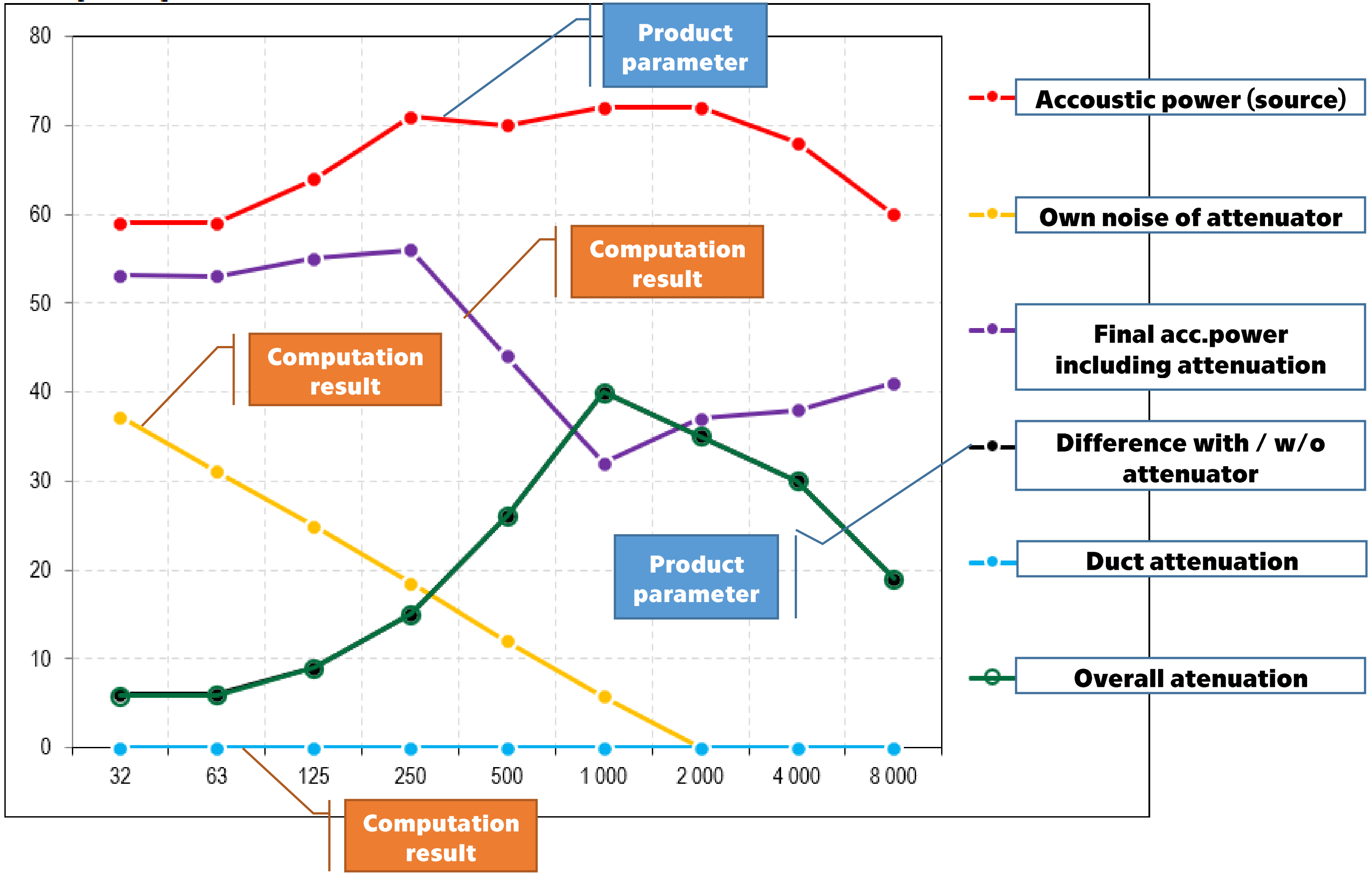


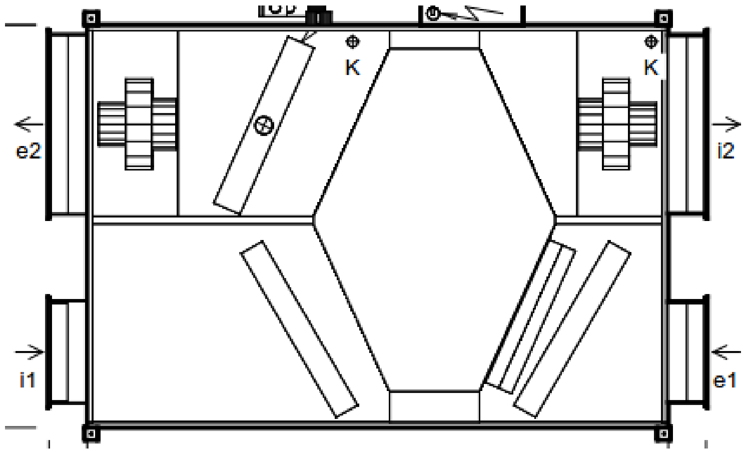
Accoustic tabular data
Accustic power

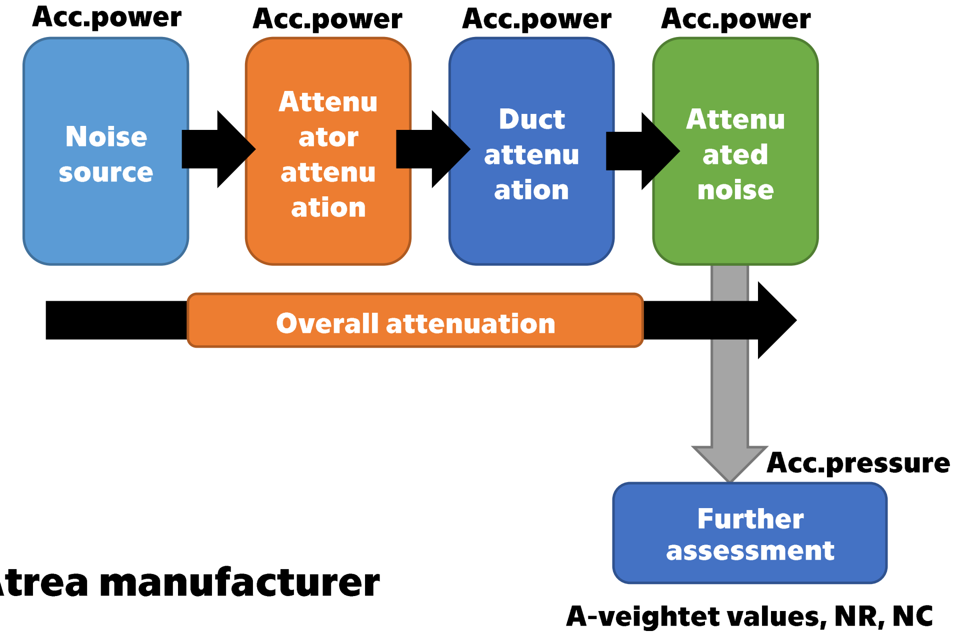
Hladina akustického výkonu LwA (dB)

Frekvence [Hz]	**Total** dB (A)	63 dB(A)	125 dB(A)	250 dB(A)	500 dB(A)	1 k dB(A)	2 k dB(A)	4 k dB(A)	8 k dB(A)
sání e1	56	46	54	49	42	40	35	25	<25
výtlak e2	73	55	63	65	63	68	67	62	54
sání i1	54	40	46	51	46	45	40	31	<25
výtlak i2	77	55	61	70	67	73	71	65	57
plášť do okolí	63	38	45	60	58	53	49	44	32

Graf - [dB / Hz]:



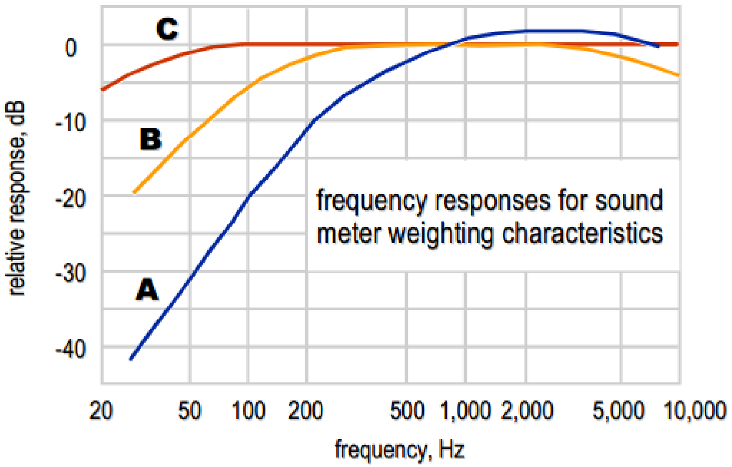




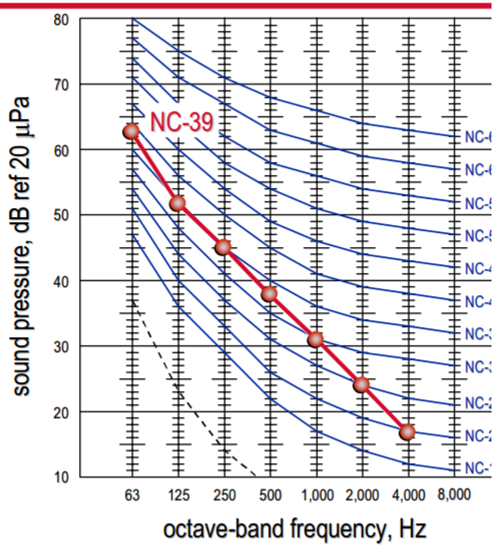
Source: excel selector Greif attenuator products, AHU unit parameters, Atrea manufacturer

Accoustic tabular data
Assessment near noice receiver
Accustic pressure and other criteria

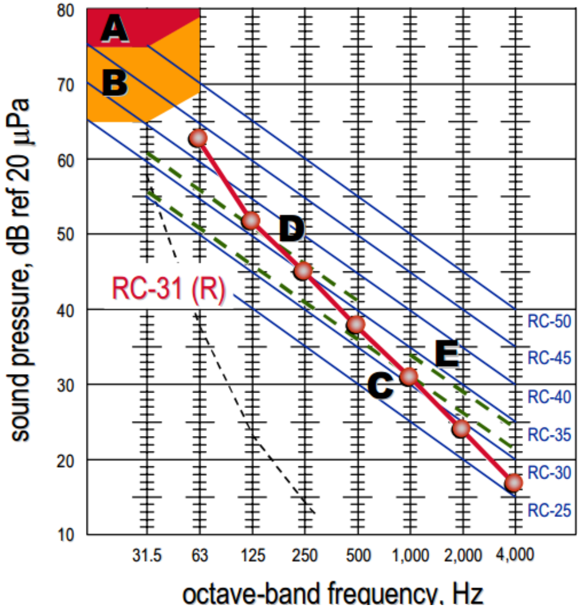
A–B–C Weighting



Noise Criteria (NC) Curves



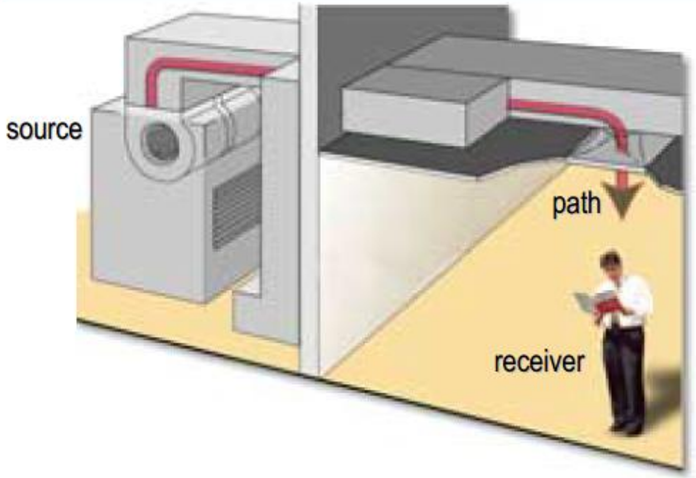
Room Criteria (RC) Curves



A–Weighting Example

octave band	center frequency (Hz)	actual sound pressure (dB)	A-weighting factor (dB)	A-weighted sound pressure (dB)
1	63	63	– 26	37
2	125	52	– 16	36
3	250	45	– 9	36
4	500	38	– 3	35
5	1,000	31	+ 0	31
6	2,000	24	+ 1	25
7	4,000	16	+ 1	17
8	8,000	10	+ 0	10
				42 dBA

Source–Path–Receiver Model



Source: Fundamentals of HVAC accoustic, Trane, TRG-TRC007-EN-01

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EXAMPLE 2 OPERATION PARAMS.

EN 13779 [4-1997] Ventilation for non-residential buildings – performance requirements for ventilation and room conditioning systems

Table 1 — Symbols and units

Quantity	Symbol	Unit
Pressure difference	Δp	Pa
Temperature difference	$\Delta\theta$ *)	K
Ventilation effectiveness	ε_v	-
Temperature	θ (theta)	K (°C)
Air temperature in the room	θ_a (theta)	K (°C)
Mean radiant temperature	θ_r (theta)	K (°C)
Operative temperature	θ_o (theta)	K (°C)
Density	ρ (rho)	$kg.m^{-3}$
Heat or cooling load	Φ (phi)	W (kW)
Area	A	m^2
Costs	C	€ [a]
Concentration	c	$mg.m^{-3}$
Specific heat capacity at constant pressure	c_p	$J.kg^{-1}.K^{-1}$
Diameter	d	m
Energy consumption (measured)	E	J (MJ, GJ)
Energy demand (calculated)	E	J (MJ, GJ)
Specific leakage	f	$l.s^{-1}.m^{-2}$
Present value factor	f_{pv}	-
Height	h	m
Initial Investment	I	€ [b]
Thermal insulation of clothing	I_{cl}	clo
Length	L	m
Metabolic rate (activity)	M	met
Life span	n	years
n_{L50}-value	n_{L50}	h^{-1}
Fan power	P	W
Specific fan power	P_{SFP}	$W.m^{-3}.s$
Present value	PV	€ [a]

End of table

Pressure	p	Pa
Mass flow rate	q_m	$kg.s^{-1}$
Volume flow rate	q_v	$m^3.s^{-1}$ ($l.s^{-1}$, $m^3.h^{-1}$)
Interest rate	r	-
Time	t	s (h)
Volume	V	m^3
Air velocity	v	$m.s^{-1}$

[a] Or National currency

[b] EN 12792 prefers Θ but t and T may be used as well.

Source: EN 16798-[3:2020] Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)
and also non-valid EN 13779 [4-1997] (non-valid)

EXAMPLE 2 OPERATION PARAMS.

According the EN 16798 , there are many air categories dependent on its function/purpose and placement of air in ventilation system and building

air

1 Outdoor (ODA)	6 Recirculation (RCA)	11 Exfiltration (EXF)
2 Supply (SUP)	7 Exhaust (EHA)	12 Mixed (MIA)
3 Indoor (IDA)	8 Secondary (SEC)	1.1 Single room outdoor
4 Transferred (TRA)	9 Leakage (LEA)	2.1 Single room supply
5 Extract (ETA)	10 Infiltration (INF)	5.1 Single room extract
		7.1 Single room exhaust

From: Table2-specification of type of air, EN 13779 [4-1997]
Resp. Table 6. EN 16798-[3:2020]

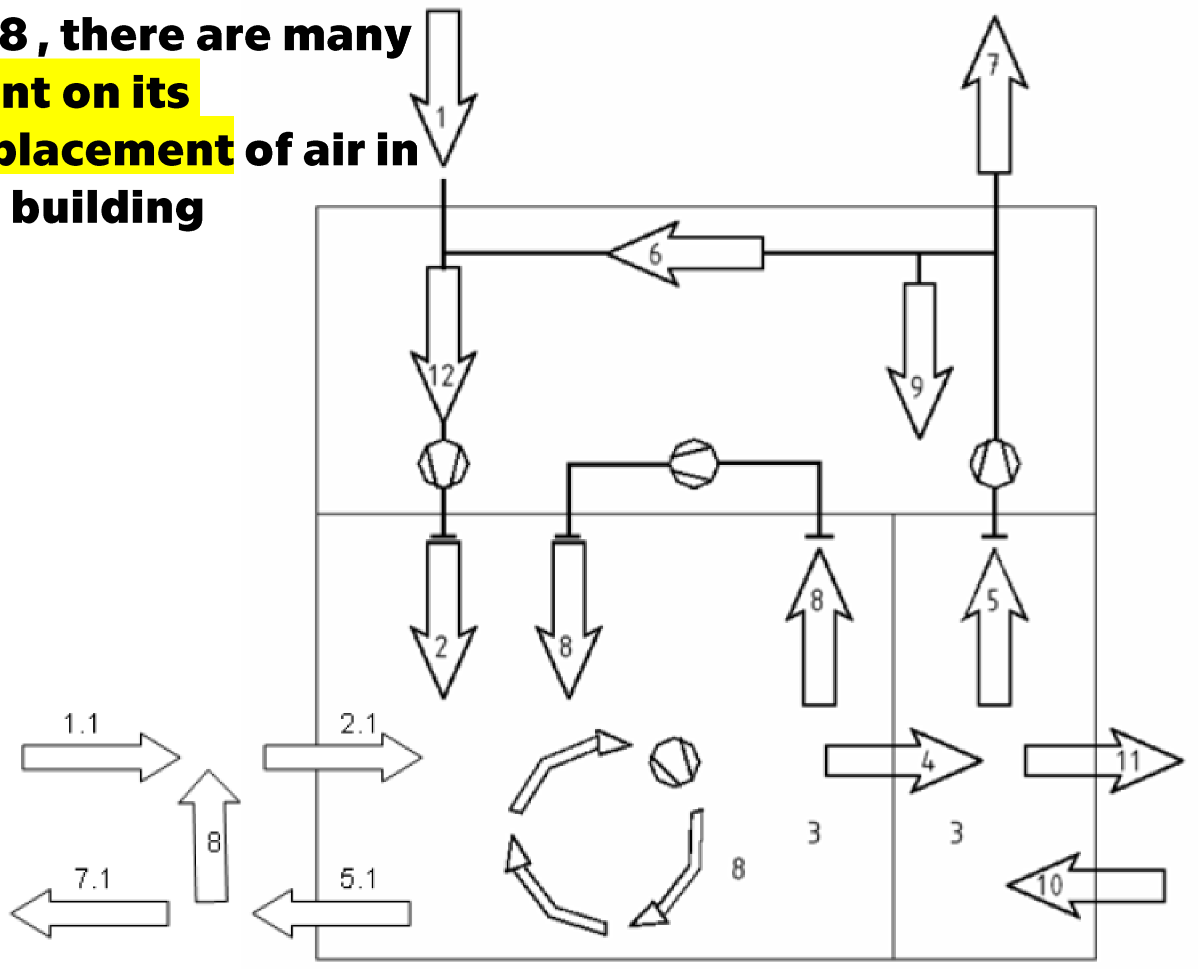


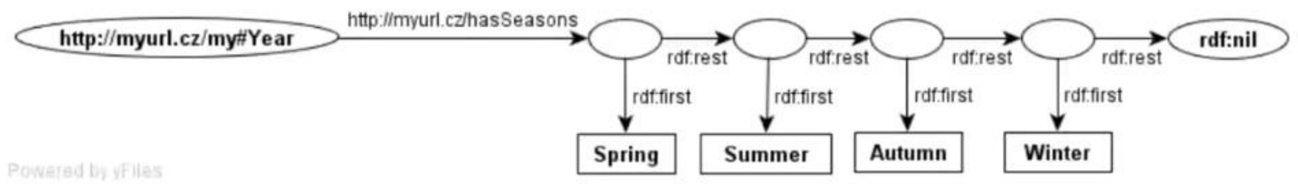
Figure 2 — Illustration of types of air using numbers given in Table 7

How to define tabular product data ?

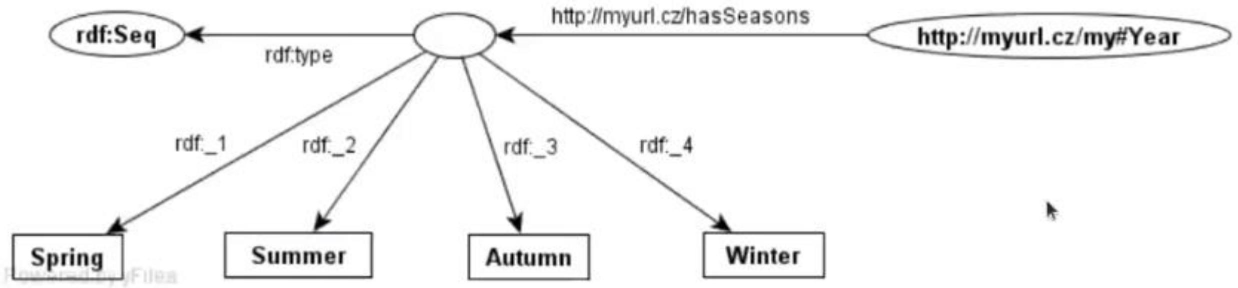
RDF collections

Examples

collection ?



container ?

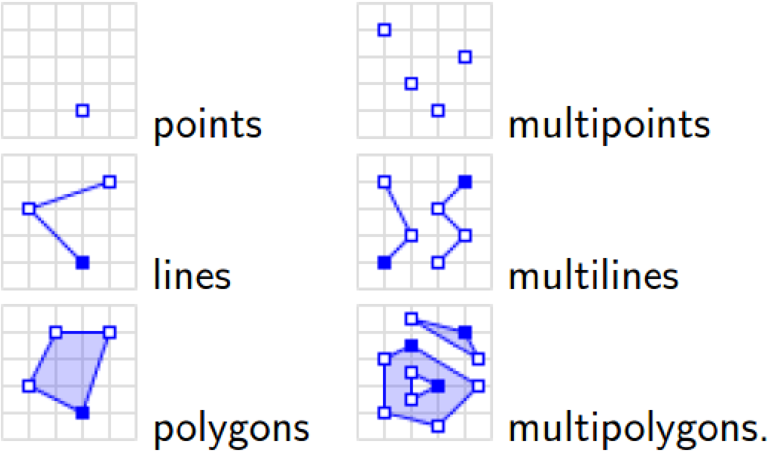


Well-Known-Text WKT ?

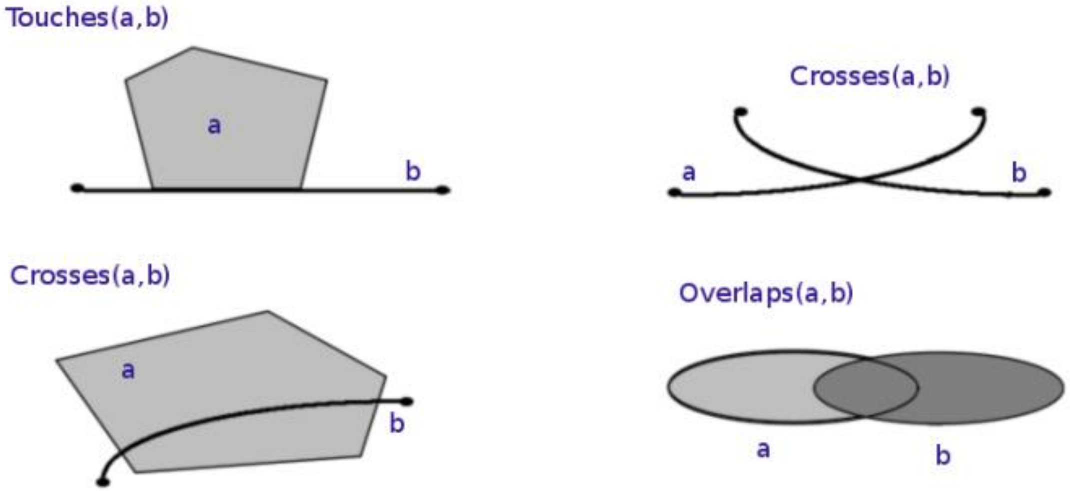
Maybe .. ?

How to define product data defined in curves And 3d shapes ?

Geosparql Spatial Objects



GeoSPARQL spatial relations



Maybe .. ?

geosparql:asWKT"MULTIPOLYGON (((…
polygon((…

Source: presentation Semantic GIS – GeoSPARQL,Michal Med, FEL – CTU Pragu

CAUSALISTIC PROPERTIES

IF some individuals reach some state/situation

THEN … do something … (e.g. align particular constant property to ind., name… define it into particular class)

ELSEIF ….

ELSE … do nothing…

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CAUSALISTIC PROPERTIES

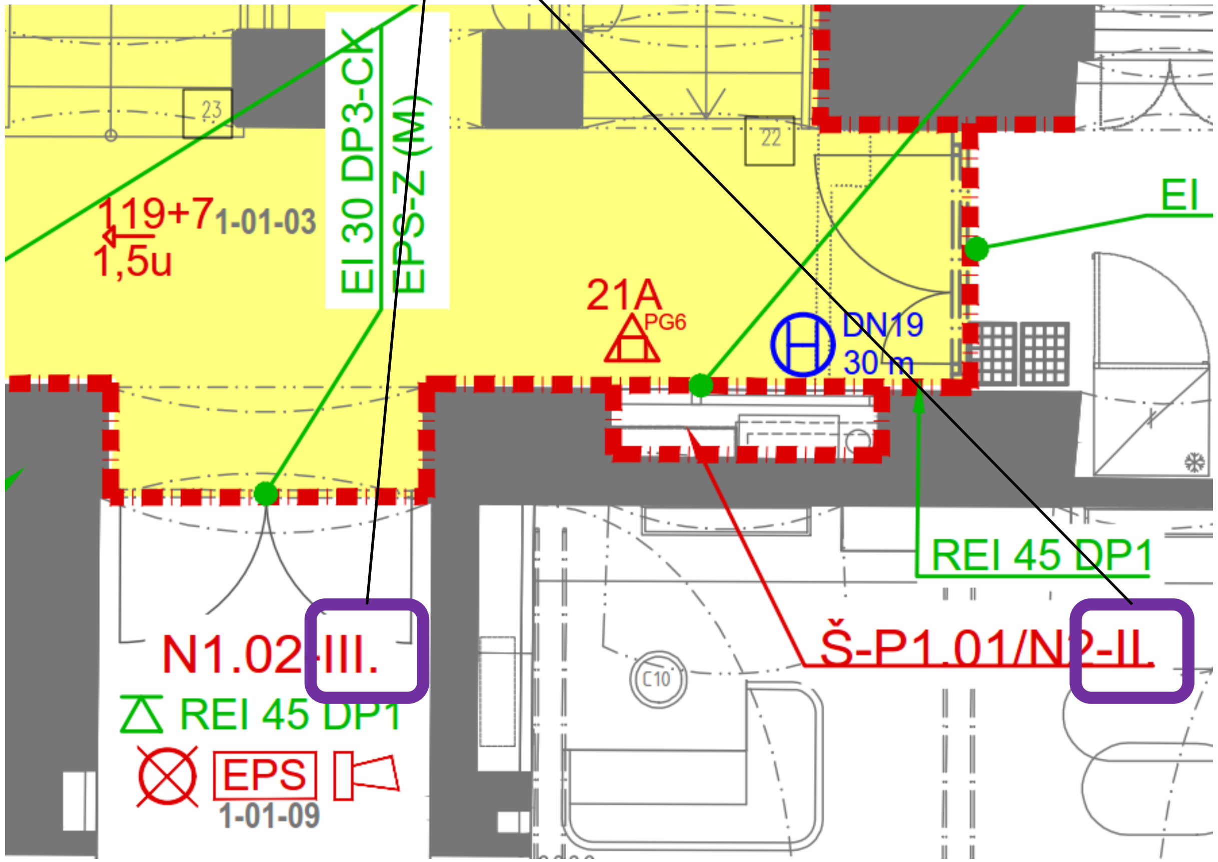
Would be possible to validate design according the fire code ?

Table 1 fire resistance of protected ventilation ducts and fire dampers

degree of fire safety of the fire zone	I.	II.	III.	IV.	V.	VI.	VII.
fire resistance of ventilation equipment [min]	15	15	30	30	45	60	90

=>Resulted required resistence is : 30 minutes

IF there would be two fire zones with adjanced area:
<u>align higher fire resistance parameter</u> to all air air systems elements passing through such area.



The basic scale of fire resistance is : 15, 30, 45, 60, 90, 120 a 180 minutes.
The classification of the product according to ČSN EN 13 501 is based on a test.

Degree of flammability 73 0823	Fire reaction class ČSN EN 13 501-1
A	A1
B	A2
C1	B
C2	C or D
C3	E or F

Tab. 1 - Stupně hořlavosti a třídy reakce na oheň

In the case of the European classification for reaction to fire classes A2, B, C and D, an additional classification is added which characterizes the product in terms of: falling or dripping of burning parts or droplets, (designation: d0, d1, d2), smoke generation (designation: s1, s2, s3).

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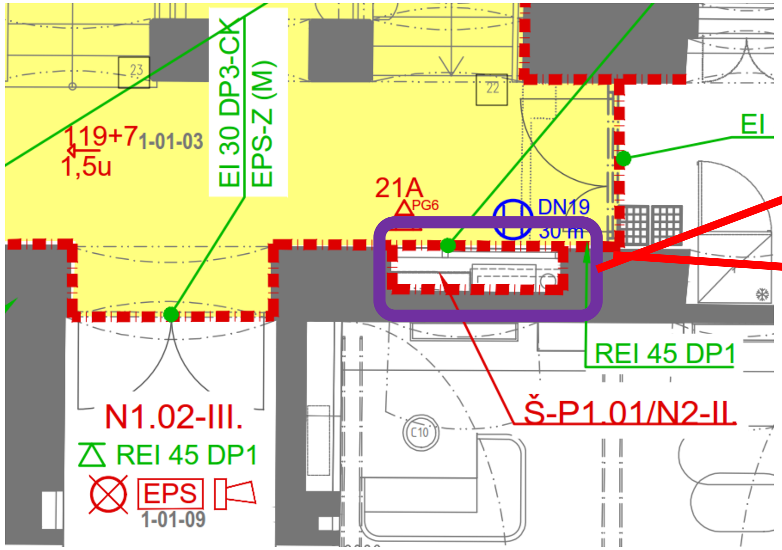
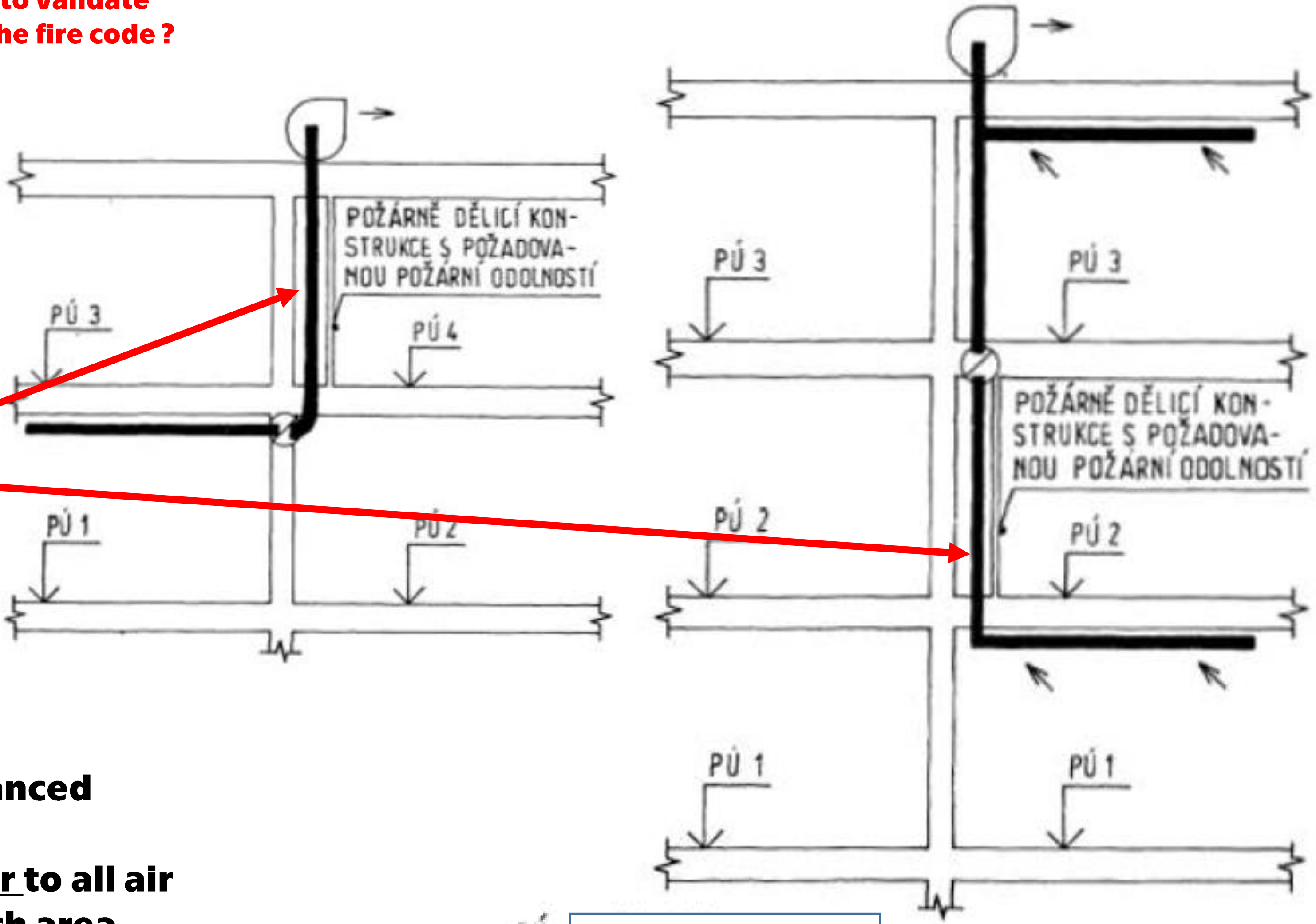
Would be possible to validate design according the fire code ?

CAUSALISTIC PROPERTIES





IF there would be two fire zones with adjanced area:

align higher fire resistance parameter to all air air systems elements passing through such area

- either define protection of duct

- or define requirement of fire damper

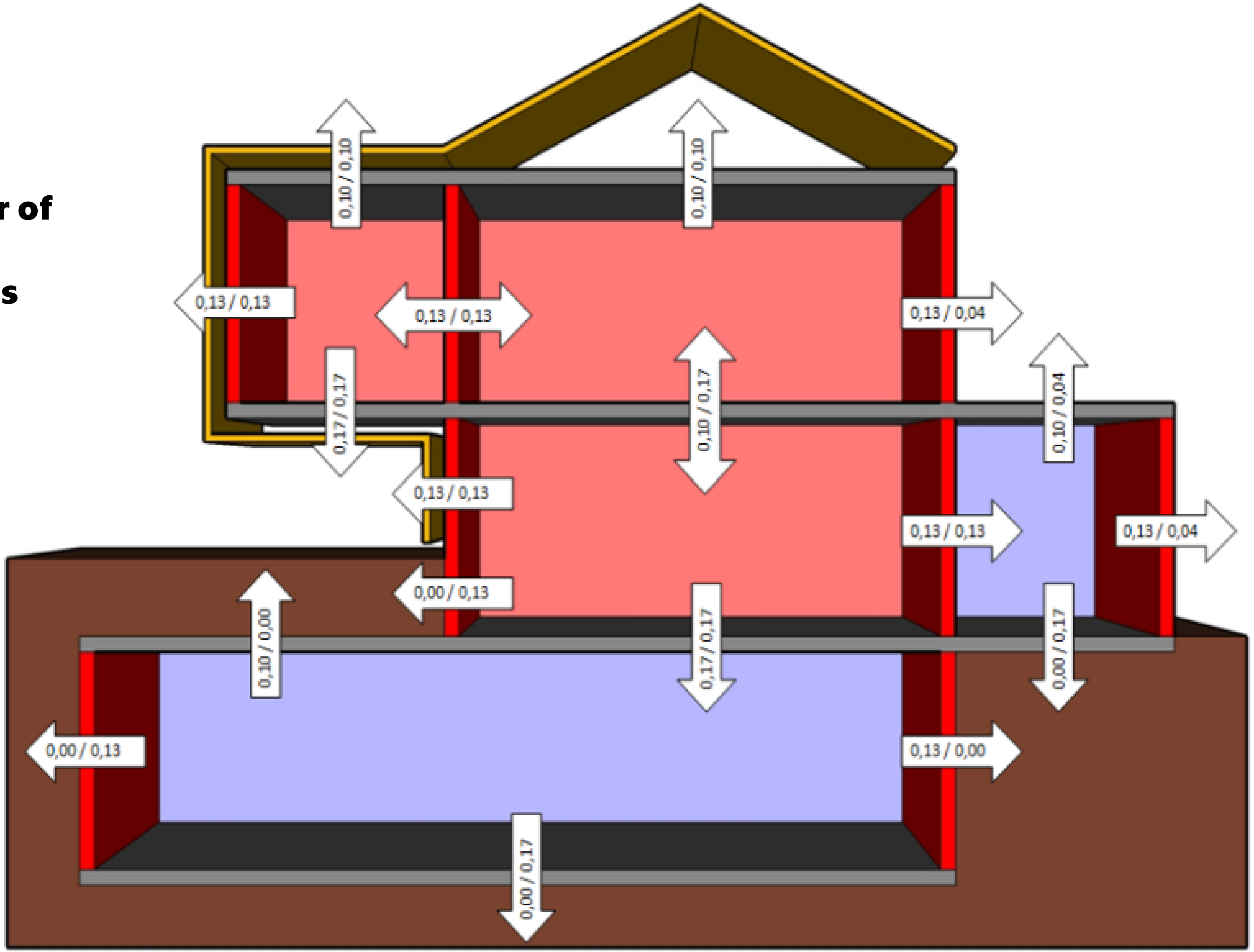
PÚ	**Fire zone**
⊘	**Fire damper**
↗	**Air inlet/outlet**

Source: ČSN 73 0872__[2-1996] fire safety of buildings (czech code)

Align particular constant to envelope element according pair of spacetypes aligned and take in account also heat-flow directions

$$U = \frac{1}{R_{si} + R + R_{se}} = \frac{1}{R_T}$$

$$R = \frac{1}{U} - (R_{si} + R_{se}) = R_T - (R_{si} + R_{se})$$



Source: EN 73 0540-2 [2011] computation UN,20 čl. 5.2.1. b)

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CAUSALISTIC PROPERTIES

Would be possible to align particular property value according spatial situation ?

IF there would be some shading element near the glazed opening:

<u>align shading data computed according space position to the glazed opening.</u>

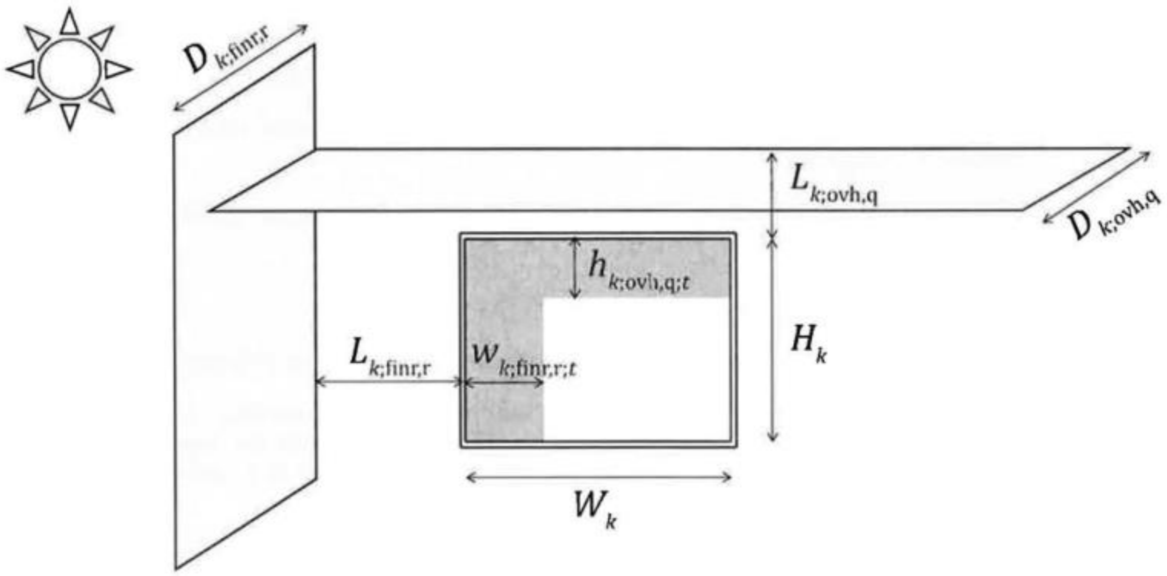


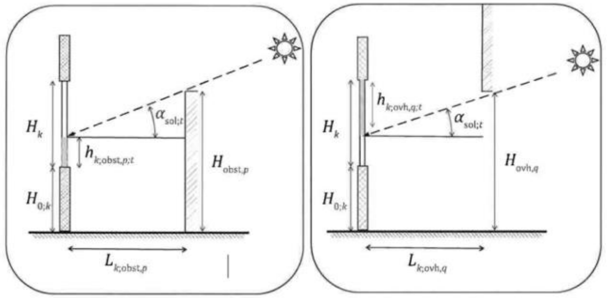
Figure F.1 — Geometry of simple overhangs or side fins

The shaded object (façade element):

The following data are needed for the façade element:

H_k the height of the façade element k, obtained from the geometry data of the element, in m; if tilted: the vertical projection of the height;

W_k the width of the façade element k, obtained from the geometry data of the element, in m.



a. Vertical cross-section - obstacles   b. Vertical cross-section - overhangs

Figure F.2 — Shading of the direct solar beam due to shading objects

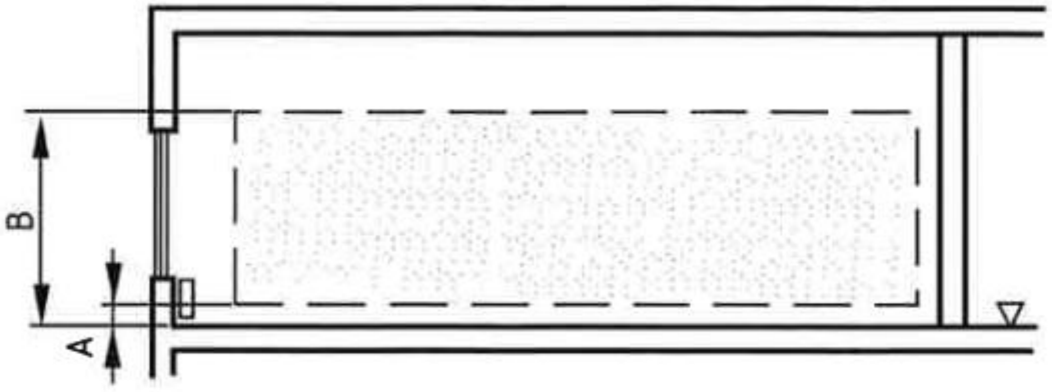
Source: **EN ISO 52016-1**

Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures

Source:EN 16798-[3:2020] Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)

EXAMPLE 3 SPATIAL

- **Could the occupied zone be „SPARQL-ed“ ?**

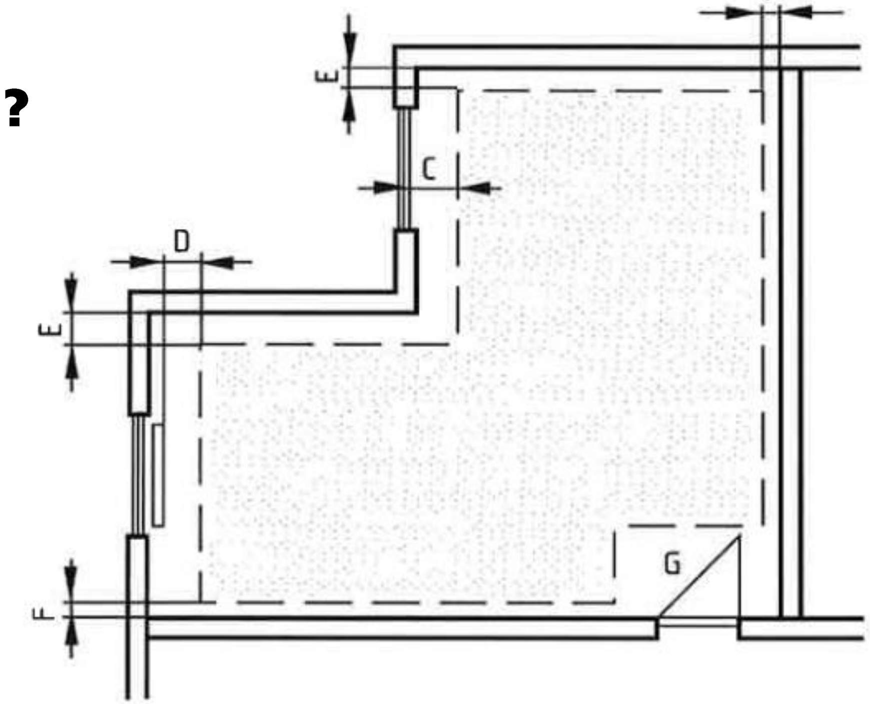


a)

Key

A vertical section

B plan view



b)

Figure 1 — Description of the occupied zone

Typical dimensions for the occupied zone are given in Table 5 and indicated in Figure 1.

Table 5 — Dimensions for the occupied zone

Distance from the inner surface of		Typical range (m)	Default value (m)
Floors (lower boundary)	A	0,00 to 0,20	0,05
Floors (upper boundary)	B	1,30 to 2,00	1,80
External windows and doors	C	0,50 to 1,50	1,00
HVAC appliances	D	0,50 to 1,50	1,00
External walls	E	0,15 to 0,75	0,50
Internal walls	F	0,15 to 0,75	0,50
Doors, transit zones etc.	G	Special agreement	-

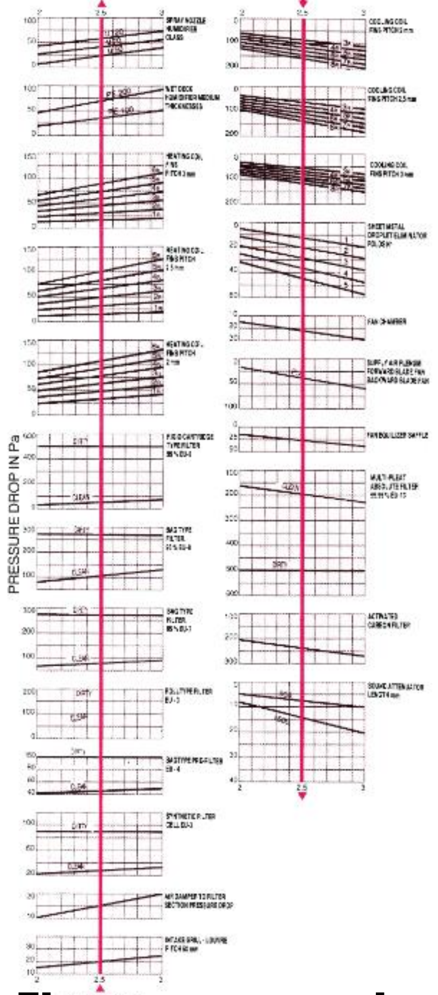
Usable for building daylight simulation processing :

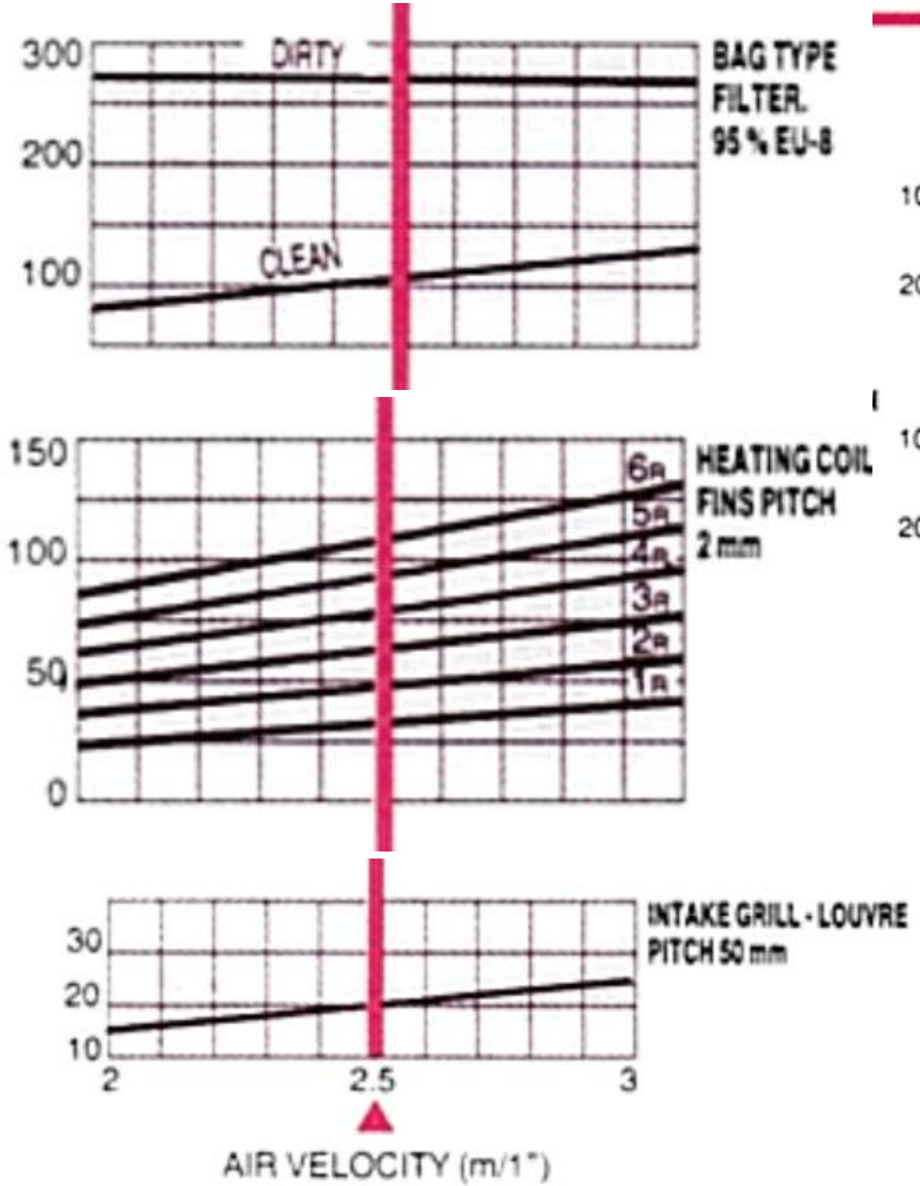
- **Visual comfort analysis BREEAM,**
- **Spatial Daylight Autonomy (sDA) etc.**

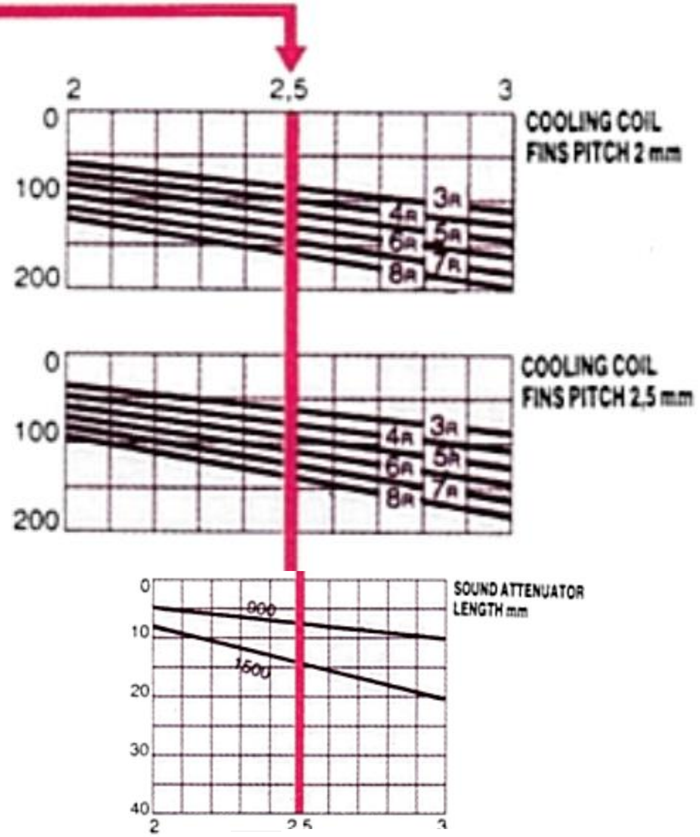
EXAMPLE 2 OPERATION PARAMS.

- **Pressure drop in AHU and its internal components -> principles**

Pressure drop of AHU components







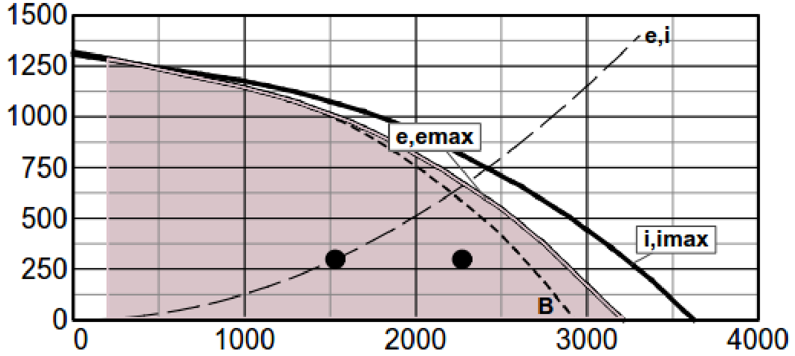


Figure: pressure drop in AHU, Source: CCVA Air handling units, Trane, CCVA-PRC-1003-EN

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Source: EN 16798-[3:2020] Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)
and also non-valid EN 13779 [4-1997] (non-valid)

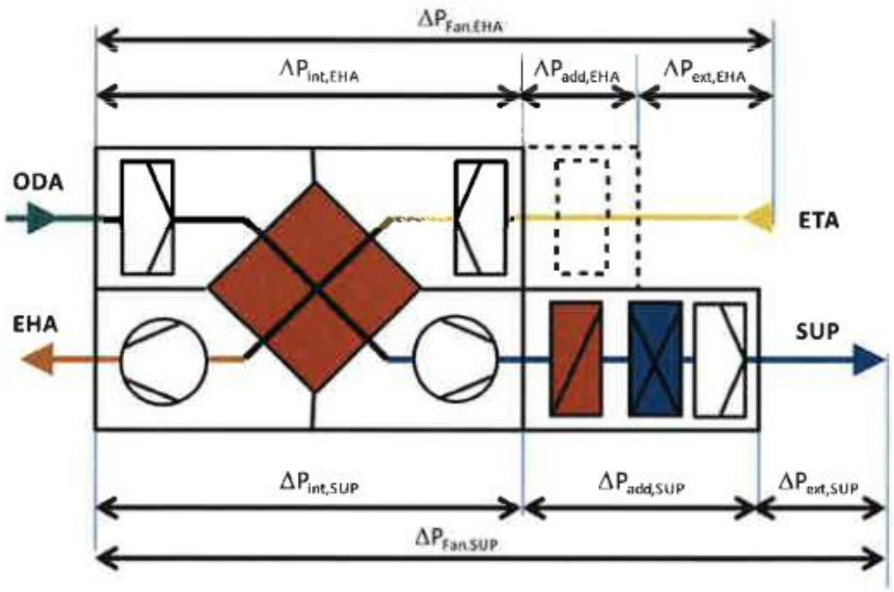

Figure 3 — AHU related P_{SFP} values

9.5.6 AHU related P_{SFP} values

To enable the designers of building projects to quickly determine whether a given air handling unit will positively or negatively meet the unit related demands on power efficiency, a $P_{SFP,int}$ and $P_{SFP,add}$ for the individual air handling unit has been defined. In this case the 3 parts of P_{SFP} (internal, additional and external pressure loads) are defined separately.

NOTE Requirements on ventilation units are specified in ErP Regulation EU 1253/2014 and EN 13053.

The **internal specific fan power** $P_{SFP,int}$ is the electric power, in kW, supplied to a fan and related to the internal pressure of all ventilation components (Filters, heat recovery and related casing) divided by the air flow expressed in m³/s under design load conditions.

EN 13053 is specifying details how $P_{SFP,int}$ shall be determined for units.

The **additional specific fan power** $P_{SFP,add}$ is the electric power, in kW, supplied to a fan and related to the internal pressure of all internal additional ventilation components (coolers, heaters, humidifier, etc.) divided by the air flow expressed in m³/s under design load conditions.

The **external specific fan power** $P_{SFP,ex}$ is the electric power, in kW, supplied to a fan and related to the external pressure divided by the air flow expressed in m³/s under design load conditions.

$$P_{SFP,\,SUP} = P_{SFP,\,SUP,\,int} + P_{SFP,\,SUP,\,add} + P_{SFP,SUP,\,ext} \tag{6}$$

$$P_{SFP,\,EXT} = P_{SFP,\,EXT,\,int} + P_{SFP,\,EXT,\,add} + P_{SFP,EXT,\,ext} \tag{7}$$

$$P_{SFP} = \frac{\Delta p_{int\,tot}}{\eta_{tot}} + \frac{\Delta p_{add\,tot}}{\eta_{tot}} + \frac{\Delta p_{ext\,tot}}{\eta_{tot}} = \frac{\Delta p_{int\,stat}}{\eta_{stat}} + \frac{\Delta p_{add\,stat}}{\eta_{stat}} + \frac{\Delta p_{ext\,stat}}{\eta_{stat}} \tag{8}$$

$$P_{SFP,int} = P_{SFP,\,SUP,\,int} + P_{SFP,\,EXT,\,,int} \tag{9}$$

Source: EN 16798-[3:2020] Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4)
and also non-valid EN 13779 [4-1997] (non-valid)

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Table 3— Input data for energy calculation

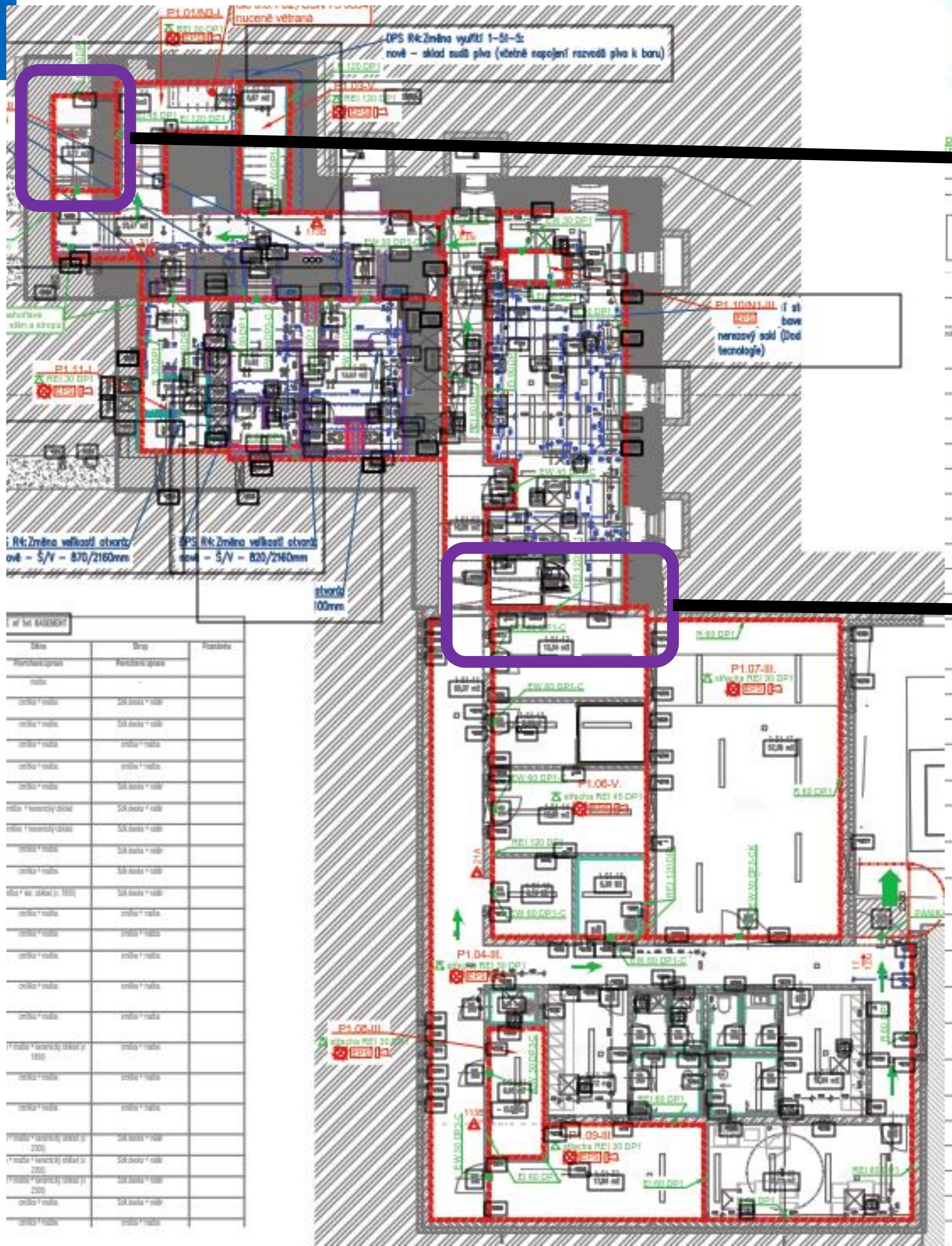
Name	Symbol	Unit	Validity interval	Ref	Varying
Ventilation rate per person	$q_{V,P}$	l/s m³/h l/(sm²) m³/(hm²)	0 - ∞	M1-6	no
Ventilation rate for building emission	$q_{V,B}$	l/s m³/h l/(sm²) m³/(hm²)	0 - ∞	M1-6	no
breathing zone ventilation	$q_{V,bz}$	l/s m³/h l/(sm²) m³/(hm²)	0 - ∞	M1-6	no
specific heating energy required for outdoor air treatment	q_{H}	Wh/(m³/h·a)	0 - ∞	M5-6-1	no
Delivered energy factor heat	f_{H}	-	0 – 1	M3-9	no
specific cooling energy required for outdoor air treatment	q_{C}	Wh/(m³/h·a)	0 - ∞	M5-6-1	no
Delivered energy factor cold	f_{C}		0 – 1	M4-8	no
specific humidification generation input	e_{HU}	Wh/(m³/h·a)	0 - ∞	M6-8	no
Primary energy factor humidifier	$F_{\mathrm{P,cr}}$		0 – 1	M6-8	no
primary energy factors electricity	$f_{\mathrm{P,S}}$		0 – 1	M1-9	no
primary energy factors heating	$f_{\mathrm{p,H}}$		0 – 1	M4-9	no

Table 4 — Output data for energy calculation

Name	Symbol	Unit	Range	Intended destination	Varying
average demand controlled air volume flow	$q_{V,dc}$	l/s m³/h l/(sm²) m³/(hm²)	0 - ∞	M5-2	no
ventilation outdoor air volume flow	$q_{V;\mathrm{ODA}}$	l/s m³/h l/(sm²) m³/(hm²)	0 - ∞	M5-2	no
Specific fan power	P_{SFP}	W.m⁻³.s	0 - ∞	M5-2 M5-6 M5-10	no
overall fan motor efficiency	η_e 1	-	0 - 1	M5-6 M5-10	no
Heat recovery coefficient of performance	ε	-	0 – 1	M5-6	no
Heat recovery energy efficiency	η_e 2	-	0 – 1	M5-6	no
Heat recovery temperature ration	η_t	-	0 – 1	M5-2	no
Heat recovery humidity ratio	η_h	-	0 – 1	M5-2	no
primary energy performance HVAC unit	$E_{\mathrm{P,V}}$	Wh/(m³/h·a)	0 - ∞	M5-9 M5-10	no

Design versioning

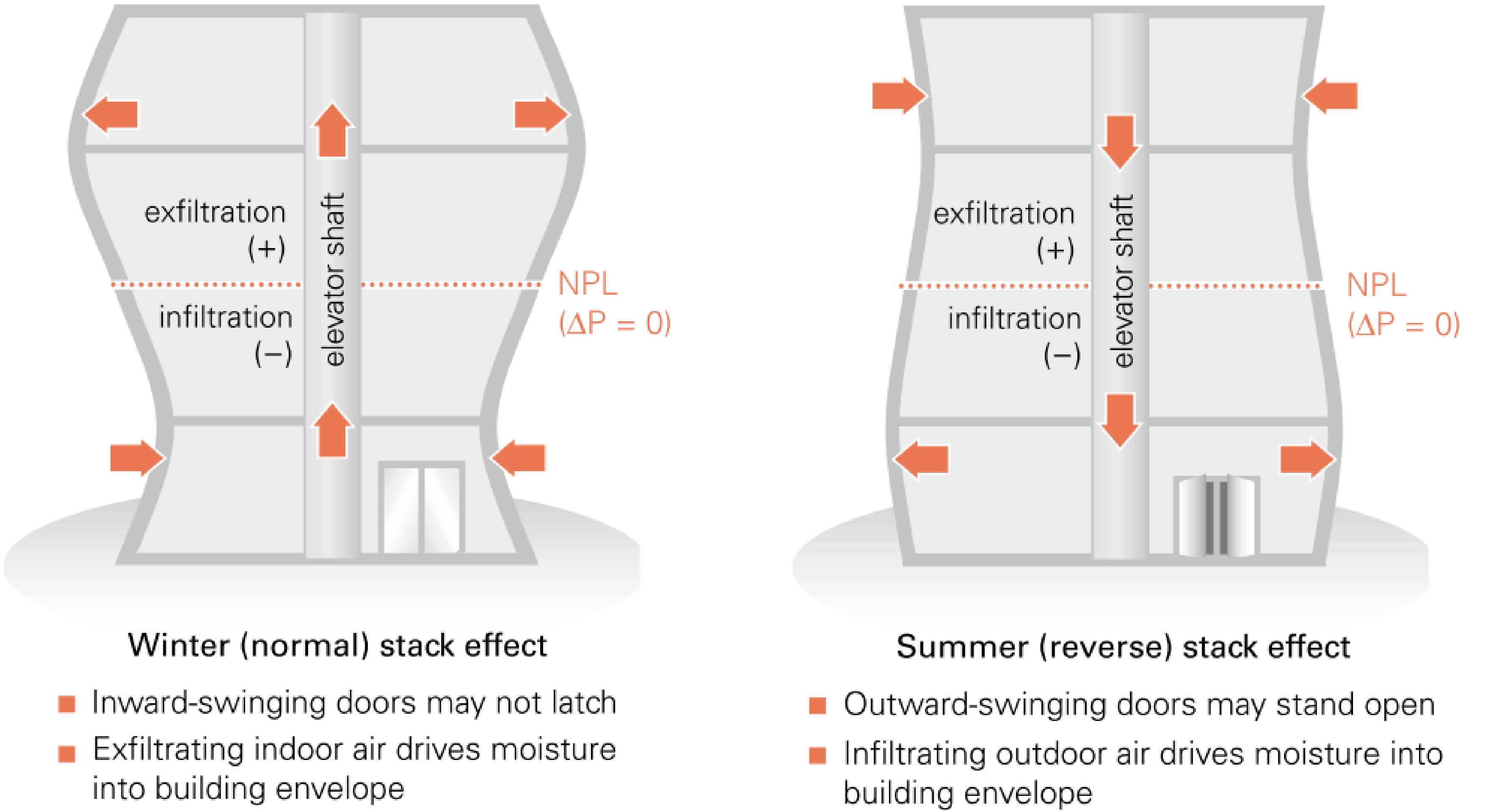
Fire protection layout [revision03]



Fire protection layout [revision04]

Pressure properties within builiding over-pressure / under-pressure estimations

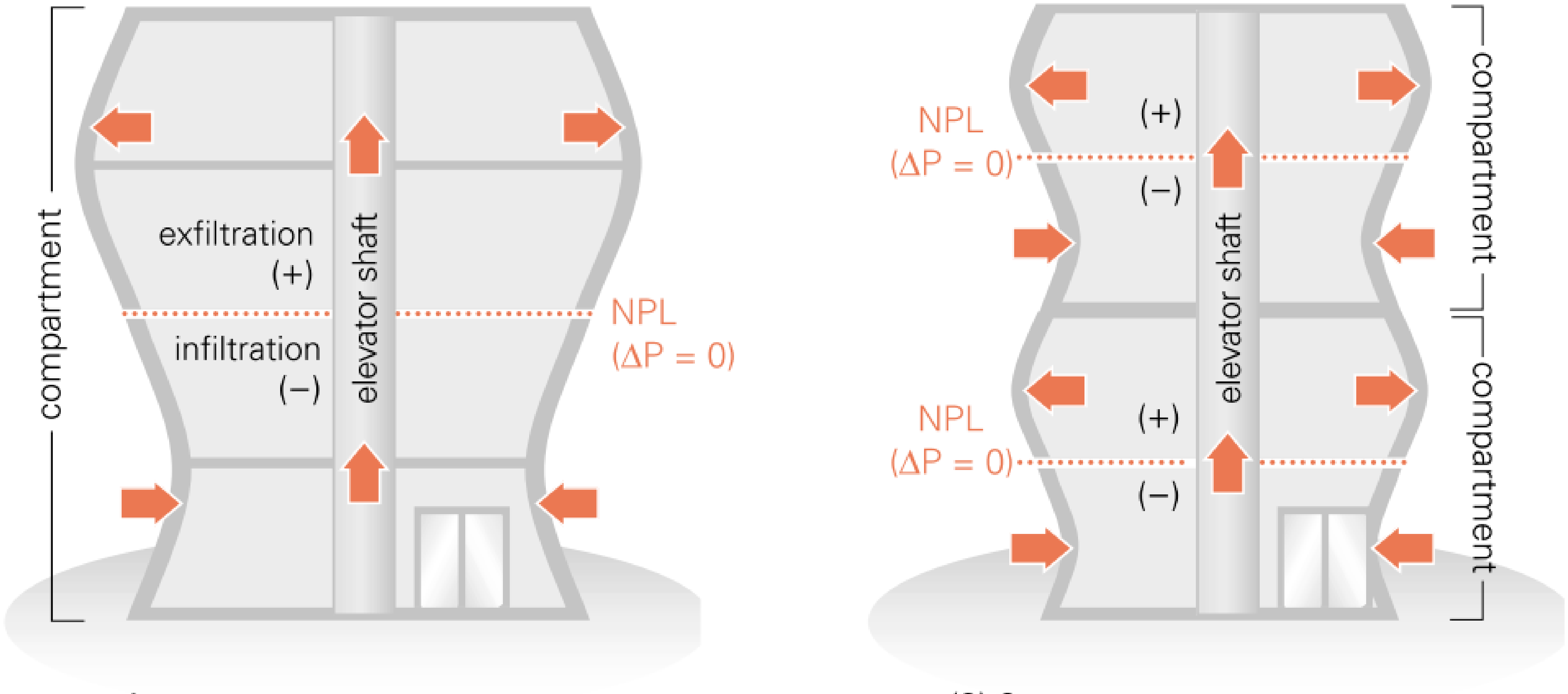
Figure 1. Stack effect and building pressure



Source: Trane Engineers Newsletter vol 31-2 (ADM-APN003-EN)

Pressure properties within builiding over-pressure / under-pressure estimations

Compartmentalization and winter stack effect



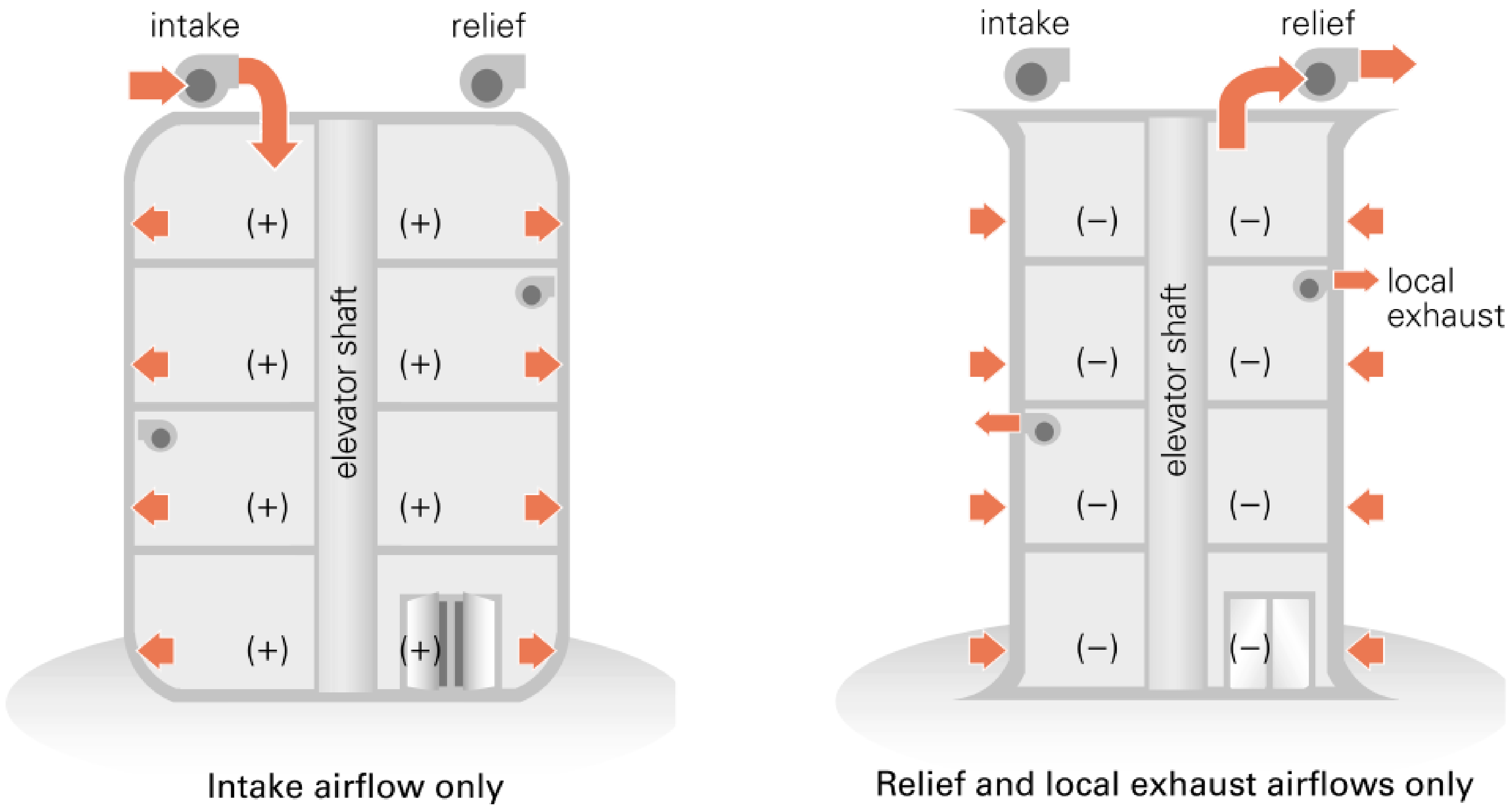
4-story pressure compartment

(2) 2-story pressure compartments

Source: Trane Engineers Newsletter vol 31-2 (ADM-APN003-EN)

Pressure properties within builiding over-pressure / under-pressure estimations

Figure 3. Effect of fan operation on building pressure



- Outward-swinging doors may stand open
- During winter, exfiltrating indoor air drives moisture into building envelope

- Inward-swinging doors may not latch
- During summer, infiltrating outdoor air drives moisture into building envelope

Source: Trane Engineers Newsletter vol 31-2 (ADM-APN003-EN)

Pressure properties within builiding FIRE SAFETY (WERY IMPORTANT)

EN 12101-6 Smoke and heat control systems - Part 6: Specification for pressure differential systems – Kits

… maybe next time