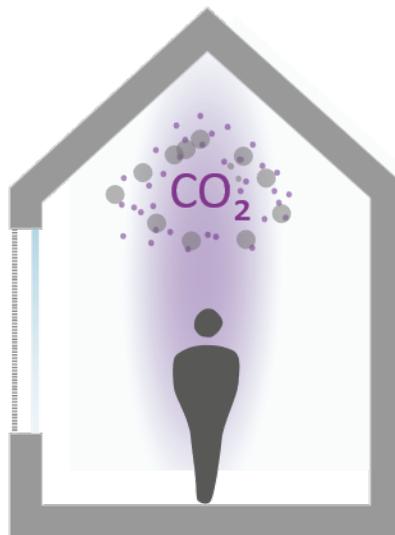


Trnsys User Manual

TYPE 388

CO₂ Concentration Model



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31.05.2022

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Table of Contents

1. Nomenclature	3
2. Introduction	4
2.1. <i>License agreement</i>	4
2.2. <i>Installation</i>	5
3. Trnsys Component Configuration	6
3.1. <i>Description of Parameters</i>	6
3.2. <i>Description of Inputs</i>	6
3.3. <i>Description of Outputs</i>	6
4. General Description	7
5. Mathematical Description	7
6. Validation based on DIN EN 16798-1:2015	9
6.1. <i>Parameters</i>	9
6.2. <i>Inputs</i>	9
6.3. <i>Results</i>	10
7. References	10

1. Nomenclature

n	1/h	air change rate \dot{V}/V
g_{Pers}	m ³ /h	CO ₂ generation in node from breathing (0.015-0.020 m ³ /h/Person)
g_{misc}	m ³ /h	CO ₂ generation in node from miscellaneous sources
V	m ³	Volume of node
\dot{V}	m ³ /h	Volume flow of supply air
ε	-	Air Supply Effectiveness
C_{Node}	ppm	CO ₂ concentration in node
C_{sup}	ppm	CO ₂ concentration in supply air
C_{ret}	ppm	CO ₂ concentration in return air

2. Introduction

This component models the CO₂ concentration of zones connected to a supply air source with a given flow rate and CO₂ concentration. Each zone is treated independently from the others and is represented by a single airnode with CO₂ sources. The air exchange of the airnode is limited to a single supply air and cannot be used to model an airflow network (airflow networks can be modelled by the TRNSYS AddOn TRNFlow). Different air distribution methods (e.g. mixed ventilation and displacement ventilation) are accounted for by means of ventilation effectiveness.

2.1. License agreement

Transsolar Energietechnik GmbH has developed the component Type 388 for the simulation program TRNSYS. The use of TRNSYS Type 388 is exclusively based on the following conditions.

I. Transfer of use free of charge

Transsolar Energietechnik GmbH grants the user a non-exclusive, non-transferable and non-sublicensable right to use TRNSYS Type 388. The transfer of use is free of charge.

II. Restrictions of use

TRNSYS Type 388 is protected by copyright and remains the property of Transsolar Energietechnik GmbH. The user is prohibited, even for parts of TRNSYS Type 388,

- to copy and distribute TRNSYS Type 388 (with the exception of the right to make a backup copy);
- modify, adapt, translate or create other derivative products of TRNSYS Type 388;
- rent, lend, lease or lease out TRNSYS Type 388 or otherwise make it available for use by third parties;
- reverse engineer, decompile, disassemble or otherwise decipher, extract or translate TRNSYS Type 388 source code. Excluded from this are the cases regulated in § 69 e UrhG.

III. Exclusion of warranty

The transfer takes place under exclusion of any warranty. Technical and professional support (support, hotline or similar) is not provided. Special features of TRNSYS Type 388 and/or its suitability for certain simulations and applications are not warranted.

IV. Liability

Except in the case of intent or gross negligence, the liability of Transsolar Energietechnik GmbH towards the user for damages, regardless of the legal reason, is excluded. Liability for culpable injury to life, body or health remains unaffected. As far as there is no intentional violation, the liability for indirect and/or consequential damages is excluded and limited to the typically foreseeable damage.

V. Hardware environment/ data backup

Transsolar Energietechnik GmbH points out that the use of software always depends on the hardware and software used by the user. The use of a suitable hardware and software environment is the sole responsibility of the user. Data backup in the sense of proper data processing and/or in order to comply with any existing legal storage or documentation obligations shall be the sole responsibility of the user.

VI. Term/ Termination

The right of use begins with the acceptance of the TRNSYS Type 388 license agreement by the user and runs for an indefinite period. Transsolar Energietechnik GmbH is entitled to terminate the right of use with a notice period of two months to the end of the year. In addition, both parties have the right to extraordinary termination for good cause. A violation will terminate the license agreement

VII. other provisions

Place of performance for services of Transsolar Energietechnik GmbH is Stuttgart. Amendments and supplements to this agreement must be made in writing. Should any provision of this agreement be or

become invalid or should the agreement contain a loophole, the legal validity of the remaining provisions shall remain unaffected. In place of the invalid provision, a valid provision shall be deemed to have been agreed which most closely approximates the economic intent of the parties; the same shall apply in the event of a loophole. This contract shall be governed by the laws of the Federal Republic of Germany to the exclusion of international private law and the UN Convention on Contracts for the International Sale of Goods. For all disputes arising from this contract, the jurisdiction of the Regional Court of Stuttgart is agreed.

2.2. Installation

For using Type388 the recent 64-bit TRNSYS Version (TRNSYS 18.04.) has to be installed. The provided installation copies files in the appropriate directories:

\\TRNSYS18\Documentation\Nostand

\\TRNSYS18\Examples\Nostand

\\TRNSYS18\SourceCode\Nostand

\\TRNSYS18\Userlib\

\\TRNSYS18\Studio\Proformas\Nostand\

NOTE: This component uses the unit “*parts-per-million*”. Please check if the unit dictionary of TRNSYS Studio has integrated this unit. Therefore, open TRNSYS Studio -> *Tools* -> *Unit dictionary*. If the unit “*parts-per-million*” doesn’t exist, click on “*Add...*” and add the dimension properties as shown in Figure 1.

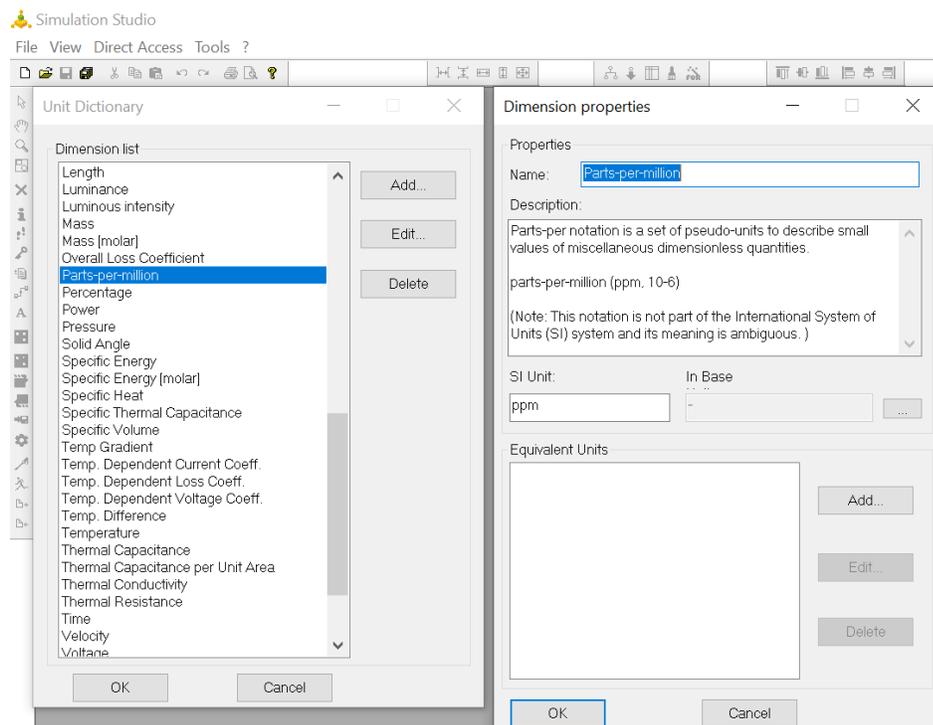


Figure 1: Unit dictionary of TRNSYS Studio

3. Trnsys Component Configuration

3.1. Description of Parameters

Par. no.	Symbol	Description	Unit
1	-	Number of air nodes	-
2	-	CO2 emission per occupant	m ³ /h

3.2. Description of Inputs

For each airnode specified in parameters:

Input no	Symbol	Description	Unit
1	-	Volume flow supply air	m ³ /h
2	-	Volume of airnode	m ³
3	-	CO2 concentration in supply air	ppm
4	-	Number of occupants	-
5	-	CO2 emission by miscellaneous sources	ppm
6	-	Supply air effectiveness	-

3.3. Description of Outputs

For each airnode specified in parameters:

Out. no	Symbol	Description	Unit
1	-	CO2 concentration in air node	ppm
2	-	CO2 concentration in return air	ppm

4. General Description

This component models the CO₂ concentration in an airnode connected to a supply air source and can be used to evaluate CO₂ dependent ventilation strategies. DIN EN 16798-1 introduced a guideline for the supply air volume flow dimensioning for such strategies, where CO₂ concentration target thresholds above the outdoor air are specified.

Type 388 is a simplified model with a defined volume flow and flow path.

The component can handle more than one airnode but each airnode is treated independently from the others and is represented by a single node with CO₂ sources. The air exchange of the airnode is limited to a single supply air and cannot be used to model an airflow network. (airflow networks can be modelled by the TRNSYS AddOn TRNFlow). Different air distribution methods (e.g. mixed ventilation and displacement ventilation) are accounted for by means of ventilation effectiveness. The corresponding ventilation effectiveness values for each ventilation set-up can be taken from the table below (VDI 3804:2009):

Table 1 Ventilation effectiveness for different air-handling systems based on [1]

Position	Ceiling			Floor		Wall			Facade		
	MV	MV	HV	HV	DV	MV	HV	DV	MV	HV	DV
Air-flow pattern											
Max. cooling load, in W/m ²	≤ 60	≤ 100	≤ 80	≤ 100	≤ 40	≤ 60	≤ 60	≤ 40	≤ 60	≤ 80	≤ 40
Temp. difference supply/indoor air at 1,1 m height	-3 to -5	-8 to -12	-6 to -8	-6 to -8	-1 to -3	-4 to -6	-6 to -8	-1 to -4	-4 to -6	-6 to -8	-1 to -3
Temp. difference supply/extract air	-3 to -5	-8 to -12	-7 to -10	-8 to -12	-2 to -7	-4 to -6	-7 to -10	-2 to -8	-4 to -6	-7 to -10	-2 to -7
Ventilation effectiveness	1	1	1.2	1.5	2	1	1.2	2	1	1.2 to 1.5	2
Type of ATU	tangentially through slot	swirl or high-ind. Slot diffuser	high-ind. slot diffuser	floor swirl diffuser	pedestal or circular floor diffuser	corridor-wall slot or grille	slot diffuser	large area diffuser	slot or window blow-out unit	inductive swirl diffuser	large-area diffuser

MV – mixed ventilation | HV – hybrid ventilation | DV – displacement ventilation

5. Mathematical Description

The CO₂ concentration in the room is calculated as described in the following paragraphs.

Eq. (1) Is the differential equation that describes the change in CO₂ concentration in the room.

$$\frac{dC_{node}}{dt} = nC_{sup} - nC_{ret} + G_{Pers} + G_{misc} \tag{1}$$

Hereby:

$$G_{Pers} = \frac{g_{Pers}}{V} 10^6 ppm \quad (2)$$

$$G_{misc} = \frac{g_{misc}}{V} 10^6 ppm \quad (3)$$

The ventilation effectiveness is defined as follows:

$$\varepsilon = \frac{C_{ret} - C_{sup}}{C_{node} - C_{sup}} \quad (4)$$

The ventilation effectiveness Eq. (4) is rearranged for C_{ret} and substituted in Eq. (1):

$$\frac{dC_{node}}{dt} = n\varepsilon C_{sup} - n\varepsilon C_{node} + G_{Pers} + G_{misc} \quad (5)$$

Eq. (5) is a first order linear nonhomogeneous differential equation of the form:

$$\frac{dY}{dt} = ay + b \quad (6)$$

Which is solved as follows:

$$Y = \left(Y_{t-1} + \frac{b}{a} \right) e^{a\Delta t} - \frac{b}{a} \quad (7)$$

Therefore, the function C_{node} that meets the requirements of Eq. (5) and describes the CO2 concentration in the room is:

$$C_{Node} = \left(C_{Node,t-1} - C_{sup} - \frac{G_{Pers} + G_{misc}}{n\varepsilon} \right) e^{-n\varepsilon\Delta t} + C_{sup} + \frac{G_{Pers} + G_{misc}}{n\varepsilon} \quad (8)$$

6. Validation based on DIN EN 16798-1:2015

Type 388 is validated with the steady state equation (Equation (2) in [2]):

$$C_{node} = \frac{g_{Pers}}{V\dot{\varepsilon}} 10^6 [ppm] - C_{sup} \tag{8}$$

Nine example scenarios were configured with Type 388 and compared to the results of the steady state equation.

ε -	g_{Pers} m ³ /h	V m ³	\dot{V} m ³ /h	C_{sup} ppm
1	1* 0.0187	90	35	400
1	2* 0.0187	90	70	400
1	3* 0.0187	90	90	400
1.5	1* 0.0187	90	35	400
1.5	2* 0.0187	90	70	400
1.5	3* 0.0187	90	90	400
2	1* 0.0187	90	35	400
2	2* 0.0187	90	70	400
2	3* 0.0187	90	90	400

6.1. Parameters

The number of airnodes was set to 9, to represent the 9 example scenarios. The CO2 emission per occupant was set to 0.0187 m³/h.

6.2. Inputs

The inputs were set up in accordance with the nine example scenarios described above.

The screenshot shows the TRNSYS software interface. On the left, a schematic diagram illustrates the connection between three components: Type388 (a house icon with a CO2 symbol), Type65d (a computer monitor icon), and Type25c (a printer icon). Arrows indicate the flow of data between these components.

On the right, a parameter input table is displayed with the following columns: Parameter, Input, Output, and Comment. The table lists 14 parameters for two different airnode scenarios (1 and 2).

Parameter	Input	Output	Comment
		Name	Value
1		Volume flow supply air-1	35
2		Volume of airnode-1	90
3		CO2 concentration of supply air-1	400
4		Number of occupants-1	1
5		CO2 emission by misc. sources-1	0
6		Supply air ventilation effectiveness-1	1
7		Volume flow supply air-2	70
8		Volume of airnode-2	90
9		CO2 concentration of supply air-2	400
10		Number of occupants-2	2
11		CO2 emission by misc. sources-2	0

Figure 2: Interface in Trnsys

6.3. Results

The results of both methods are in good agreement, as seen in the table below.

ε -	g_{Pers} m ³ /h	V m ³	\dot{V} m ³ /h	C_{sup} ppm	C_{node} (DIN) ppm	C_{node} (Type) ppm
1	1* 0.0187	90	35	400	934.3	934.2
1	2* 0.0187	90	70	400	934.3	934.3
1	3* 0.0187	90	90	400	1023.3	1023.3
1.5	1* 0.0187	90	35	400	756.2	756.2
1.5	2* 0.0187	90	70	400	756.2	756.2
1.5	3* 0.0187	90	90	400	815.6	815.6
2	1* 0.0187	90	35	400	667.1	667.1
2	2* 0.0187	90	70	400	667.1	667.1
2	3* 0.0187	90	90	400	711.7	711.7

7. References

[1] VDI 3804 - Air-conditioning Office buildings (VDI ventilation code of practice), March 2009

[2] DIN EN 16798-1 - Energy performance of buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics