Eurovent Industry Recommendation / Code of Good Practice

EUROVENT
EUROPEAN INDUSTRY ASSOCIATION

Eurovent 6/19-1 - 2024

Life Cycle Cost calculation for AHUs

Part 1. Energy consumption

First Edition

Published on 20 March 2024 by
Eurovent, 80 Bd A. Reyers Ln, 1030 Brussels, Belgium
secretariat@eurovent.eu

Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1st edition	Current document

Preface

In a nutshell

This Eurovent recommendation defines a standardised methodology for calculating the life cycle cost (LCC) of air handling units (AHU) in order to estimate the total cost associated with the unit over its lifetime, including both capital and operating expenditure. The aim is to enable a reliable comparison of different products and to support an informed choice when making an investment decision, considering all costs and environmental impacts. In addition to detailed guidelines on calculating energy consumption and costs, the recommendation provides novel methods for estimating the frequency and cost of regular maintenance and occasional repair and replacement.

The recommendation provides detailed calculation procedures for direct implementation in the AHU selection programme.

Eurovent 6/19 consists of two parts. Part 1 provides a detailed methodology for calculating annual energy consumption. Part 2, in addition provides a methodology for estimating the cost of regular maintenance and the cost of occasional repairs and replacements over the AHU lifetime. For the time being, Part 2 is only available to the SP-AHU1 members.

Authors

This document was published by the Eurovent Association and was developed in a joint effort by participants of the Special Project 'Air Handling Units 2030' (SP-AHU1), which comprised the companies 2VV, AIOLOS AIR, ALDAG, ALKO, ARFIT, ATREA, CAREL, COVENT, DAIKIN, EVAC, EXHAUSTO, FLÄKTGROUP, FLOWAIR, LINDAB, ROSENBERG VENTILATOREN BV, SALDA, SWEGON, SYSTEMAIR and TROX.

Particularly important contributions have been provided (in alphabetical order) by Gunnar Berg, Andy Bijmans, Bohumil Cimbal, Alvise Favaretto, Kees van Haperen, Pedro Lapa, Martin Lenz, Viktor Levickij, Peter Müller, Igor Sikonczyk, Peter Sundelin, Nicklas Svensson and Martin Törpe.

Copyright

© Eurovent, 2024

Unless otherwise stated hereafter, this publication may be reproduced in whole or in part, provided acknowledgement of the source is made. For any use or reproduction of photos or other material that is not owned by Eurovent, permission must be sought directly from the copyright holders.

Suggested citation

Eurovent AISBL / IVZW / INPA. (2024). Eurovent 6/19-1 - 2024 - Life Cycle Cost calculation for AHUs. Part 1. Energy consumption. Brussels: Eurovent.

Important remarks

The Eurovent Association does not grant any certification based on this document. All certification-related issues are managed by the association's independent subunit Eurovent Certita Certification in Paris. For more information, visit www.eurovent-certification.com.

Contents

List of abbreviations

AHU	Air Handling Unit
EHA	Exhaust Air (airflow leaving the extract air treatment system and discharged to the atmosphere)
ETA	Extract Air (airflow leaving the treated room and entering the air treatment system)
HRS / HR	Heat Recovery System
LCC	Life cycle cost
ODA	Outdoor Air (airflow entering the system from outdoors)
ORR	Occasional repair and replacement
PHE	Plate Heat Exchanger
RAC	Run-around coil
RMC	Regular maintenance cost
ROT	Rotary Heat Exchanger
SUP	Supply Air (airflow entering the treated room)

Main symbols used

symbol	UOM	Item
AW_C	kg	Annual water consumption for humidification
AW_{CAC}	kg	Annual water consumption for humidification, adiabatic cooling
C_C	€/kWh	Price of cooling energy, average EU market value
C_{EL}	€/kWh	Price of electricity, average EU market value
CMC	logic	Cooling coil operating mode
C_{TH}	€/kWh	Price of thermal energy – heating, average EU market value
C_{TS}	€/kWh	Price of thermal energy - steam humidifier, average EU market value
C_W	€/dm³	Price of water, average EU market value
DWO	logic	Indication of dry or wet cooling coil operation in j hour
E_{AC}	kWh	Annual adiabatic cooling energy
E_c	kWh	Annual energy consumption for cooling (sum)
E_{EAUX}	kWh	Annual auxiliary electric energy consumption - HRS drive, controls, pumps (sum)
E_{EAUX_AC}	kWh	Annual auxiliary electric energy consumption for adiabatic cooling
E_{EF}	kWh	Annual electric energy consumption for fans (sum)
E_{EH}	kWh	Annual electric energy consumption for heating (sum)
E_{EHU}	kWh	Annual electric energy consumption for steam humidification
E_{EpH}	kWh	Annual electric energy consumption for frost preheating (sum)
EFP	logic	Exhaust fan position
ER_c	kWh	Annual energy recovery for cooling, total (latent + sensible)
ER_H	kWh	Annual energy recovery for heating, total (latent + sensible)
E_{TH}	kWh	Annual thermal energy consumption for heating (sum)
E_{THU}	kWh	Annual thermal energy consumption for adiabatic humidifier
E_{THUs}	kWh	Annual thermal energy consumption for steam humidifier (central or gas)
E_{TpH}	kWh	Annual thermal energy consumption for frost preheating (sum)
F	-	Water consumption factor for humidifier (Eurovent Recommendation 6/8)
HT	logic	Type of steam humidifier (electric/gas fired/life steam system)

symbol	UOM	Item
IC	€	Acquisition cost of the AHU
j	-	Subsequent hour of the year
MR_{HU}	kg	Annual moisture recovery for humidification
n	year	Calculation period (AHU life span)
$P_{c,j}$	kW	Cooling coil power in j hour
PDR_E	dec.	Price development rate for electricity, thermal energy, cooling energy and water price, default
PDR_L	dec.	Price development rate for labour cost, default
$P_{e\_drv,j}$	kW	Electrical power input of rotary heat exchanger drive in j hour
$P_{e\_hu,j}$	kW	Electric power input for humidification in j hour (steam humidifier)
$P_{el\_pump,j}$	kW	Electrical power input of adiabatic humidifier pump in j hour
$P_{el\_pump\_nom}$	kW	Nominal power of adiabatic humidifier pump
PH	logic	Type of preheater for plate exchanger
$P_{h(s),j}$	kW	Heating coil power (of S type) in j hour
PHE	Logic	Type of plate heat exchanger (cross flow or counter flow)
$P_{HRS\_C,j}$	kW	Cool recovery power in j hour
$P_{HRS\_H,j}$	kW	Heat recovery power in j hour
$P_{PH(s),j}$	kW	Preheater power (of S type) in j hour
$P_{RH(Sr),j}$	kW	Reheater power in j hour (for moisture control in summer)
$P_{t(s),j}$	kW	Thermal power (of S type) for humidification in j hour
$P_{t\_hu,j}$	kW	Thermal power input for humidification in j hour
$q_{v1,j}$	m^3/s	Exhaust air flow rate in j hour
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate
$q_{v2,j}$	m^3/s	Supply air flow rate in j hour
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate
r_R	dec.	Risk-free real discount rate, default
S	logic	Type of heating / cooling source to determine energy price
Sr	logic	Type of re-heater for cooling coil with moisture control

symbol	UOM	Item
$t_{1,j}$	°C	Air Inlet temperature in j hour
$t_{11,j}$	°C	Exhaust air Inlet temperature in j hour
$t_{12,j}$	°C	Exhaust air outlet temperature in j hour
$t_{2,j}$	°C	Air outlet temperature in j hour
$t_{21,j}$	°C	Supply air Inlet temperature in j hour
$t_{22,j}$	°C	Supply air outlet temperature in j hour
$t_{ETA,j}$	°C	Extract air temperature in j hour
t_{ETA_DS}	°C	Design extract air temperature in summer
t_{ETA_DW}	°C	Design extract air temperature in winter
$t_{ODA,j}$	°C	Outdoor air temperature in j hour
t_{ODA_DS}	°C	Design outdoor air temperature in summer
t_{ODA_DW}	°C	Design outdoor air temperature in winter
$t_{SUP,j}$	°C	Supply air temperature in j hour
t_{SUP_DS}	°C	Design supply air temperature in summer
$Wc_{,j}$	kg/h	Water consumption for humidification in j hour
$x_{1,j}$	kg/kg	Air Inlet moisture content in j hour
$x_{11,j}$	kg/kg	Exhaust air Inlet moisture content in j hour
$x_{12,j}$	kg/kg	Exhaust air outlet moisture content in j hour
$x_{2,j}$	kg/kg	Air outlet moisture content in j hour
$x_{21,j}$	kg/kg	Supply air Inlet moisture content in j hour
$x_{22,j}$	kg/kg	Supply air outlet moisture content in j hour
$x_{ETA,j}$	kg/kg	Extract air moisture content in j hour
x_{ETA_DW}	kg/kg	Design extract air moisture content in winter
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in j hour
x_{ODA_DS}	kg/kg	Desing outdoor air moisture content in summer
x_{ODA_DW}	kg/kg	Desing outdoor air moisture content in winter
$x_{SUP,j}$	kg/kg	Supply air moisture content in j hour

symbol	UOM	Item
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in j hour
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in j hour
$\Delta t_{SH,j}$	°C	Air temperature increase during steam humidification in j hour
$\eta_{h(nom)}$	%	Adiabatic humidifier efficiency at nominal q_{v2}
$\eta_{t(nom)}$	%	Temperature efficiency (dry) of HRS at nominal q_{v1nom} and q_{v2nom}
$\eta_{x(nom)}$	%	Humidity efficiency of HRS at nominal q_{v1} and q_{v2}
$\phi_{1,j}$	%	Air inlet moisture content in j hour
$\phi_{11,j}$	%	Exhaust air inlet moisture content in j hour
$\phi_{12,j}$	%	Exhaust air outlet moisture content in j hour
$\phi_{2,j}$	%	Air outlet moisture content in j hour
$\phi_{21,j}$	%	Supply air inlet moisture content in j hour
$\phi_{22,j}$	%	Supply air outlet moisture content in j hour
$\phi_{ETA,j}$	%	Extract air moisture content in j hour
$\phi_{ODA,j}$	%	Outdoor air moisture content in j hour
ϕ_{ODA_DS}	%	Desing outdoor air moisture content in summer
ϕ_{ODA_DW}	%	Desing outdoor air moisture content in winter
$\phi_{SUP,j}$	%	Supply air moisture content in j hour

Main referred standards, regulations and documents

[1] EN 13053:2019 - Ventilation for buildings - Air handling units - Rating and performance for units, components and sections

[2] EN 15459-1:2017 - Energy performance of buildings - Economic evaluation procedure for energy systems in buildings - Part 1: Calculation procedures

[3] EN 16798-3:2017 - Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems

[4] EN 16798-5-1:2017 - Energy performance of buildings - Ventilation for buildings - Part 5-1: Calculation methods for energy requirements of ventilation and air conditioning systems - Performance requirements for ventilation and room-conditioning systems - Method 1: Distribution and generation

[5] EN 308:2022 - Heat exchangers - Test procedures for establishing performance of air to air and flue gases heat recovery devices

[6] EN ISO 12944 - Paints and varnishes. Corrosion protection of steel structures by protective paint systems

[7] EN ISO 9223 - Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation

[8] Commission Regulation (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for ventilation

[9] 2001 ASHRAE Fundamentals Handbook (SI)

[10] Stull. R, 2011: Wet-Bulb Temperature from Relative Humidity and Air Temperature, Journal of applied meteorology and climatology, Volume 50

[11] Tetens, O., 1930: Uber einige meteorologische Begriffe. Zeitschrift fur Geophysik, Vol. 6:297

Scope and purpose

The product price is often a dominant factor influencing investment decisions regarding air handling units. The CapEx-based decision approach focuses on the expenditure involved in the construction phase, but disregards the operational expenditure of the system, which usually far outweighs the investment costs over the lifetime of the unit.

The key elements that impact the system's operating costs over its lifetime include:

- Energy and utilities consumption
- Regular maintenance costs
- Occasional repair and replacement costs related to product wear and tear.

No less important, these factors have the biggest effect on the environmental impact of the product. The product use phase, which involves energy use, repairs and renovation, accounts for most CO_2 emissions over the product life cycle.

The design, energy efficiency and quality of a product have a major impact on all these factors.

The objective of this Recommendation is to define a standardised methodology for calculating the air handling unit's life cycle cost (LCC) in order to estimate the total cost associated with the unit over its lifetime, including both capital and operating expenditure. The aim of this tool is to enable a fair comparison of different products and to support an informed choice when making an investment decision, considering all costs and environmental impacts.

The Recommendation was developed with the intention of providing a comprehensive but also easy-to-implement tool, so if the omission of computational complexity did not significantly affect the accuracy of the results, some simplifications were applied to make the methodology easy to apply.

The AHU LCC methodology proposed by Eurovent members involves a number of novel elements that allow consideration of impacts such as:

- On energy consumption: moisture recovery, exchangers freezing, position of a fan and a related air temperature increase in the fan, part-load operation,
- On regular maintenance cost: ease of access to components
- On occasional repair: environment corrosivity and the AHU components corrosivity resistance class.

The Recommendation consists of two parts. The first part explains fundamentals of AHU LCC calculation and provides specific and exhaustive guidelines and procedures for calculating annual energy consumed by an air handling unit. Part 2, in addition provides a methodology for estimating the cost of regular maintenance and the cost of occasional repairs and replacements over the AHU lifetime.

The detailed algorithms presented in part 1 form the basis for the development of a LCC calculation module in the AHU selection software.

1 Life cycle cost for air handling unit

As per the general definition, the life cycle cost (LCC) is a technique to determine the sum of all recurring and one-off (non-recurring) costs over the full life span or a specified period of a product, service, structure, or system. It includes the purchase price, installation cost, operating costs, maintenance and repair costs, and remaining (residual or salvage) value at the end of ownership or its useful life. These summary costs are discounted to so called present value, in order to find the total cost at the time of taking the investment decision.

In a wider approach, all side costs related to the maintenance of system infrastructure may be addressed as well. These include for instance the building's operational costs (annual cost of insurance, utility fixed charges), staff training or costs of greenhouse gas emissions. These aspects however are not addressed in this recommendation.

1.1 Calculation of LCC for air handling units

The approach to the LCC calculation presented in this Recommendation provides for consideration of all costs related to the air handling unit, using data available to the manufacturer and system designer. This enables a simple comparison of various design options taking into account actual operating and environmental conditions. The evaluation includes:

- Investment cost (IC)
- Running costs - Energy and utilities (RC_{EU})
- Running costs - Regular maintenance (RC_{RM})
- Occasional Repair and Replacement costs (ORR)
- End of life costs (FC)

Annual energy consumption and costs are calculated using the degree-hours method for all components according to the defined unit configuration, operating schedule and scenarios.

The maintenance costs calculation includes all related activities and replacement of spare parts. Furthermore, it allows for specific features of the unit which facilitates these operations.

Occasional repair and replacement costs account for any renovations required due to corrosion of components and parts in order to keep the unit in proper condition over its lifetime. This assessment is based on the corrosivity of the operating environment.

The investment cost occurs only in the first year of the life cycle cost. Cost of energy and utilities consumption occurs each year. Consumptions are constant in each year but due to the price development rate (PDR), costs may vary in successive years. Regular maintenance costs occur in each year, yet their amount can differ in respective years. Occasional Repair and Replacement costs might occur in some years or do not appear at all. End of life costs occur in the last year of the life cycle.

The total cost (TC) related to the AHU in a given year (t) of a lifetime is defined as

$$TC_{(t)} = IC_{(t)} + RC_{EU(t)} + RC_{RM(t)} + ORR_{(t)} + FC_{(t)} \qquad [€]$$

The Life Cycle Cost of the unit is defined as

$$LCC = \sum_{t=1}^{n} \frac{TC_{(t)}}{(1+r_R)^t} = \sum_{t=1}^{n} \frac{IC_{(t)}+RC_{EU(t)}+RC_{RM(t)}+ORR_{(t)}+FC_{(n)}}{(1+r_R)^t} \qquad [€]$$

Where

n	–	assumed calculation period (AHU life span) in years
r_R	–	discount rate, decimal

The specific cost groups and cost elements used in the calculations are explained in the following paragraphs.

1.2 Economic and price factors for LCC calculations

To ensure comparability of the LCC analysis results, irrespective of local economic conditions, calculations should be carried out based on the Eurovent reference input data. In addition, if it is necessary to reflect the specifics of a particular market, calculations can be carried out based on case-specific economic and price factors. Therefore, two sets of economic and price inputs can be used to calculate the LCC result:

- Eurovent reference data (default),
- data for local market defined by the user.

Eurovent reference data include the general economic factors, energy and utility prices (for energy cost calculation) and labour rates (for regular maintenance and occasional repair and replacement costs calculation). The reference (default) prices and labour rates reflect the average EU market price level. Data provided by the user refer to a specific market. Both the reference and actual input data, as well as outcomes, should be presented on the printout.

The default Eurovent general economic factors include:

- LCC calculation period which represents the AHU life span.
- Discount rate, which is defined as the risk-free interest rate (the real interest rate allowing for inflation).
- Price development rate for energy price and labour cost, to take into account the different pace of growth of these cost components and inflation.

The Eurovent reference values are given in Annex 5

1.3 Presentation of LCC calculation results

In order to provide an unambiguous, fair and comprehensive comparison of the LCC analysis for different products, the calculation results should be presented in a standardised way.

The structure and list of items to be presented is outlined in Annex 6.

1.4 Costs related to the Life Cycle of AHU

The specific cost groups and cost elements used in the calculations are explained in the following paragraphs.

1.4.1 Investment cost (IC)

This refers to the AHU cost (purchase price). This value is provided by the manufacturer or supplier and includes all discounts applied. Services provided by third parties at the construction stage (installation of the unit, ductwork connection, commissioning etc.) are not included in the analysis. It is assumed that these costs are very similar regardless of the product and do not influence the outcome of the LCC. The investment cost occurs only in the first year of life cycle cost.

1.4.2 Energy and utility costs (RC_{EU})

This group covers all annual costs of energy and utility (water) consumption related to air handling, transport of air and driving components.

Annual cost of energy and utility consumption in respective years (t) is calculated as follows:

$$RC_{EU\,(t)} = RC_{EL(t)} \cdot (1 + PDR_E)^t + RC_{H(t)} \cdot (1 + PDR_E)^t + RC_{C(t)} \cdot (1 + PDR_E)^t + RC_{W(t)} \cdot (1 + PDR_E)^t$$

Where:

t - year of the AHU life cycle

PDR_E - Price development rate for electricity, thermal energy, cooling energy and water price.

Other factors are explained in following sections.

1.4.2.1 Cost of the annual electricity consumption (RC_{EL})

$RC_{EL(t)}$ is the cost of electricity annually consumed – depending on the unit configuration – by fans, electric heaters, drive of rotary exchanger, pumps of RAC and adiabatic humidifier, electric steam humidifier and control system. It is calculated based on a set energy price (C_{EL}).

$$RC_{EL(t)} = (E_{EF} + E_{EH} + E_{EpH} + E_{EAUX} + E_{EAUX\_AC} + E_{EHU} + E_{THU}{}^{*}) \cdot C_{EL}$$

Where:

E_{EF} - Annual electric energy consumption of fans, kWh
see section 3.5.1.1

E_{EH} - Annual electric energy consumption for heating, kWh
see section 3.5.1.2

E_{EpH} - Annual electric energy consumption for frost protection preheating, kWh
see section 3.5.1.3

E_{EAUX} - Annual auxiliary electric energy consumption - HRS drive, controls and pumps, kWh
see section 3.5.1.4

E_{EAUX_AC} - Annual auxiliary electric energy consumption for adiabatic cooling, kWh
see section 3.5.1.5

E_{EHU} - Annual electric energy consumption for steam humidification, kWh
see section 3.5.1.6

$E_{THU}{}^{*}$ - Annual thermal energy consumption for adiabatic humidifier, kWh
see section 3.5.1.7
*E_{THU} counts into electric energy consumption only if the electric heater is applied. Otherwise, it counts in $RC_{H(t)}$

C_{EL} - Electric energy price, €/kWh

1.4.2.2 Cost of the annual heating energy consumption (RC_H)

$RC_{H(t)}$ is the annual cost of heating energy consumed – depending on the unit configuration – by water heating coil(s), adiabatic humidifier and steam humidifier (central steam system or gas-fired). It is calculated based on a set energy price, separate for heating (C_{TH}) and for steam (C_{TS}).

$$RC_{H(t)} = (E_{TH} + E_{TpH} + E_{THU}) \cdot C_{TH} + E_{THUs} \cdot C_{TS}$$

Where

E_{TH} - Annual thermal energy consumption for heating, kWh
see section 3.5.2.1

E_{TpH} - Annual thermal energy consumption for frost preheating, kWh
see section 3.5.2.2

E_{THU} - Annual thermal energy consumption for adiabatic humidifier, kWh see section 3.5.2.3
E_{THUs} - Annual thermal energy consumption for steam humidifier (central or gas), kWh see section 3.5.2.4
C_{TH} - Heating energy price for water heating coils, €/kWh
C_{TS} - Thermal energy price for steam generation, €/kWh

1.4.2.3 Cost of the annual cooling energy consumption (RC_C)

$RC_{C(t)}$ is the annual cost of cooling energy consumed by a cooling coil (DX or water). It is calculated based on a set energy price (C_C).

$$RC_{C(t)} = E_C \cdot C_C$$

Where
E_C - Annual energy consumption for cooling, kWh see section 3.5.3
C_C - Cooling energy price, €/kWh

1.4.2.4 Cost of the annual water consumption (RC_W)

$RC_{W(t)}$ is the cost of the annual water consumption by humidifiers. It is calculated based on a set water price (C_w).

$$RC_{W(t)} = (AWc + AWc_{AC}) \cdot C_W$$

Where
AWc - Annual water consumption for humidification, kg see section 3.5.4.1
AWc_{AC} - Annual water consumption for humidification, adiabatic cooling, kg see section 3.5.4.2
C_W - Water price, €/kg

1.4.3 Regular maintenance costs (RC_{RM})

The Regular Maintenance Costs (RMC) part of the LCC calculations aims at estimating all expenses associated with the AHU maintenance activities occurring over the service lifetime.

The calculation model considers both the labour and material (spare parts) costs. Furthermore, it takes into account:

- types of activities and related labour rates,
- different replacement interval for respective spare parts (having regard to the actual annual operating time and outdoor/indoor air quality),
- AHU design features that facilitate maintenance activities (reducing labour time).

The complete calculation procedure is set out in Part 2 of the Recommendation.

1.4.4 Occasional Repair and Replacement costs (ORR)

Occasional repair and replacement (ORR) term means all measures related to the renovation of the unit structure (casing surfaces/panel) including painting, rust removal, etc., or replacement of entire components (coils, HRS, fans), resulting from corrosion damage.

The ORR assessment consists in estimating the period after which a component will need to be replaced and the cost of related repairs. Each component is evaluated separately, which means that parts of a particular AHU may have different renovations in different years of the life cycle time.

The ORR part of the LCC makes it possible to evaluate whether the corrosion protection measures applied to a unit are correctly matched to the corrosivity of the environment (no repairs needed over its lifetime), and if not, what additional costs will be incurred during the service life of the device.

This aspect is particularly important for AHUs operating in difficult corrosivity conditions (e.g., swimming pool or industrial applications).

The detailed procedure for calculating ORR is explained in Part 2 of the Recommendation.

1.4.5 End of life costs (FC)

End of life costs occur in the last year of the life cycle cost (n) and are calculated as:

$$FC_{(t=n)} = FC_{DS} - FC_{RV(t)}$$

Where:

FC_{DS} - Disposal cost including cost for disassembling at the end of life, removal, transport and recycling.

$FC_{RV(t)}$ - Residual value of a unit – defined as a percent of IC (acquisition cost).

With the life cycle period of 15 years (reference Eurovent calculation), the residual value is equal to zero. However, with a considerably shorter life cycle period (e.g., in case of systems in temporary buildings), the residual value is positive and represents income. It can be calculated as a percentage of the IC (AHU purchase price) using the straight-line depreciation method.

2 General introduction to the calculation methodology

The methodology includes three calculation modules that make use of common input data:

Energy and utility module

To estimate, depending on the AHU configuration, the annual consumption and cost of

- electricity (fans, electric heater and pre-/post-heater, HRS pump and drive, electric steam humidifier)
- heating energy (heating coil, pre-/post-heater, and gas-fired stem humidifier)
- cooling energy (cooling coil, in the temperature and moisture content control mode)
- water consumption (humidifier, adiabatic cooling)

Regular maintenance costs module

To estimate, depending on the AHU configuration, the annual costs for inspection, cleaning, servicing and part replacing activities. This module is presented in Part 2 of the Recommendation.

Occasional Repair and Replacement costs module

To estimate, depending on the AHU configuration, the cost of all measures related to the renovation of the unit structure (casing surfaces/panel) including painting and rust removal resulting from corrosion damage. This module is presented in Part 2 of the Recommendation.

2.1 Degree-hour approach

The energy calculations are based on the degree-hour approach, meaning that the calculations are carried out separately for each hour for the corresponding outdoor conditions (temperature and relative humidity) at a specific geographical location and for the extract and supply air conditions modelled according to a specific scenario. The total annual number of AHU operating hours depends on the defined operating mode schedule. It is also used for calculations in the regular maintenance and occasional repair modules.

2.2 Input data

In addition to the general design input data needed for unit selection (including air flow rates, external static pressure drop, design summer and winter temperatures), the following data are used for calculations.

2.2.1 Outdoor air parameters (temperature and moisture content)

Energy calculations are made for a defined geographic location based on a verified climate database, i.e. test reference years (TRY) considering long terms mean values for temperature and relative humidity of the outdoor air in each hour of the year. The most up to date climate data available from one of the main acknowledged data providers must be used in the LCC calculations. The database used must be stated in the calculation results. The climate data suppliers recommended by Eurovent are ASHRAE and METONORM.

2.2.2 Extract and supply air parameters (temperature and moisture content)

The temperature and moisture content of supply and extract air in each hour are determined depending on the corresponding outdoor temperature and moisture content based on defined scenarios.

The scenario functions are defined as follow:

- Supply air temperature: linear function of outdoor temperature with 3 inflexion points
- Extract air temperature: linear function of outdoor temperature with 2 inflexion points
- Supply air moisture content: linear function of outdoor air moisture content with 3 inflexion points
- Extract air moisture content = supply air moisture content + internal moisture load (defined, fixed and expressed in g/kg)

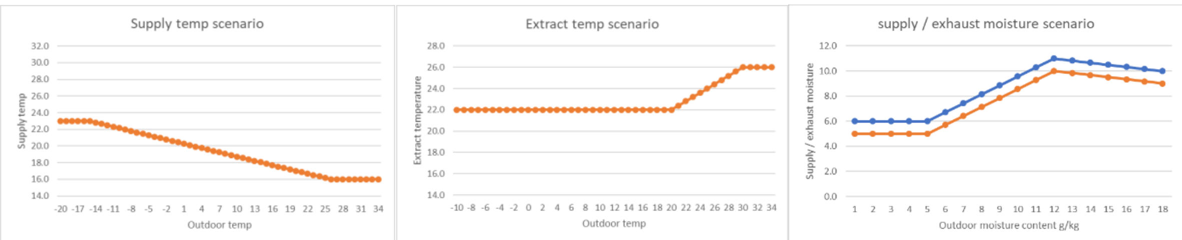

Figure 1. Examples of defined scenarios

This approach allows modelling of realistic temperature relationships and reproducing typical control system logic. Therefore, the coefficients of scenario functions are set based on an individual design specification. An example scenario for supply and exhaust air temperature and humidity in relation to the outdoor air parameters is presented in Figure 2.

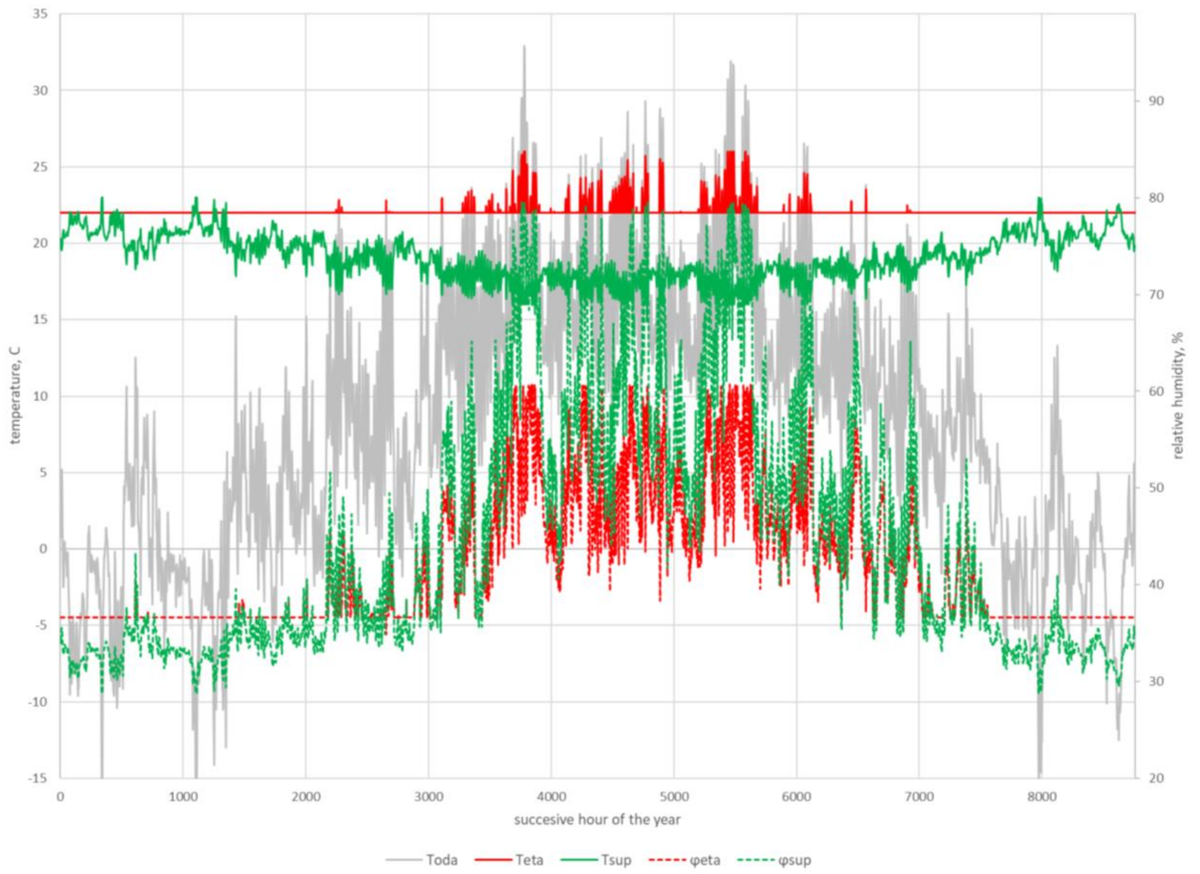

Figure 2. Example scenario for supply and extract air parameters in relation to the outdoor air

2.2.3 Definition of operating time

The operating mode schedule for the calculation involves setting a specific supply and extract airflow rate at each hour for each day of the week, defined in 20% increments. Possible inputs are: 0/20/40/60/80/100% of the nominal air flow rate.

Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun
00:00-01:00	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$
00:01-02:00	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$
……							
23:00-00:00	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$	$q_{v1,j}$, $q_{v2,j}$

Table 1. Example operating mode schedule table

The operating mode schedule should also allow to define an AHU downtime period (days of the year), e.g. due to a holiday break.

2.2.4 AHU technical specification and configuration

The LCC calculation uses a range of AHU technical and performance data for nominal design conditions. These are listed:

- For energy calculations in Annex 4.11 and description of each function.
- For regular maintenance calculations in part 2 of the Recommendation.
- For occasional repair and replacement calculations in part 2 of the Recommendation.

In addition, the configuration of the air handling unit, in other words the composition and sequence of components, must be defined for the energy calculation. The presented LCC methodology is flexible to calculate various configurations, and this Recommendation provides detailed guidelines and predefined calculation models for the following configurations:

No.	Main configuration type	Applicable to
1	HR+H	PHE/ROT/RAC
2	HR+H+C	PHE/ROT/RAC
3	HR+H+SH	PHE/ROT/RAC
4	HR+H+C+SH	PHE/ROT/RAC
5	HR+H+AH	PHE/ROT/RAC
6	HR+H+C+AH	PHE/ROT/RAC
7	AC+HR+H+C	PHE/ROTc/RAC
8	AC+HR+H+C+SH	PHE/ROTc/RAC
9	AC+HR+H+C+AH	PHE/ROTc/RAC
10	HR+MIX+H	PHE
11	HR+MIX+H+C	PHE
12	HR+MIX+H+SH	PHE
13	HR-MIX+H+C+SH	PHE
14	HR+MIX+H+AH	PHE
15	HR+MIX+H+C+AH	PHE
16	H	SUP
17	H+SH	SUP
18	H+AH	SUP
19	H+C	SUP
20	H+C+SH	SUP
21	H+C+AH	SUP
22	FAN only	EHA

Key	Function
AC	Adiabatic cooling
AH	Adiabatic humidifier
C	Cooling
EHA	Exhaust air only
H	Heating
HR	Heat recovery
MIX	Mixing
SH	Steam humidifier
SUP	Supply air only

Key	HR type
PHE	Plate HE
RAC	Round-around coil
ROT	Rotary HE, any type
ROTc	Rotary HE, condensation

Table 2. AHU configurations

3 Calculations of energy and utilities consumption

This part of the LCC calculation relates to annual consumption of electricity, heating energy, cooling energy and water consumption for humidification.

3.1 General structure of calculations

Energy and water consumption is calculated separately for each relevant AHU component and for each hour of the year included in the defined operating mode schedule. The hourly consumption values are then summed to obtain an annual value. The general calculation concept is presented in Figure 3.

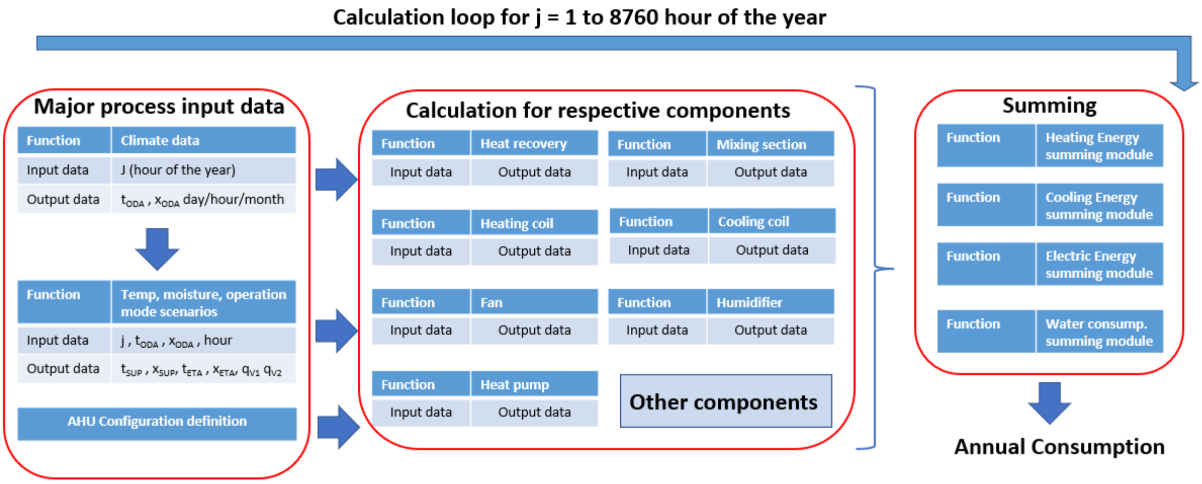

Figure 3. General concept of calculations

3.1.1 Functions for AHU components. Input and Output data

The calculation procedure for each AHU component is defined as a function. Each function has defined its set of inputs and outputs.

The inputs are, for example, information of the AHU technical specification (e.g., location of the exhaust fan upstream or downstream of the heat recovery, type of rotary exchanger – condensation or sorption), output values from the upstream component (e.g., heat recovery outlet temperature and moisture content) or outdoor air parameters. The inputs determine the course of calculation for a given component at a given hour of the year (e.g., whether to start heating).

The outputs are typically the results of calculations for energy and air parameter changes. They are used to determine the annual energy consumption and control the calculation for a downstream component.

In addition to the AHU component functions, there are separate functions for the operating mode schedule, climate data and supply and exhaust air parameters scenario. Their role is to determine the main process input data for each calculation hour, such as unit in operation (yes/no), actual air flow rate, and air temperatures.

The detailed description of functions is presented in Paragraph 3.3 and in Annex 4.

3.1.2 Configurations of AHU components. Data flow and calculation sequence

For a consistent and correct outcome, the LCC calculations need to be carried out in the proper order and sequence. The Recommendation provides models for configurations listed in section 2.2.4, which define the data flow and links between inputs and outputs of the relevant functions and AHU technical specification data. A general concept of the configuration model definition is presented in Figure 4. More information can be found in section 3.3 and models are presented in Annex 4.

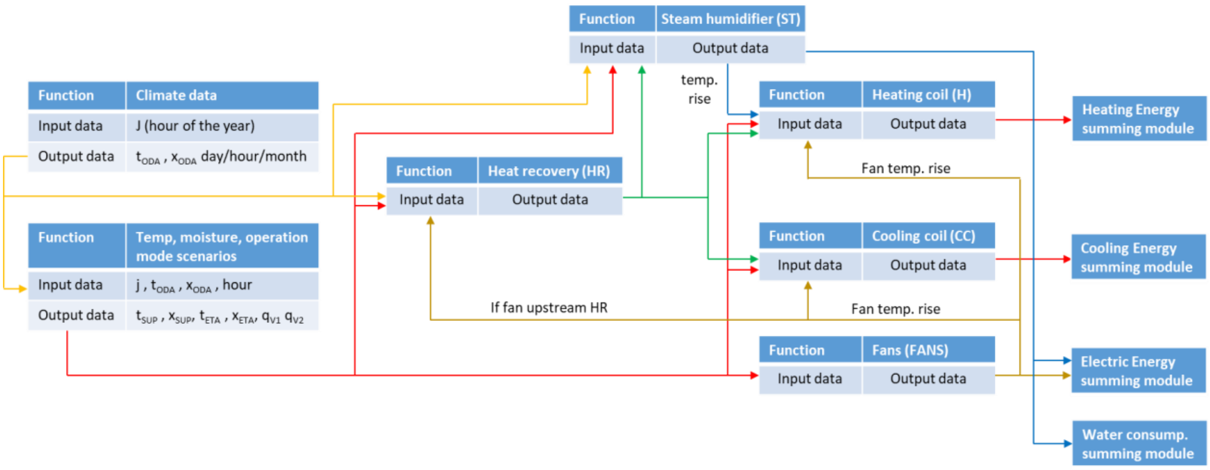

Figure 4. Configuration model concept

3.2 Psychrometric equations used in calculations

Definition of constants and psychrometric functions used in energy consumption calculations.

3.2.1 Constants

Standard air Density, ρ_s $\rho_s = 1{,}2$ kg/m^3

Air specific heat capacity, c_p $c_p = 1{,}006$ kJ/kgK

Moisture specific heat capacity, c_m $c_m = 1{,}86$ kJ/kgK

Evaporation heat of water (at 0°C), r r = 2501 kJ/kg

Standard atmospheric pressure, p_{atm} p_{atm} = 1013 hPa = 101325 Pa

3.2.2 Basic functions

Water vapour saturation pressure, p_{ws} [Pa]

Input data

t = air temperature (dry bulb), [°C]

For temperature range of -100 to 0°C

$$ln\, p_{ws} = \frac{C_1}{T} + C_2 + C_3 \cdot T + C_4 \cdot T^2 + C_5 \cdot T^3 + C_6 \cdot T^4 + C_7 lnT \qquad \{1\}$$

For temperature range of 0 to 200°C

$$ln\, p_{ws} = \frac{C_8}{T} + C_9 + C_{10} \cdot T + C_{11} \cdot T^2 + C_{12} \cdot T^3 + C_{13} lnT \qquad \{2\}$$

Where,

T = t + 273.15 [K]
C_1 = −5.674 535 9 E+03
C_2 = 6.392 524 7 E+00
C_3 = −9.677 843 0 E−03
C_4 = 6.221 570 1 E−07
C_5 = 2.074 782 5 E−09
C_6 = −9.484 024 0 E−13

C_7 = 4.163 501 9 E+00
C_8 = −5.800 220 6 E+03
C_9 = 1.391 499 3 E+00
C_{10} = −4.864 023 9 E−02
C_{11} = 4.176 476 8 E−05
C_{12} = −1.445 209 3 E−08
C_{13} = 6.545 967 3 E+00

Moisture content, x (kg/kg)

Input data

ϕ = relative humidity, [decimal]
t = air temperature (dry bulb), [°C]

$$x = 0.62198 \cdot \frac{\varphi \cdot p_{ws}}{p_{atm} - \varphi \cdot p_{ws}} \quad \{3\}$$

References: 2001 ASHRAE Fundamentals Handbook (SI)

Relative humidity, **ϕ** (decimal)

Input data

x = moisture content, [kg/kg]

$$\varphi = \frac{x \cdot p_{atm}}{p_{ws}(0.62198 + x)} \quad \{4\}$$

Moist air specific enthalpy, h (kJ/kg)

Input data

t = air temperature (dry bulb), [°C]
x = moisture content, [kg/kg]

$$h = c_p \cdot t + x \cdot (r + c_m \cdot t) = 1{,}006 \cdot t + x \cdot (2501 + 1{,}86 \cdot t) \quad \{5\}$$

Dew point temperature, t_d (°C)

Input data

t = air temperature (dry bulb), [°C]
ϕ = relative humidity, [decimal]
x = relative humidity, [kg/kg]

Approximate formulas:

$$t_d = \sqrt[8]{\varphi} \cdot [112 + (0.9 \cdot t)] + 0.1 \cdot t - 112 \quad \{6a\}$$

or

$$t_d = \frac{241.88 \cdot \ln\left(\frac{\varphi \cdot p_{ws}}{610.78}\right)}{17.558 - \ln\left(\frac{\varphi \cdot p_{ws}}{610.78}\right)} \quad \{6b\}$$

3.3 Functions for AHU components and major process input data

Functions are used to calculate momentary (in a given hour of the year) parameters pertaining to the components and main process input data (operating hours, outdoor air parameters, temperature and moisture content scenarios). Each function has a set of inputs and outputs that are assigned in the calculation data flow defined in the configuration models.

The structure of inputs and outputs definition is the following:

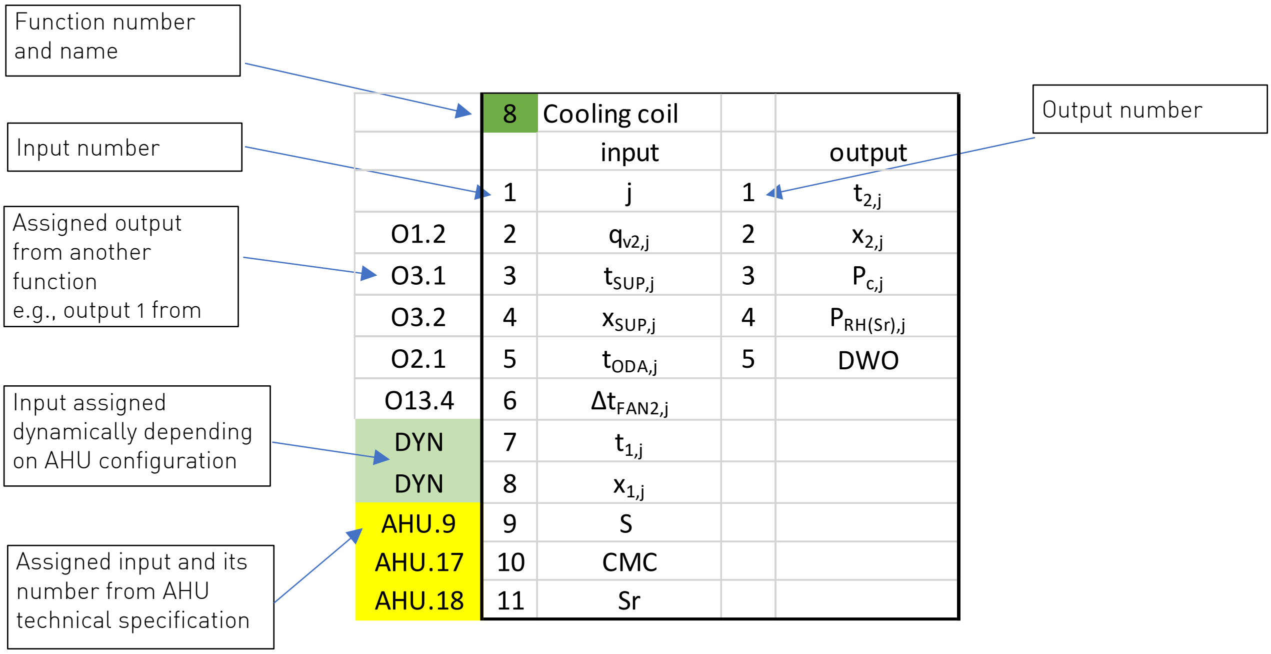

Figure 5. Structure of function inputs and outputs

The inputs and outputs of each function are presented in the following sections. For the list of AHU inputs see Annex 4.11. The detailed calculation procedures for each function are given in the Annexes.

No.	Symbol	Function	Annex number / notes
1		Operating mode scenario	Within the AHU selection software
2		Outdoor climate data	Within the AHU selection software
3		Temperature-moisture scenario	Within the AHU selection software
4	PHE	Cross and counterflow plate heat exchanger	Annex 4.1
5	ROT	Rotary heat exchanger	Annex 4.2
6	RAC	Run-around coils	Annex 4.3
7	H	Heating coil (water or electric)	Annex 4.4
8	CC	Cooling coil	Annex 4.5

No.	Symbol	Function	Annex number / notes
9	HUM-AD	Adiabatic humidifier	Annex 4.6
10	HUM-ST	Steam humidifier	Annex 4.7
11	ADC	Adiabatic cooling	Annex 4.8
12	HRS+MIX	Heat recovery and mixing section	Annex 4.9
13	FANS	Supply and exhaust fans	Annex 4.10

Table 3. List of functions and related annexes with detailed description

3.3.1 Operating mode scenario

This function is to be integrated into the AHU selection software and its LCC interface in accordance with section 2.2.3.

1	Operating mode scenario		
	input		output
1	j	1	$q_{v1,j}$
		2	$q_{v2,j}$

3.3.2 Outdoor climate data

This function is to be integrated into the AHU selection software and its LCC interface in accordance with section 2.2.1.

2	Outdoor climatic data		
	input		output
1	j	1	$t_{ODA,j}$
		2	$x_{ODA,j}$

3.3.3 Temperature-moisture scenario

This function is to be integrated into the AHU selection software and its LCC interface in accordance with section 2.2.2.

	3	Temperature-moisture scenario		
		input		output
	1	j	1	$t_{SUP,j}$
O2.1	2	$t_{ODA,j}$	2	$x_{SUP,j}$
O2.2	3	$x_{ODA,j}$	3	$t_{ETA,j}$
			4	$x_{ETA,j}$

3.3.4 Cross and counterflow plate exchanger (PHE)

The function PHE calculates outlet air parameters and energy recovery in a given j hour based on the value of input parameters. If applicable, the power of the anti-freeze preheater (water or electric) is also calculated. The freezing risk temperature is determined depending on the actual operating conditions, and if freezing risk occurs, the energy recovery is reduced accordingly. The efficiency of the exchanger is corrected according to the actual air flow rate. The function defines logical conditions for heat recovery activation depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.1

	4	Plate heat exchanger		
		input		output
	1	j	1	$t_{22,j}$
O1.1	2	$q_{v1,j}$	2	$x_{22,j}$
O1.2	3	$q_{v2,j}$	3	$P_{HRS\_H,j}$
O3.3	4	$t_{ETA,j}$	4	$P_{HRS\_C,j}$
O3.4	5	$x_{ETA,j}$	5	$P_{PH(s),j}$
O2.1	6	$t_{ODA,j}$		
O2.2	7	$x_{ODA,j}$		
O3.1	8	$t_{SUP,j}$		
O13.3	9	$\Delta t_{FAN1,j}$		
O13.4	10	$\Delta t_{FAN2,j}$		
AHU.1	11	q_{v1nom}		
AHU.2	12	q_{v2nom}		
AHU.3	13	$\eta_{t(nom)}$		
AHU.5	14	$\upsilon_{hr;nom}$		
AHU.4	15	EFP		
AHU.6	16	x_{ETA_DW}		
AHU.8	17	t_{ETA_DW}		
AHU.11	18	PH		
AHU.12	19	PHE		

Additional considerations:

If electric preheater, S = E and $P_{PH(s),j} = P_{PH(E),j}$

If water coil preheater, S = W and $P_{PH(s),j} = P_{PH(W),j}$

3.3.5 Rotary Heat Exchangers (ROT)

The function ROT distinguishes three types of rotors (condensate, hygroscopic and sorption) and calculates accordingly the outlet air parameters, energy (heat) recovery and moisture recovery in a given j hour based on the value of input parameters. Electric power input of the rotor drive is also calculated. The freezing risk temperature is determined depending on the rotor type and actual operating conditions. If freezing risk occurs, the energy recovery is reduced accordingly. The temperature efficiency is corrected according to the actual air flow rate. The moisture recovery efficiency is corrected according to the actual air flow rate and condensation potential. The function defines logical conditions for heat recovery activation depending on the actual conditions.

The calculation procedure for the function is detailed Annex 4.2

	5	Rotary heat exchanger		
		input		output
	1	j	1	$t_{22,j}$
O1.1	2	$q_{v1,j}$	2	$x_{22,j}$
O1.2	3	$q_{v2,j}$	3	$P_{HRS\_H,j}$
O3.3	4	$t_{ETA,j}$	4	$P_{HRS\_C,j}$
O3.4	5	$x_{ETA,j}$	5	$P_{e\_drv,j}$
O2.1	6	$t_{ODA,j}$		
O2.2	7	$x_{ODA,j}$		
O3.1	8	$t_{SUP,j}$		
O13.3	9	$\Delta t_{FAN1,j}$		
O13.4	10	$\Delta t_{FAN2,j}$		
AHU.1	11	q_{v1nom}		
AHU.2	12	q_{v2nom}		
AHU.3	13	$\eta_{t(nom)}$		
AHU.5	14	$\upsilon_{hr;nom}$		
AHU.4	15	EFP		
AHU.6	16	x_{ETA_DW}		
AHU.13	17	$\eta_{x(nom)}$		
AHU.14	18	P_{e_drv}		
AHU.15	19	ROTyp		

3.3.6 Run-around coils (RAC)

The function RAC calculates outlet air parameters and energy recovery in a given j hour based on the value of input parameters. Electric power input of the circulation pump is also calculated. The freezing risk temperature is determined depending on the actual operating conditions, and if freezing risk occurs, the energy recovery is reduced accordingly. The efficiency of the exchanger is corrected according to the actual air flow rate. The function defines logical conditions for heat recovery activation depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.3

	6	Run-around coil		
		input		output
	1	j	1	$t_{22,j}$
O1.1	2	$q_{v1,j}$	2	$x_{22,j}$
O1.2	3	$q_{v2,j}$	3	$P_{HRS\_H,j}$
O3.3	4	$t_{ETA,j}$	4	$P_{HRS\_C,j}$
O3.4	5	$x_{ETA,j}$	5	$P_{pump,j}$
O2.1	6	$t_{ODA,j}$		
O2.2	7	$x_{ODA,j}$		
O3.1	8	$t_{SUP,j}$		
O13.3	9	$\Delta t_{FAN1,j}$		
O13.4	10	$\Delta t_{FAN2,j}$		
AHU.1	11	q_{v1nom}		
AHU.2	12	q_{v2nom}		
AHU.3	13	$\eta_{t(nom)}$		
AHU.5	14	$\upsilon_{hr;nom}$		
AHU.4	15	EFP		
AHU.6	16	x_{ETA_DW}		
AHU.8	17	t_{ETA_DW}		
AHU.16	18	P_{el_pump}		

3.3.7 Heating Coil / Electric Heater (H)

Function H calculates outlet air parameters and heater output (thermal or electric) in a given j hour based on the value of input parameters. The function defines logical conditions for activating the component depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.4

	7	Heating coil		
		input		output
	1	j	1	$t_{2,j}$
O1.2	2	$q_{v2,j}$	2	$x_{2,j}$
O3.1	3	$t_{SUP,j}$	3	$P_{h(s),j}$
O2.1	4	$t_{ODA,j}$		
O13.4	5	$\Delta t_{FAN2,j}$		
O10.2	6	$\Delta t_{SH,j}$		
DYN	7	$t_{1,j}$		
DYN	8	$x_{1,j}$		
AHU.9	9	S		

Additional considerations:

If electric heater, S = E and $P_{h(s),j} = P_{h(E),j}$

If water coil, S = W and $P_{h(s),j} = P_{h(W),j}$

3.3.8 Cooling Coil (CC) for temperature or moisture control mode

Function CC provides two calculation modes: temperature control mode and moisture control mode. The first mode involves only the cooling coil, and its output is calculated so that it maintains the set supply temperature. The humidity of supply air is not controlled. The second mode involves the cooling coil and the post heater (water or electric) and calculates outlet air parameters and output of both cooling coil and reheater to maintain the set supply air temperature and moisture content. For both modes, calculations are carried out for a given hour of the year based on input parameter values. The adopted calculation method applies to both water and direct expansion (DX) cooling coils, and due to assumed simplifications, which only insignificantly impact the accuracy of results, does not require the water or refrigerant temperatures to be considered. Dry (without condensation) and wet (with condensation) operation are recognised, and the relevant information is communicated to the FAN function to adjust internal static pressure in a given hour of calculation. The function defines logical conditions for activating the component(s) depending on the actual conditions.

The calculation procedure for the function is detailed Annex 4.5

	8	Cooling coil		
		input		output
	1	j	1	$t_{2,j}$
O1.2	2	$q_{v2,j}$	2	$x_{2,j}$
O3.1	3	$t_{SUP,j}$	3	$P_{c,j}$
O3.2	4	$x_{SUP,j}$	4	$P_{RH(Sr),j}$
O2.1	5	$t_{ODA,j}$	5	DWO
O13.4	6	$\Delta t_{FAN2,j}$		
DYN	7	$t_{1,j}$		
DYN	8	$x_{1,j}$		
AHU.9	9	S		
AHU.17	10	CMC		
AHU.18	11	Sr		

3.3.9 Adiabatic humidifier (HUM-AD)

The function HUM-AD calculates outlet air parameters and thermal power for the adiabatic humidification process in a given hour based on value of inputs parameters. Water consumption and electric power input of the water pump are also calculated. The thermal power for humidification (beyond power needed to reach a set supply temperature) is calculated jointly for all heaters applied (one or two), so all heaters must be of the same type. The function defines logical conditions for activating the component(s) depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.6

	9	Adiabatic humidifier		
		input		output
	1	j	1	$x_{2,j}$
O1.2	2	$q_{v2,j}$	2	$P_{t\_hu,j}$
O3.2	3	$x_{SUP,j}$	3	$Wc_{,j}$
DYN	4	$x_{1,j}$	4	$P_{el\_pump,j}$
AHU.19	5	x_{ODA_DW}		
AHU.10	6	P_{el_nom}		
AHU.7	7	F		

3.3.10 Steam humidifier (HUM-ST)

The function HUM-ST calculates outlet air parameters, water consumption and the humidifier's power input in a given hour based on the value of input parameters. Power input can be electric, for an electric humidifier, or thermal for a gas-fired humidifier or one supplied from a central steam system. The temperature increase during the steam humidification process is also calculated and taken into consideration in other functions. The function defines logical conditions for activating the component(s) depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.7

	10	Steam humidifier		
		input		output
	1	j	1	$x_{2,j}$
O1.2	2	$q_{v2,j}$	2	$\Delta t_{SH,j}$
O3.2	3	$x_{SUP,j}$	3	$Wc_{,j}$
DYN	4	$x_{1,j}$	4	$P_{e\_hu,j}$
AHU.20	5	HT	5	$P_{t\_hu,j}$
AHU.7	6	F		

3.3.11 Adiabatic cooling (ADC)

The ADC function calculates the cooling effect of the supply air by a system comprising an adiabatic humidifier on the exhaust side and a heat recovery exchanger, which can be a plate heat exchanger, RAC or condensing rotary heat exchanger. The results calculated in a given hour include parameters of the indirectly cooled outlet air from the exchanger on the supply side, water consumption and power input of the humidifier pump. As a relevant function of the exchanger used is called during the computation, the results also include all outcomes calculated by this function. The function defines logical conditions for activating the component(s) depending on the actual conditions.

The calculation procedure for the function is detailed in Annex 4.8

	11	Adiabatic coolong		
		input		output
	1	j	1	$t_{22,j}$
O1.1	2	$q_{v1,j}$	2	$x_{22,j}$
O1.2	3	$q_{v2,j}$	3	$Wc_{,j}$
O3.3	4	$t_{ETA,j}$	4	$P_{el\_pump,j}$
O3.4	5	$x_{ETA,j}$	5	$P_{AC,j}$
O2.1	6	$t_{ODA,j}$		
O2.2	7	$x_{ODA,j}$		
O3.1	8	$t_{SUP,j}$		
O13.3	9	$\Delta t_{FAN1,j}$		
O13.4	10	$\Delta t_{FAN2,j}$		
AHU.1	11	q_{v1nom}		
AHU.21	12	η_{h_nom}		
AHU.10	13	P_{el_nom}		
AHU.7	14	F		
AHU.4	15	EFP		

3.3.12 Heat recovery and mixing section (HRS+MIX)

The HRS+MIX function calculates parameters of the mixed air with consideration of the heat recovery impact. Due to the complexity of calculations for the mixing section – heat recovery set-up (variability of temperature/moisture efficiency, HRS freezing, difficulty with finding the mixing point at enthalpy control mode), the calculation procedure involves a number of limitations, which are outlined in the function description.

The calculation procedure for the function is detailed in Annex 4.9

	12	HRS + MIXING		
		input		output
	1	j	1	$t_{mix,j}$
O1.1	2	$q_{v1,j}$	2	$x_{mix,j}$
O1.2	3	$q_{v2,j}$		
O3.3	4	$t_{ETA,j}$		
O3.4	5	$x_{ETA,j}$		
O2.1	6	$t_{ODA,j}$		
O2.2	7	$x_{ODA,j}$		
O3.1	8	$t_{SUP,j}$		
O13.4	10	$\Delta t_{FAN2,j}$		
AHU.1	11	q_{v1nom}		
AHU.2	12	q_{v2nom}		
AHU.35	13	q_{VODA_min}		

Additional considerations:

Function PHE (4) is called inside function HRS+MIXING. All input data relevant for function PHE also apply.

3.3.13 Fans (FAN)

The FAN function calculates the electric power input of the supply and/or exhaust fan, and the associated air temperature rise in a given hour based for the nominal or actual set air flow rates and a number of input parameters from the AHU technical specification.

The calculation procedure for the function is detailed in Annex 4.10

	13	Fans		
		input		output
	1	j	1	$P_{el\_FAN1,j}$
O1.1	2	$q_{v1,j}$	2	$P_{el\_FAN2,j}$
O1.2	3	$q_{v2,j}$	3	$\Delta t_{FAN1,j}$
O8.5	4	DWO	4	$\Delta t_{FAN2,j}$
AHU.1	5	q_{v1nom}		
AHU.2	6	q_{v2nom}		
AHU.22	7	$P_{mot\_rated\_1}$		
AHU.23	8	$P_{mot\_rated\_2}$		
AHU.24	9	MT1		
AHU.25	10	MT2		
AHU.26	11	WPC		
AHU.27	12	Δp_{ext1_nom}		
AHU.28	13	Δp_{int1_nom}		
AHU.29	14	Δp_{ext2_nom}		
AHU.30	15	Δp_{int2_nom}		
AHU.31	16	Δp_C		
AHU.32	17	$P_{el\_FAN1(nom)}$		
AHU.33	18	$P_{el\_FAN2(nom)}$		
AHU.34	19	$P_{el\_FAN2\mathbf{w}(nom)}$		

3.4 Calculation data flow-chart and sequence

The sequence and data flow for energy calculations involving the various component functions for different AHU configurations are presented in charts in the Annex 4 - energy calculations.

Each chart, for a given AHU configuration, explains the sequence of calculation procedures and the links between outputs and inputs of the involved functions. It also indicates the inputs that are assigned dynamically depending on the AHU configuration. An example chart is shown in Figure 6.

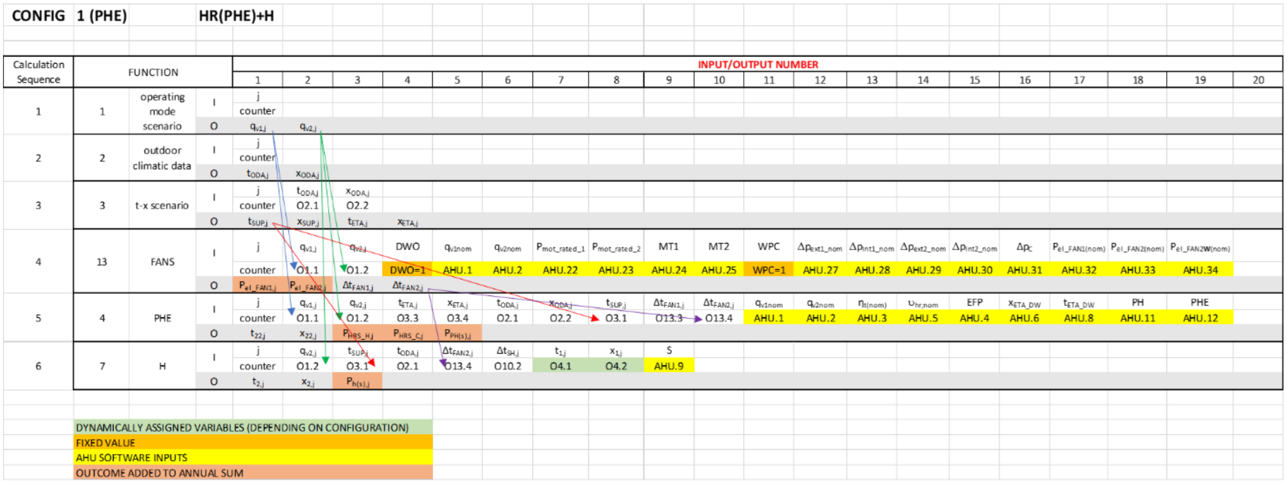

Figure 6. Example chart for calculation sequence and dataflow.

In addition to the general AHU component configuration layout, the function input values that define the AHU technical specification, enable to take into account a number of individual AHU features in the calculation. The functionalities covered for various AHU configurations are presented in the following sections.

3.4.1 PHE configurations

Where applicable, preheater (for frost protection) and reheater (for humidity control) calculations are embedded, respectively in the PHE and CC functions.

		COMPONENT / FUNCTION INCLUDED (*Embeded subcomponent calculation if applicable)							
Config. number	configuration type	HRS type preheater*	EHA fan position	Mixing section	heater water/electric	cooler water/dx reheater*	humidifier steam	humidifier adiabatic	adiabatic cooling
1 (PHE)	HR+H	Plate	down or up	no	yes	no	no	no	no
2 (PHE)	HR+H+C	Plate	down or up	no	yes	yes	no	no	no
3 (PHE)	HR+H+SH	Plate	down or up	no	yes	no	yes	no	no
4 (PHE)	HR+H+C+SH	Plate	down or up	no	yes	yes	yes	no	no
5 (PHE)	HR+H+AH	Plate	down or up	no	yes	no	no	yes	no
6 (PHE)	HR+H+C+AH	Plate	down or up	no	yes	yes	no	yes	no
7 (PHE)	AC+HR+H+C	Plate	down or up	no	yes	yes	no	no	yes
8 (PHE)	AC+HR+H+C+SH	Plate	down or up	no	yes	yes	yes	no	yes
9 (PHE)	AC+HR+H+C+AH	Plate	down or up	no	yes	yes	no	yes	yes
10 (PHE)	HR+MIX+H	Plate	down or up	yes	yes	no	no	no	no
11 (PHE)	HR+MIX+H+C	Plate	down or up	yes	yes	yes	no	no	no
12 (PHE)	HR+MIX+H+SH	plate	down or up	yes	yes	no	yes	no	no
13 (PHE)	HR-MIX+H+C+SH	Plate	down or up	yes	yes	yes	yes	no	no
14 (PHE)	HR+MIX+H+AH	Plate	down or up	yes	yes	no	no	yes	no
15 (PHE)	HR+MIX+H+C+AH	Plate	down or up	yes	yes	yes	no	yes	no

Table 4. Available functionalities for PHE configurations.

3.4.2 ROT configurations

If applicable, the reheater calculation (for humidity control) is embedded in the CC function. Adiabatic cooling can only be applied in combination with a condensation rotary heat exchanger.

		COMPONENT / FUNCTION INCLUDED (*Embeded subcomponent calculation if applicable)							
Config. number	configuration type	HRS type	EHA fan position	Mixing section	heater water/electric	cooler water/dx reheater*	humidifier steam	humidifier adiabatic	adiabatic cooling
1 (ROT)	HR+H	Rotor	down or up	no	yes	no	no	no	no
2 (ROT)	HR+H+C	Rotor	down or up	no	yes	yes	no	no	no
3 (ROT)	HR+H+SH	Rotor	down or up	no	yes	no	yes	no	no
4 (ROT)	HR+H+C+SH	Rotor	down or up	no	yes	yes	yes	no	no
5 (ROT)	HR+H+AH	Rotor	down or up	no	yes	no	no	yes	no
6 (ROT)	HR+H+C+AH	Rotor	down or up	no	yes	yes	no	yes	no
7 (ROTc)	AC+HR+H+C	Rotor cond.	down or up	no	yes	yes	no	no	yes
8 (ROTc)	AC+HR+H+C+SH	Rotor cond.	down or up	no	yes	yes	yes	no	yes
9 (ROTc)	AC+HR+H+C+AH	Rotor cond.	down or up	no	yes	yes	no	yes	yes

Table 5. Available functionalities for ROT configurations.

3.4.3 RAC configurations

If applicable, the reheater calculation (for humidity control) is embedded in the CC function.

		COMPONENT / FUNCTION INCLUDED (*Embeded subcomponent calculation if applicable)							
Config. number	configuration type	HRS type	EHA fan position	Mixing section	heater water/electric	cooler water/dx reheater*	humidifier steam	humidifier adiabatic	adiabatic cooling
1 (RAC)	HR+H	RAC	down or up	no	yes	no	no	no	no
2 (RAC)	HR+H+C	RAC	down or up	no	yes	yes	no	no	no
3 (RAC)	HR+H+SH	RAC	down or up	no	yes	no	yes	no	no
4 (RAC)	HR+H+C+SH	RAC	down or up	no	yes	yes	yes	no	no
5 (RAC)	HR+H+AH	RAC	down or up	no	yes	no	no	yes	no
6 (RAC)	HR+H+C+AH	RAC	down or up	no	yes	yes	no	yes	no
7 (RAC)	AC+HR+H+C	RAC	down or up	no	yes	yes	no	no	yes
8 (RAC)	AC+HR+H+C+SH	RAC	down or up	no	yes	yes	yes	no	yes
9 (RAC)	AC+HR+H+C+AH	RAC	down or up	no	yes	yes	no	yes	yes

Table 6. Available functionalities for RAC configurations.

3.4.4 SUP only configurations

If applicable, the reheater calculation (for humidity control) is embedded in the CC function.

		COMPONENT / FUNCTION INCLUDED (*Embeded subcomponent calculation if applicable)							
Config. number	configuration type	HRS type	EHA fan position	Mixing section	heater water/electric	cooler water/dx reheater*	humidifier steam	humidifier adiabatic	adiabatic cooling
16 (SUP)	H	supply only	N/A	no	yes	no	no	no	N/A
17 (SUP)	H+SH	supply only	N/A	no	yes	no	yes	no	N/A
18 (SUP)	H+AH	supply only	N/A	no	yes	no	no	yes	N/A
19 (SUP)	H+C	supply only	N/A	no	yes	yes	no	no	N/A
20 (SUP)	H+C+SH	supply only	N/A	no	yes	yes	yes	no	N/A
21 (SUP)	H+C+AH	supply only	N/A	no	yes	yes	no	yes	N/A

Table 7. Available functionalities for SUP configurations.

3.4.5 EHA only configurations

		COMPONENT / FUNCTION INCLUDED							
Config. number	configuration type	HRS type	EHA fan position	Mixing section	heater water/electric	cooler water/dx	humidifier steam	humidifier adiabatic	adiabatic cooling
22 (EHA)	EHA	exhaust only	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 8. Available functionalities for EHA configuration.

3.5 Annual energy and utilities consumption

Annual consumption is determined by summing the hourly output values of functions that apply to a given AHU configuration, calculated for each hour of the year. The output values calculated within the individual functions depend on the climatic data, the defined temperature scenarios and operating schedule, as well as the logical conditions for the activation of the respective component. If, for a given hour of the year, a component does not operate due to, for example, a defined operating schedule or lack of demand, its function returns zero as the output value. The annual consumption includes the following elements:

$E_{EL(t)}$ - Annual electric energy consumption in year (t) of the AHU life cycle, kWh
$E_{H(t)}$ - Annual thermal energy consumption for heating in year (t) of the AHU life cycle, kWh
$E_{C(t)}$ - Annual thermal energy consumption for cooling in year (t) of the AHU life cycle, kWh
$W_{(t)}$ - Annual water consumption by humidifiers in year (t) of the AHU life cycle, kg

Since by assumption the annual energy consumption is equal in each year of the AHU life cycle, the subscript denoting the year is not used in the following sections.

3.5.1 Annual consumption of electric energy

Depending on the AHU configuration, the annual electricity consumption may include all or some of the following components.

$E_{EL} = E_{EF} + E_{EH} + E_{EpH} + E_{EAUX} + E_{EAUX\_AC} + E_{EHU} + E_{THU}^{*}$

Where:
E_{EF} - Annual electric energy consumption of fans, kWh
E_{EH} - Annual electric energy consumption for heating, kWh
E_{EpH} - Annual electric energy consumption for frost protection preheating, kWh
E_{EAUX} - Annual auxiliary electric energy consumption - HRS drive and pumps, kWh
E_{EAUX_AC} - Annual auxiliary electric energy consumption for adiabatic cooling, kWh
E_{EHU} - Annual electric energy consumption for steam humidification, kWh
E_{THU}^{*} - Annual thermal energy consumption for adiabatic humidifier, kWh
* E_{THU} counts into electric energy consumption only if the electric heater is applied. Otherwise, it counts in thermal energy for heating.

3.5.1.1 Annual electric energy consumption of fans (E_{EF})

Annual electricity consumption by the supply and exhaust fan is determined by summing hourly values for each hour of the year of the outputs O13.1 ($P_{el\_FAN1,j}$ for exhaust fan) and O13.2 ($P_{el\_FAN2,j}$ for supply fan) of the function 'Supply and exhaust fan (FANS)'.

$$E_{EF} = \sum_{j=1}^{8760} P_{el\_FAN1,j} + P_{el\_FAN2,j}$$

Where:
j - subsequent hour of the year
$P_{el\_FAN1,j}$ - Output value 013.1 of function 'Supply and exhaust fan', kW
$P_{el\_FAN2,j}$ - Output value 013.2 of function 'Supply and exhaust fan', kW

3.5.1.2 Annual electric energy consumption for heating (E_{EH})

If the AHU is equipped with the electric heater(s), the annual consumption of electric energy for heating the supply air to a set supply temperature includes, depending on the AHU configuration, the energy consumed by the master electric heater and/or the secondary electric heater for relative humidity control. It is determined by summing the momentary output of the heater(s) in each hour of the year. These values are calculated, for the master heater by the function 'Heating coil - H' as output 07.3 ($P_{h(E),j}$), and for the secondary heater by function 'Cooling coil - CC' as output 08.4 ($P_{RH(E),j}$), if moisture control mode is applied.

$$E_{EH} = \sum_{j=1}^{8760} P_{h(E),j} + P_{RH(E),j}$$

Where:
j - subsequent hour of the year
$P_{h(E),j}$ - Output value 07.3 of function 'Heating coil (H)', kW
$P_{RH(E),j}$ - Output value 08.4 of function 'Cooling coil (CC)', kW

3.5.1.3 Annual electric energy consumption for frost protection preheating (E_{EpH})

Frost protection preheating applies to plate heat recovery exchanger. The annual electricity consumption by the electric preheater is determined by summing its output in each hour of the year, that is calculated by the function 'Cross and counterflow plate heat exchanger – PHE' as output 04.5 ($P_{PH(E),j}$).

$$E_{EpH} = \sum_{j=1}^{8760} P_{PH(E),j}$$

Where:
j - subsequent hour of the year
$P_{h(E),j}$ - Output value 04.5 of function 'Cross and counterflow plate heat exchanger (PHE)', kW

3.5.1.4 Annual auxiliary electric energy consumption for drives and pumps (E_{AUX})

Depending on the AHU configuration, the annual auxiliary electricity consumption may include the consumption by the rotary exchanger drive as output 05.5 ($P_{e\_drv,j}$) or the run-around coil pump as output 06.5 ($P_{pump,j}$), and/or the adiabatic humidifier pump as output 09.4 ($P_{el\_pump,j}$).

$$E_{AUX} = \sum_{j=1}^{8760} P_{e_{drv},j} + P_{pump,j} + P_{el\_pump,j}$$

Where:
j - subsequent hour of the year
$P_{e\_drv,j}$ - Output value 05.5 of function 'Rotary heat exchanger (ROT)', kW
$P_{pump,j}$ - Output value 06.5 of function 'Run-around coils (RAC)', kW
$P_{el\_pump,j}$ - Output value 09.4 of function 'Adiabatic humidifier (HUM-AD)', kW

3.5.1.5 Annual auxiliary electric energy consumption for adiabatic cooling (E_{AUX_AC})

Annual electricity consumption by the adiabatic cooling humidifier is determined by summing in each hour of the year the output value O11.4 ($P_{el\_pump,j}$) of the function 'Adiabatic cooling (ADC)'.

$$E_{AUX\_AC} = \sum_{j=1}^{8760} P_{e\_pump,j}$$

Where:

j - subsequent hour of the year

$P_{e\_pump,j}$ - Output value O11.4 of function 'Adiabatic cooling (ADC)', kW

3.5.1.6 Annual electric energy consumption for steam humidification (E_{EHU})

Annual electricity consumption by the electric steam humidifier is determined by summing in each hour of the year the output value O10.4 ($P_{e\_hu,j}$) of the function 'Steam humidifier (HUM-ST)'.

$$E_{AUX\_AC} = \sum_{j=1}^{8760} P_{e\_hu,j}$$

Where:

j - subsequent hour of the year

$P_{e\_pump,j}$ - Output value O10.4 of function 'Steam humidifier (HUM-ST)', kW

3.5.1.7 Annual thermal energy consumption for adiabatic humidifier (E_{THU})

If an AHU is equipped with an adiabatic humidifier and only with electric heater(s), the annual electricity consumption by the electric heater(s) to heat the air to a temperature required by the adiabatic humidification process, and above the set supply temperature, is calculated by summing the output value O9.2 ($P_{t\_hu,j}$) of the function 'Adiabatic humidifier (HUM-AD)'. As this energy is calculated jointly for all heaters applied (depending on the design conditions, one or two), all heaters on the unit must be electric. In case only water coils are used on the unit, the annual thermal energy consumption for adiabatic humidifier is calculated according to section 3.5.2.4

$$E_{THU} = \sum_{j=1}^{8760} P_{t\_hu,j}$$

Where:

j - subsequent hour of the year

$P_{t\_hu,j}$ - Output value O9.2 of function 'Adiabatic humidifier (HUM-AD)', kW

3.5.2 Annual consumption of thermal energy for heating

Depending on the AHU configuration, the annual electricity consumption may include all or some of the following components.

$$E_H = E_{TH} + E_{TpH} + E_{THU} + E_{THUs}$$

Where:

E_{TH} - Annual thermal energy consumption for heating coil(s), kWh

E_{TpH} - Annual thermal energy consumption for frost preheating, kWh

E_{THU} - Annual thermal energy consumption for adiabatic humidifier, kWh

E_{THUs} - Annual thermal energy consumption for steam humidifier (central or gas), kWh

3.5.2.1 Annual thermal energy consumption for heating coil (E_{TH})

The annual consumption of thermal energy for heating the supply air to a set supply temperature includes, depending on the AHU configuration, the energy consumed by the master water heating coil and/or the secondary water heating coil for relative humidity control. It is determined by summing the momentary output of the coil(s) in each hour of the year. These values are calculated, for the master coil by the function 'Heating coil - H' as output 07.3 ($P_{h(W),j}$), and for the secondary coil by function 'Cooling coil - CC' as output 08.4 ($P_{RH(W),j}$), if moisture control mode is applied.

$$E_{TH} = \sum_{j=1}^{8760} P_{h(W),j} + P_{RH(W),j}$$

Where:

j	-	subsequent hour of the year
$P_{h(W),j}$	-	Output value 07.3 of function 'Heating coil (H)', kW
$P_{RH(W),j}$	-	Output value 08.4 of function 'Cooling coil (CC)', kW

3.5.2.2 Annual thermal energy consumption for frost protection preheating (E_{TpH})

Frost protection preheating applies to plate heat recovery exchangers. The annual consumption of thermal energy by the water coil preheater is determined by summing its output in each hour of the year, that is calculated by the function 'Cross and counterflow plate heat exchanger – PHE' as output 04.5 ($P_{PH(W),j}$).

$$E_{TpH} = \sum_{j=1}^{8760} P_{PH(W),j}$$

Where:

j	-	subsequent hour of the year
$P_{h(W),j}$	-	Output value 04.5 of function 'Cross and counterflow plate heat exchanger (PHE)', kW

3.5.2.3 Annual thermal energy consumption for adiabatic humidifier (E_{THU})

Annual consumption of thermal energy by the water heating coil(s) to heat the air to a temperature required by the adiabatic humidification process, and above the set supply temperature, is calculated by summing the output value 09.2 ($P_{t\_hu,j}$) of the function 'Adiabatic humidifier (HUM-AD)'.

$$E_{THU} = \sum_{j=1}^{8760} P_{t\_hu,j}$$

Where:

j	-	subsequent hour of the year
$P_{t\_hu,j}$	-	Output value 09.2 of function 'Adiabatic humidifier (HUM-AD)', kW

3.5.2.4 Annual thermal energy consumption for steam humidifier (E_{THUs})

If a gas-fired humidifier or humidifier supplied from a central steam boiler is applied, its annual thermal energy consumption is calculated by summing for each hour of the year the output value 010.5 ($P_{t\_hu,j}$) of the function 'Steam humidifier (HUM-ST)'.

$$E_{THUs} = \sum_{j=1}^{8760} P_{t\_hu,j}$$

Where:

j - subsequent hour of the year

$P_{t\_hu,j}$ - Output value O10.5 of function 'Steam humidifier (HUM-ST)', kW

3.5.3 Annual consumption of thermal energy for cooling

Annual energy for cooling consumed by a direct expansion (DX) or water cooling coil, E_c in kWh, is calculated by summing the hourly output values O8.3 ($P_{c,j}$) of the function 'Cooling coil (CC)'.

$$E_C = \sum_{j=1}^{8760} P_{c,j}$$

Where:

j - subsequent hour of the year

$P_{c,j}$ - Output value O8.3 of function 'Cooling coil (CC)', kW

3.5.4 Annual water consumption for humidification

Depending on the AHU configuration, the annual consumption of water for humidification may include all or some of the following components.

$$W = AWc + AWc_{AC}$$

Where:

AWc - Annual water consumption for humidification, kg

AWc_{AC} - Annual water consumption for humidification, adiabatic cooling, kg

3.5.4.1 Annual water consumption for humidification (AWc)

Depending on the humidifier type applied, the annual water consumption for humidification is determined by summing in each hour of the year, the $W_{c,j}$ value, calculated either as output O9.3 of the function 'Adiabatic humidifier (HUM-AD)' or output O10.3 of function 'Steam humidifier (HUM-ST)'.

$$AWc = \sum_{j=1}^{8760} W_{c,j}$$

Where:

j - subsequent hour of the year

AWc - Output value O9.3 or O10.3, kg/h

3.5.4.2 Annual water consumption for humidification, adiabatic cooling (AWc_{AC})

Annual water consumption for adiabatic cooling is determined by summing in each hour of the year, the output value O11.3 ($W_{c,j}$) of the function 'Adiabatic cooling (ADC)'.

$$AWc_{AC} = \sum_{j=1}^{8760} W_{c,j}$$

Where:

j - subsequent hour of the year

AWc - Output value O11.3 of function 'Adiabatic cooling (ADC)', kg/h

4 Annexes – Energy calculations

Functions for AHU components

4.1 - Function PHE - Cross and counterflow plate heat exchanger

4.2 - Function ROT – Rotary heat exchanger

4.3 - Function RAC – Run-around coils

4.4 - Function H – Heating coil

4.5 - Function CC – Cooling coil

4.6 - Function HUM-AD – Adiabatic humidifier

4.7 - Function HUM-ST – Steam humidifier

4.8 - Function ADC – Adiabatic cooling

4.9 - Function HRS+MIX – Heat recovery and mixing section

4.10 - Function FAN – Supply and Exhaust fan

AHU input data

4.11 - Input data from AHU technical specification and data assignment chart

Calculation sequence and data flow-charts for AHU configurations

4.12 - Data-flow chart for Configuration 1 (PHE) - HR+H

4.13 - Data-flow chart for Configuration 2 (PHE) - HR+H+C

4.14 - Data-flow chart for Configuration 3 (PHE) - HR+H+SH

4.15 - Data-flow chart for Configuration 4 (PHE) - HR+H+C+SH

4.16 - Data-flow chart for Configuration 5 (PHE) - HR+H+AH

4.17 - Data-flow chart for Configuration 6 (PHE) - HR+H+C+AH

4.18 - Data-flow chart for Configuration 7 (PHE) - AC+HR+H+C

4.19 - Data-flow chart for Configuration 8 (PHE) - AC+HR+H+C+SH

4.20 - Data-flow chart for Configuration 9 (PHE) - AC+HR+H+C+AH

4.21 - Data-flow chart for Configuration 10 (PHE) - HR+MIX+H

4.22 - Data-flow chart for Configuration 11 (PHE) - HR+MIX+H+C

4.23 - Data-flow chart for Configuration 12 (PHE) - HR+MIX+H+SH

4.24 - Data-flow chart for Configuration 13 (PHE) - HR+MIX+H+C+SH

4.25 - Data-flow chart for Configuration 14 (PHE) - HR+MIX+H+AH

4.26 - Data-flow chart for Configuration 15 (PHE) - HR+MIX+H+C+AH

4.27 - Data-flow chart for Configuration 1 (ROT) - HR+ H

4.28 - Data-flow chart for Configuration 2 (ROT) - HR+H+C

4.29 - Data-flow chart for Configuration 3 (ROT) - HR+H+SH

4.30 - Data-flow chart for Configuration 4 (ROT) - HR+H+C+SH

4.1 Function PHE - Cross and counterflow plate heat exchanger

Function	Cross and Counter flow plate heat exchanger
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components.

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m^3/s	Exhaust air flow rate in *j* hour	O1.1
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
$t_{21,j}$	°C	Supply air Inlet temperature in *j* hour	
$x_{21,j}$	kg/kg	Supply air Inlet moisture content in *j* hour	
$t_{11,j}$	°C	Exhaust air Inlet temperature in *j* hour	
$x_{11,j}$	kg/kg	Exhaust air Inlet moisture content in *j* hour	

-

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$t_{ETA,j}$	°C	Extract air temperature in j hour	O3.3
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in *j* hour	O13.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in *j* hour	O2.2
$x_{ETA,j}$	kg/kg	Extract air moisture content in *j* hour	O3.4

-

Alternative UOM inputs

Symbol	UOM	Description	Input source / remarks
$\phi_{21,j}$	%	Supply air Inlet relative humidity in *j* hour	Instead of $x_{21,j}$
$\phi_{ETA,j}$	%	Extract air relative humidity in *j* hour	Instead of $x_{ETA,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Input source / remarks
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
$\eta_{t(nom)}$	%	Nominal (design) temperature efficiency (dry) at q_{v1nom} and q_{v2nom} for EN308 reference temperature conditions	AHU.3 If $q_{v1nom} = q_{v2nom}$ $\eta_{t(nom)} = \eta_t$
$\upsilon_{hr;nom}$	m/s	Air velocity over exchanger at nominal conditions according EN 16798-5-1	AHU.5
t_{ETA_DW}	°C	Design extract air temperature in winter	AHU.8
x_{ETA_DW}	kg/kg	Design extract air moisture content in winter	AHU.6
PHE	Logic	Type of plate heat exchanger 1 = counterflow 2 = crossflow	AHU.12
PH	Logic	Type of the pre-heater applied 0 = no preheater (other frost protection measures) E = electric W = water coil	AHU.11
EFP	Logic	Exhaust fan position 0 = Upstream 1 = Downstream	AHU.4

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{22,j}$	°C	Supply air outlet temperature in *j* hour	O4.1
$x_{22,j}$	kg/kg	Supply air outlet moisture content in *j* hour	O4.2
$P_{HRS\_H,j}$	kW	Heat recovery in *j* hour	O4.3
$P_{HRS\_C,j}$	kW	Cool recovery in *j* hour	O4.4
$P_{PH(S),j}$	kW	preheater power (of S type) in *j* hour S = W (water) S = E (electric)	O4.5

3. Parameters for internal calculations within the function

Symbol	UOM	Description	Remarks
$\eta_{t,j}$	%	Actual temperature efficiency in *j* hour	for $q_{V1,j}$ and $q_{V2,j}$
t_{d11}	°C	Dewpoint of inlet air, exhaust side	At t_{ETA_DW} and x_{ETA_DW}
t_{12_MIN}	°C	Minimum outlet air temperature, exhaust side without freezing	
$t_{12,j}$	°C	Momentary t_{12} (for freezing calculation)	
P_{HRS_min}	kW	'locked' heat recovery power at 'no freezing risk' conditions	
$t_{21\_min,j}$	°C	Minimum t_{21} with no 'freeze risk' in *j* hour	
$f_{v,j}$	-	Correction factor of the temperature efficiency for the air velocity in *j* hour	EN 16798-5-1

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
ϕ	dec.	Relative humidity	**Relative humidity (t,x)**	t, x
t_d	°C	Dew point temperature	**Dew point (t, ϕ)**	t, ϕ

4. Description of calculation procedure (without adiabatic cooling)

4.1. Assign input parameters

If **ϕ** values are given as input data, convert them to **x** values using Moisture content (t, **ϕ**)

$x_{11,j} = x_{ETA,j}$

$x_{21,j} = x_{ODA,j}$

$t_{21,j} = t_{ODA,j}$

$x_{22,j} = x_{ODA,j}$

IF EFP = 0 Exhaust fan upstream the exchanger

$t_{11,j} = t_{ETA,j} + \Delta t_{FAN1,j}$

ELSE Exhaust fan downstream the exchanger

$t_{11,j} = t_{ETA,j}$

4.2. Calculate actual temperature efficiency

Comment:
EN 16798-5-1:2017 gives the following equation for the temperature efficiency correction

$\eta_{t,j} = \eta_t \cdot f_q \cdot f_v$

where:
f_q – the correction factor for the mass flow ratio other than 1.
f_v – the correction factor for the air velocity.

Factor f_q will not be calculated as recommended in the standard. Instead $\eta_{t(nom)}$ calculated by AHU software will be considered. $H_{t(nom)} = \eta_t \cdot f_q$

$\eta_{t,j} = \eta_{t(nom)} \cdot f_v$

However, this means that at a reduced air flow rate (according to the operating schedule), the unbalanced mass flow ration (if applicable) will be fixed (always the same).

$F_{v,j} = C_1 \cdot \upsilon_{hr;nom} ((q_{V2,j} / q_{v2nom}) – 1) + C_2$

C factors based on EN 16798-5-1:2017 table B.6

C_1 = -0.0201
C_2 = 1

Calculate actual temperature efficiency in *j* hour

$\eta_{t,j} = \eta_{t(nom)} \cdot f_{v,j}$

4.3. Conditions to skip calculations

IF $t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} \geq t_{ODA,j}$

OR $t_{11,j} = t_{ODA,j}$

OR $t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} – \Delta t_{FAN2,j} \leq t_{ODA,j}$

jump to END without changing input parameters ($t_{22,j} = t_{21,j}$, $P_{HRS\_C,j} = 0$, $P_{HRS\_H,j} = 0$, $P_{PH(S),j} = 0$)

4.4. Calculation procedure summer period

Proceed calculations IF:

$t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} < t_{ODA,j}$

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} – t_{21,j})$

$P_{HRS\_C,j} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{21,j} – t_{22,j})$

<u>Annual values</u>
Determination of annual energy recovery for cooling
Add the hourly $P_{HRS\_C,j}$ value to the sum of energy recovery for cooling from the preceding hour.

$ER_{C,j} = ER_{C,j-1} + P_{HRS\_C,j}$

4.5. Calculation procedure for winter period

Proceed calculations IF:

$t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} – \Delta t_{FAN2,j} > t_{ODA,j}$

Determine freezing protection starting point

Calculate dew point of inlet air on the exhaust side

t_{d11} = Dew point ($t_{ETA\_DW,}$, x_{ETA_DW})

t_{ETA_DW} and x_{ETA_DW} design values for winter from the AHU software

Calculate min. t_{12_MIN} without freezing.

$T_{12\_MIN} = \min[\ SF\ ;\ t_{d11} + SF\ ]$

SF – safety factor for nonuniform temperature distribution

Case PHE = 1 -> SF = 2 counterflow

Case PHE = 2 -> SF = 4 crossflow

Calculate momentary $t_{12,j}$ without freezing

Assumed that air on extract side is cooled without moisture content change.

$T_{12,j} = t_{11,j} - q_{V2,j} \cdot \eta_{t,j}\ (t_{11,j} - t_{21,j})\ /\ q_{V1,j}$

IF $t_{12,j} > t_{21\_MIN}$ OR $t_{oda,j} > -4$ THEN No freezing operation

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

Check if t_{22} is not higher than the set t_{SUP}

IF $t_{22,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$

THEN

$t_{22,j} = t_{SUP,j} - \Delta t_{FAN2,j}$ Operation with efficiency reduced by controls

ELSE

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$ Operation with full efficiency

$\mathbf{P_{HRS\_H,j} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{22,j} - t_{21,j})}$

ELSE Operation in freezing risk conditions

Assumed that under freezing risk conditions exchanger operates with a 'locked' capacity equal to max. possible capacity under 'no freezing risk' conditions

$P_{HRS\_min} = \rho_s \cdot c_P \cdot q_{V1,j} \cdot (t_{11,j} - t_{12\_MIN})$

$\mathbf{P_{HRS\_H,j} = P_{HRS\_min}}$

IF PH = 0 no preheater upstream HRS (other frost protection measures applied)

$t_{22j} = t_{21,j} + P_{HRS\_min}\ /\ \rho_s \cdot c_P \cdot q_{V2,j}$

IF PH <> 0 Pre-heater is applied upstream HRS

pre-heater warms up the outdoor air to a 'no freeze risk' temperature t_{21}_min

Comment:
at the 'freeze risk limit point' (no $\eta_{t,j}$ reduction)

$P_{HRS\_min} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{22,j} - t_{21\_min,j})$
and
$t_{22,j} = t_{21\_min,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21\_min,j})$
thus

$t_{21\_min,j} = t_{11,j} - P_{HRS\_min} / \eta_{t,j} \cdot \rho_s \cdot c_P \cdot q_{V2,j}$

$t_{22,j} = t_{21\_min,j} + P_{HRS\_min} / \rho_s \cdot c_P \cdot q_{V2,j} = t_{21\_min,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21\_min,j})$

Calculation of a pre-heater momentary power

IF PH = W	water pre-heater in applied upstream HRS
$P_{PH(W),j} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{21\_min,j} - t_{ODA,j})$	water pre-heater momentary power
IF PH = E	electric pre-heater in applied upstream HRS
$P_{PH€,j} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{21\_min,j} - t_{ODA,j})$	electric pre-heater momentary power

<u>Annual values</u>

Determination of annual energy recovery for heating

Add the hourly $P_{HRS\_H,j}$ value to the sum of energy recovery for heating from the preceding hour.

$ER_{H,j} = ER_{H,j-1} + P_{HRS\_H,j}$

Determination of annual energy consumption for frost protection pre-heating

Add the hourly $P_{PH(S),j}$ value to the sum of energy consumption from the preceding hour.

IF PH = W
$E_{TpH,j} = E_{TpH,j-1} + P_{PH(W),j}$ -↑ see also section 3.5.2.2

IF PH = E
$E_{EpH,j} = E_{EpH,j-1} + P_{PH€,j}$ -↑ see also section 3.5.1.3

4.2 Function ROT – Rotary heat exchanger

Function	Rotary heat exchanger (condensation, hygro or sorption type)
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m^3/s	Exhaust air flow rate in *j* hour	O1.1
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
$t_{21,j}$	°C	Supply air Inlet temperature in *j* hour	
$x_{21,j}$	kg/kg	Supply air Inlet moisture content in *j* hour	
$t_{11,j}$	°C	Exhaust air Inlet temperature in *j* hour	
$x_{11,j}$	kg/kg	Exhaust air Inlet moisture content in *j* hour	

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$t_{ETA,j}$	°C	Extract air temperature in j hour	O3.3
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in *j* hour	O13.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in *j* hour	O2.2
$x_{ETA,j}$	kg/kg	Extract air moisture content in *j* hour	O3.4

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{21,j}$	%	Supply air Inlet relative humidity in *j* hour	Instead of $x_{21,j}$
$\phi_{ETA,j}$	%	Extract air relative humidity in *j* hour	Instead of $x_{ETA,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Input source / remarks
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
$\eta_{t(nom)}$	%	Nominal (design) temperature efficiency (dry) at q_{V1nom} and q_{V2nom} for EN 308 reference temperature conditions	AHU.3 If $q_{V1nom} = q_{V2nom}$ $\eta_{t(nom)} = \eta_t$
$\eta_{x\,(nom)}$	%	Nominal (design) humidity efficiency at q_{V1nom} and q_{V2nom} for winter design conditions	AHU.13 at t_{ETA_DW} , x_{ETA_DW} , t_{ODA_DW} and x_{ODA_DW}
$\upsilon_{hr;nom}$	m/s	Air velocity over exchanger at nominal conditions according to EN 16798-5-1	AHU.5
x_{ETA_DW}	kg/kg	Design extract air moisture content in winter	AHU.6
ROTyp	Logic	Type of rotary heat exchanger C = condensation H = hygroscopic S = sorption	AHU.15
P_{e_drv}	kW	Rotor drive nominal power input from mains	AHU.14
EFP	Logic	Exhaust fan position 0 = Upstream 1 = Downstream	AHU.4

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{22,j}$	°C	Supply air outlet temperature in *j* hour	05.1
$x_{22,j}$	kg/kg	Supply air outlet moisture content in *j* hour	05.2
$P_{HRS\_H,j}$	kW	Heat recovery (total) in *j* hour	O5.3
$P_{HRS\_C,j}$	kW	Cool recovery (total) in *j* hour	05.4
$P_{e\_drv,j}$	kW	Rotor drive electric power input in *j* hour	O5.5

3. Parameters for internal calculations within the function

Symbol	UOM	Description	Remarks
$\eta_{t,j}$	%	Actual temperature efficiency in *j* hour	for $q_{V1,j}$ and $q_{V2,j}$

$\eta_{x,j}$	%	Actual humidity efficiency in *j* hour	for $q_{v1,j}$ and $q_{v2,j}$
t_{12_MIN}	°C	Min. outlet air temperature, exhaust side without freezing	Freezing calculation
$t_{12,j}$	°C	Momentary t_{12}	For freezing calculation
P_{HRS_min}	kW	'locked' heat recovery power at 'no freezing risk' conditions	For freezing calculation
$x_{e;sat}$	kg/kg	Saturation moisture content of the outdoor air	EN 16798-5-1
$P_{e;sat}$	Pa	Saturation pressure	EN 16798-5-1
$f_{v,j}$	-	Correction factor of the temperature efficiency for the air velocity in j hour	EN 16798-5-1
$f_{\Delta x;x,j}$	-	correction factor of the humidity efficiency for the condensation potential	EN 16798-5-1
$f_{v;x,j}$	-	Correction factor of the humidity efficiency for the air velocity in j hour	EN 16798-5-1

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
x	kg/kg	Moisture content	**Moisture content (t, ϕ)**	t, ϕ
ϕ	dec.	Relative humidity	**Relative humidity (t,x)**	t, x
t_d	°C	Dew point temperature	**Dew point (t, ϕ)**	t, ϕ
h	kJ/kg	Moist air specific enthalpy	**Enthalpy (t,x)**	t, x

4. Description of calculation procedure

4.1. Assign input parameters

If **ϕ** values are given as input data, convert them to **x** values using **Moisture content (t, ϕ)**

$x_{11,j} = x_{ETA,j}$

$x_{21,j} = x_{ODA,j}$

$t_{21,j} = t_{ODA,j}$

IF EFP = 0 Exhaust fan upstream the exchanger

$t_{11,j} = t_{ETA,j} + \Delta t_{FAN1,j}$

ELSE Exhaust fan downstream the exchanger

$t_{11,j} = t_{ETA,j}$

4.2. Calculate actual temperature efficiency

Comment:
EN 16798-5-1:2017 gives the following equitation for the temperature efficiency correction

$\eta_{t,j} = \eta_t \cdot f_q \cdot f_v$

where:
f_q – the correction factor for the mass flow ratio other than 1.
f_v – The correction factor for the air velocity.

Factor f_q will not be calculated as recommended in the standard. Instead $\eta_{t(nom)}$ calculated by the AHU software will be considered. $\eta_{t(nom)} = \eta_t \cdot f_q$

$\eta_{t,j} = \eta_{t(nom)} \cdot f_v$

However, this means that at reduced air flow rate (according to a set schedule), the unbalanced mass flow ration (if applicable) will be fixed (always the same).

$f_{v,j} = C_1 \cdot \square_{hr;nom} \left((q_{V2,j} / q_{v2nom}) - 1 \right) + C_2$

C factors based on EN 16798-5-1:2017 table B.6

ROTyp	C_1	C_2
C = condensation	−0,0643	1
H = hygroscopic	−0,0684	1
S = sorption	−0,0665	1

Calculate actual temperature efficiency in j hour

$\boldsymbol{\eta_{t,j} = \eta_{t(nom)} \cdot f_{v,j}}$

4.3. Calculate actual humidity efficiency

Comment:
EN 16798-5-1 gives the following equitation for the humidity efficiency correction

$\eta_{x,j} = \eta_x \cdot f_{\Delta x;x} \cdot f_{q;x} \cdot f_{v;x} \cdot f_{n;x}$

where:
$f_{\Delta x;x}$ – correction factor of the humidity efficiency for the condensation potential.
$f_{q;x}$ – the correction factor for the mass flow ratio other than 1
$f_{v;x}$ – The correction factor for the air velocity
$f_{n;x}$ – the correction factor for the rotation number

Factor $f_{q;x}$ will not be calculated as recommended in the standard. Instead $\eta_{x(nom)}$ calculated by the AHU software will be considered. $\eta_{x(nom)} = \eta_x \cdot f_{q;x}$
This means however, that at reduced air flow rate (according to a set schedule), the unbalanced mass flow ration (if applicable) will be fixed (always the same).

Factor $f_{n;x}$ will not be considered in the LCC calculation. Its impact on the outcome would be negligible. (in the adopted approach reduction of a rotor speed occurs only if $t_{22} \uparrow t_{SUP}$ normally in interim periods when moisture recovery is very low or under freezing condition, but here assessment based on the sensible heat only was agreed).

Calculate actual $f_{\Delta x;x,j}$ factor in j hour

$$p_{e;sat,j} = 611{,}2 \cdot e^{\frac{17{,}62 \cdot t_{ODA,j}}{243.12 + t_{ODA,j}}}$$

$$x_{e;sat,j} = 0{,}622 \cdot \frac{p_{e;sat,j}}{p_{atm} - p_{e;sat,j}}$$

CASE ROTyp = C OR ROTyp = S — For condensation or sorption rotors

$f_{\Delta x;x,j} = \max[0 \,;\, C_6 \cdot (x_{11,j} - x_{e;sat,j}) + C_7)$

CASE ROTyp = H — For hygroscopic rotors

IF $(x_{11,j} - x_{e;sat,j}) > 0$: $f_{\Delta x;x,j} = C_6 \cdot (x_{11,j} - x_{e;sat,j}) + C_7$

IF $(x_{11,j} - x_{e;sat,j}) \leq 0$: $f_{\Delta x;x,j} = \max[0 \,;\, C_8 \cdot (x_{11,j} - x_{e;sat,j}) + C_7)$

Calculate actual $\mathbf{f_{v;x,j}}$ factor in j hour

$\mathbf{f_{v;x,j}} = C_{10} \cdot \upsilon_{hr;nom} \, ((q_{v2,j} / q_{v2nom}) - 1) + C_{11}$

C factors based on EN 16798-5-1:2017 table D.1

ROTyp	C_6	C_7	C_8	C_{10}	C_{11}
C = condensation	248	−0,240		−0,200	1
H = hygroscopic	129	0,357	23,8	−0,152	1
S = sorption	16,4	0,918		−0,098	1

Calculate actual humidity efficiency in j hour

$\boldsymbol{\eta_{x,j} = \eta_{x(nom)} \cdot f_{\Delta x;x,j} \cdot f_{v;x,j}}$

4.4. Conditions to skip calculations

Comment: Only temperature is considered (no moisture content) to control the calculations.

IF $t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} \geq t_{ODA,j}$

OR $t_{11,j} = t_{ODA,j}$

OR $t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} - \Delta t_{FAN2,j} \leq t_{ODA,j}$

jump to END without changing input parameters ($t_{22,j} = t_{21,j}$, $x_{22,j} = x_{21,j}$, $P_{HRS\_C,j} = 0$, $P_{HRS\_H,j} = 0$, $P_{e\_drv,j} = 0$).

4.5. Calculation procedure for summer period

Proceed with calculations IF:

$t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} < t_{ODA,j}$

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

$x_{22,j} = x_{21,j} + \eta_{x,j} \cdot (x_{11,j} - x_{21,j})$

$P_{HRS\_C,j} = \rho_s \cdot q_{V2,j} \cdot$ (**Enthalpy** $(t_{21,j}, x_{21,j})$ - **Enthalpy** $(t_{22,j}, x_{22,j})$)

$P_{e\_drv,j} = P_{e\_drv}$

Annual values

Determination of annual energy recovery for cooling

Add the hourly $P_{HRS\_C,j}$ value to the sum of energy recovery for cooling from the preceding hour.

$ER_{C,j} = ER_{C,j-1} + P_{HRS\_C,j}$

Determination of the annual auxiliary electric energy consumption (rotor drive)

Add the hourly $P_{e\_drv,j}$ value to the sum of auxiliary electric energy consumption from the preceding hour.

$E_{EAUX,j} = E_{EAUX,j-1} + P_{e\_drv,j}$ -↑ see also section 3.5.1.4

IMPORTANT – don't count E_{EAUX} in hours with active Adiabatic cooling (ADC function) to avoid double counting.

4.6. Calculation procedure for winter period

Proceed with calculations IF:

$t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} - \Delta t_{FAN2,j} > t_{ODA,j}$

Determine freezing protection starting point

Calculate min. t_{12_MIN} without freezing.

Comment: Approximation of $t_{12\_MIN} = f(x_{ETA\_DW})$ is based on the following assumed typical efficiencies:

Condensation rotor: sensible 80%, latent: 25%
Hygroscopic rotor: sensible 80%, latent: 50%
Sorption rotor: sensible 80%, latent: 80%

CASE ROTyp = C condensation rotor

$t_{12\_MIN} = \max[-1 ;\ 0.3394 \cdot (x_{ETA\_DW} \cdot 10^3)^3 - 4.2987 \cdot (x_{ETA\_DW} \cdot 10^3)^2 + 20.107 \cdot (x_{ETA\_DW} \cdot 10^3) - 36.99]$

CASE ROTyp = H hygroscopic rotor

$t_{12\_MIN} = \max[-2 ;\ -0.3844 \cdot (x_{ETA\_DW} \cdot 10^3)^2 + 7.6132 \cdot (x_{ETA\_DW} \cdot 10^3) - 30.606]$

CASE ROTyp = S sorption rotor

$t_{12\_MIN} = 0.3333 \cdot (x_{ETA\_DW} \cdot 10^3)^2 - 0.6762 \cdot (x_{ETA\_DW} \cdot 10^3) - 18.95$

Calculate momentary $t_{12,j}$ without freezing

Assumed that air on extract side is cooled without moisture content change (only sensible heat).

$t_{12,j} = t_{11,j} - q_{V2,j} \cdot \eta_{t,j} (t_{11,j} - t_{21,j}) / q_{V1,j}$

IF $t_{12,j} > t_{21\_MIN}$ OR $t_{oda,j} > -4$ THEN No freezing operation

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

Check if t_{22} is not higher than the set t_{SUP}

IF $t_{22,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$

THEN

$t_{22,j} = t_{SUP,j} - \Delta t_{FAN2,j}$ Operation with efficiency reduced by controls

ELSE

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

$x_{22,j} = x_{21,j} + \eta_{x,j} \cdot (x_{11,j} - x_{21,j})$

$\mathbf{P_{HRS\_H,j}} = \rho_s \cdot q_{V2,j} \cdot (\textbf{Enthalpy}(t_{22,j}, x_{22,j}) - \textbf{Enthalpy}(t_{21,j}, x_{21,j}))$

ELSE Operation in freezing risk conditions

Assumed that under freezing risk conditions exchanger operates with a 'locked' capacity equal to max. possible capacity under 'no freezing risk' conditions. Only sensible heat considered under 'frost risk conditions'.

$P_{HRS\_min} = \rho_s \cdot c_P \cdot q_{V1,j} \cdot (t_{11,j} - t_{12\_MIN})$

$\mathbf{P_{HRS\_H,j} = P_{HRS\_min}}$

$t_{22j} = t_{21,j} + P_{HRS\_min} / \rho_s \cdot c_P \cdot q_{V2,j}$

$x_{22,j} = x_{21,j}$

Calculate the Rotor drive power input in *j* hour (regardless of the freezing risk operation conditions)

$\mathbf{P_{e\_drv,j} = P_{e\_drv}}$

Annual values

Determination of annual energy recovery for heating

Add the hourly $P_{HRS\_H,j}$ value to the sum of energy recovery for heating from the preceding hour.

$$ER_{H,j} = ER_{H,j-1} + P_{HRS\_H,j}$$

Determination of the annual auxiliary electric energy consumption (rotor drive)

Add the hourly $P_{e\_drv,j}$ value to the sum of auxiliary electric energy consumption from the preceding hour.

$$E_{EAUX,j} = E_{EAUX,j-1} + P_{e\_drv,j}$$

-> see also section 3.5.1.4

Determination of annual moisture recovery for humidification

Add the hourly moisture recovery value to the sum of moisture recovery from the preceding hour.

$$MR_{HU,j} = MR_{HU,j-1} + \rho_s \cdot q_{V2,j} \cdot (x_{22,j} - x_{21,j}) \cdot 3600$$

4.3 Function RAC – Run-around coils

Function	Run-around coils for heat recovery
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components.

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m^3/s	Exhaust air flow rate in *j* hour	O1.1
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
$t_{21,j}$	°C	Supply air Inlet temperature in *j* hour	
$x_{21,j}$	kg/kg	Supply air Inlet moisture content in *j* hour	
$t_{11,j}$	°C	Exhaust air Inlet temperature in *j* hour	
$x_{11,j}$	kg/kg	Exhaust air Inlet moisture content in *j* hour	

Auxiliary parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$t_{ETA,j}$	°C	Extract air temperature in j hour	O3.3
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in *j* hour	O13.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in *j* hour	O2.2
$x_{ETA,j}$	kg/kg	Extract air moisture content in *j* hour	O3.4

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{21,j}$	%	Supply air Inlet relative humidity in *j* hour	Instead of $x_{21,j}$
$\phi_{ETA,j}$	%	Extract air relative humidity in *j* hour	Instead of $x_{ETA,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Input source / remarks
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
$\eta_{t(nom)}$	%	Nominal (design) temperature efficiency (dry) at q_{v1nom} and q_{v2nom} for EN308 reference temperature conditions	AHU.3 If $q_{v1nom} = q_{v2nom}$ $\eta_{t(nom)} = \eta_t$
$\upsilon_{hr;nom}$	m/s	Air velocity over exchanger at nominal conditions according to EN 16798-5-1	AHU.5
t_{ETA_DW}	°C	Design extract air temperature in winter	AHU.8
x_{ETA_DW}	kg/kg	Design extract air moisture content in winter	AHU.6
P_{el_pump}	kW	Electric power input of a circulation pomp at selected system working point (fluid flow rate and fluid side pressure drop – coils + pipes + valve)	AHU.16
EFP	Logic	Exhaust fan position 0 = Upstream 1 = Downstream	AHU.4

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{22,j}$	°C	Supply air outlet temperature in *j* hour	06.1
$x_{22,j}$	kg/kg	Supply air outlet moisture content in *j* hour	06.2
$P_{HRS\_H,j}$	kW	Heat recovery in *j* hour	06.3
$P_{HRS\_C,j}$	kW	Cool recovery in *j* hour	06.4
$P_{pump,j}$	kW	Circulation pump electric power input in j hour	O6.5

3. Parameters for internal calculations within the function

Symbol	UOM	Description	Remarks
$\eta_{t,j}$	%	Actual temperature efficiency in *j* hour	for $q_{V1,j}$ and $q_{V2,j}$
t_{d11}	°C	Dewpoint of inlet air, exhaust side	At t_{ETA_DW} and x_{ETA_DW}
t_{12_MIN}	°C	Min. outlet air temperature, exhaust side without freezing	

$t_{12,j}$	°C	Momentary t_{12}	For freezing risk calculation
P_{HRS_min}	kW	‘locked’ heat recovery power at ‘no freezing risk’ conditions	
$t_{21\_min,j}$	°C	Min. t_{21} with no ‘freeze risk’ in *j* hour	
$f_{v,j}$	-	Correction factor of the temperature efficiency for the air velocity in j hour	EN 16798-5-1

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
ϕ	dec.	Relative humidity	**Relative humidity (t,x)**	t, x
t_d	°C	Dew point temperature	**Dew point (t, ϕ)**	t, ϕ

4. Description of calculation procedure (without adiabatic cooling)

4.1. Assign input parameters

If **ϕ** values are given as input data, recalculate them to **x** values using Moisture content (t, **ϕ**)

$x_{11,j} = x_{ETA,j}$

$x_{21,j} = x_{ODA,j}$

$t_{21,j} = t_{ODA,j}$

$x_{22,j} = x_{ODA,j}$

IF EFP = 0 Exhaust fan upstream exchanger

$t_{11,j} = t_{ETA,j} + \Delta t_{FAN1,j}$

ELSE Exhaust fan downstream exchanger

$t_{11,j} = t_{ETA,j}$

4.2. Calculate actual temperature efficiency

Comment:
EN 16798-5-1:2017 gives the following equitation for the temperature efficiency correction

$\eta_{t,j} = \eta_t \cdot f_q \cdot f_v$

where:
f_q – the correction factor for the mass flow ratio other than 1.
f_v – The correction factor for the air velocity.

Factor f_q will not be calculated as recommended in the standard. Instead $\eta_{t(nom)}$ calculated by the AHU software will be considered. $\eta_{t(nom)} = \eta_t \cdot f_q$

$\eta_{t,j} = \eta_{t(nom)} \cdot f_v$

However, this means that at reduced air flow rate (according to a set schedule), the unbalanced mass flow ratio (if applicable) will be fixed (always the same).

$f_{v,j} = C_1 \cdot \upsilon_{hr;nom} ((q_{v2,j} / q_{v2nom}) - 1) + C_2$

C factors based on EN 16798-5-1:2017 table B.6

C_1 = -0.0491
C_2 = 1

Calculate actual temperature efficiency in j hour

$\eta_{t,j} = \eta_{t(nom)} \cdot f_{v,j}$

4.3. Conditions to skip calculations

IF $t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} \geq t_{ODA,j}$

OR $t_{11,j} = t_{ODA,j}$

OR $t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} - \Delta t_{FAN2,j} \leq t_{ODA,j}$

jump to END without changing input parameters ($t_{22,j} = t_{21,j}$, $P_{HRS\_C,j} = 0$, $P_{HRS\_H,j} = 0$).

4.4. Calculation procedure summer period

Proceed with calculations IF

$t_{11,j} < t_{ODA,j}$ AND $t_{SUP,j} < t_{ODA,j}$

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

$P_{HRS\_C,j} = \rho_s \cdot c_P \cdot q_{v2,j} \cdot (t_{21,j} - t_{22,j})$

$P_{pump,j} = P_{el\_pump}$

<u>Annual values</u>

Determination of annual energy recovery for cooling

Add the hourly $P_{HRS\_C,j}$ value to the sum of energy recovery for cooling from the preceding hour.

$ER_{C,j} = ER_{C,j-1} + P_{HRS\_C,j}$

Determination of the annual auxiliary electric energy consumption (RAC pump)

Add the hourly $P_{e\_pump,j}$ value to the sum of auxiliary electric energy consumption from the preceding hour.

$E_{EAUX,j} = E_{EAUX,j-1} + P_{e\_pump,j}$ -> see also section 3.5.1.4

IMPORTANT – don't count E_{EAUX} in hours with active Adiabatic cooling (ADC function) to avoid double counting.

4.5. Calculation procedure for winter period

Proceed with calculations IF

$t_{11,j} > t_{ODA,j}$ AND $t_{SUP,j} - \Delta t_{FAN2,j} > t_{ODA,j}$

Determine freezing protection starting point

Calculate dew point of inlet air on exhaust side

t_{d11} = **Dew point** ($t_{ETA\_DW,}$, x_{ETA_DW})

Calculate min. t_{12_MIN} without freezing.

$t_{12\_MIN} = \min[\, SF \,;\, t_{d11} + SF \,]$

SF – safety factor for nonuniform temperature distribution

SF = 2

Calculate momentary $t_{12,j}$ without freezing

Assumed that air on extract side is cooled without moisture content change.

$t_{12,j} = t_{11,j} - q_{V2,j} \cdot \eta_{t,j} \, (t_{11,j} - t_{21,j}) \,/\, q_{V1,j}$

IF $t_{12,j} > t_{12\_MIN}$ OR $t_{ODA,j} > -4$ THEN No freezing operation

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$

Check if t_{22} is not higher than the set t_{SUP}

IF $t_{22,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$

THEN

$t_{22,j} = t_{SUP,j} - \Delta t_{FAN2,j}$ Operation with efficiency reduced by controls

ELSE

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{11,j} - t_{21,j})$ Operation with full efficiency

$\mathbf{P_{HRS\_H,j} = \rho_s \cdot c_P \cdot q_{V2,j} \cdot (t_{22,j} - t_{21,j})}$

ELSE Operation in freezing risk conditions

Assumed that under freezing risk conditions exchanger operates with a 'locked' capacity equal to max. possible capacity under 'no freezing risk' conditions.

$P_{HRS\_min} = \rho_s \cdot c_P \cdot q_{V1,j} \cdot (t_{11,j} - t_{12\_MIN})$

$\mathbf{P_{HRS\_H,j} = P_{HRS\_min}}$

$t_{22j} = t_{21,j} + P_{HRS\_min} \,/\, \rho_s \cdot c_P \cdot q_{V2,j}$

Calculate the circulating pump power input in *j* hour (regardless of the freezing risk operation conditions)

$\mathbf{P_{pump,j} = P_{el\_pump}}$

<u>Annual values</u>

Determination of annual energy recovery for heating

Add the hourly $P_{HRS\_H,j}$ value to the sum of energy recovery for heating from the preceding hour.

$$ER_{H,j} = ER_{H,j-1} + P_{HRS\_H,j}$$

Determination of the annual auxiliary electric energy consumption (RAC pump)

Add the hourly $P_{e\_pump,j}$ value to the sum of auxiliary electric energy consumption from the preceding hour.

$$E_{EAUX,j} = E_{EAUX,j-1} + P_{e\_pump,j}$$ -> see also section 3.5.1.4

4.4 Function H – Heating coil

Function	Heating coil / electric heater
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V2,j}$	m³/s	Supply air flow rate in j hour	O1.2
$t_{1,j}$	°C	Inlet air temperature in *j* hour	
$x_{1,j}$	kg/kg	Air Inlet moisture content in *j* hour	

Auxiliary parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$\Delta t_{SH,j}$	°C	Temperature rise in steam humidifier in *j* hour	O10.2

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{1,j}$	%	Air Inlet relative humidity in *j* hour	Instead of $x_{1,j}$
$\phi_{SUP,j}$	%	Supply air relative humidity in *j* hour	Instead of $x_{SUP,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Remarks
S	Logic	Type of heating source for the heater W = water E = electric	AHU.9

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{2,j}$	°C	Air outlet temperature in *j* hour	O7.1
$x_{2,j}$	kg/kg	Air outlet moisture content in *j* hour	O7.2
$P_{h(s),j}$	kW	Heating output in *j* hour of 'S' type W = water heating coil and $P_{h(s),j} = P_{h(W),j}$ E = electric heater and $P_{h(s),j} = P_{h(E),j}$	07.3

3. Description of calculation procedure

3.1. Assign input parameters

IF no heat recovery (unidirectional supply unit): Only for the SUP configuration

$t_{1,j} = t_{ODA,j}$

$x_{1,j} = x_{ODA,j}$

IF heat recovery For PHE, ROT and RAC configurations

$t_{1,j} = t_{22,j}$ of a heat recovery section upstream

$x_{1,j} = x_{22,j}$ of a heat recovery section upstream

3.2. Logical conditions to start calculations

Proceed with calculations IF

$t_{ODA,j} \leq t_{SUP,j} - \Delta t_{FAN2,j} - \Delta t_{SH,j}$ AND $t_{1,j} \leq t_{SUP,j} - \Delta t_{FAN2,j} - \Delta t_{SH,j}$

ELSE jump to END without changing the input parameters ($t_{2,j} = t_{1,j}$ and $x_{2,j} = x_{1,j}$ and $P_{h(S),j} = 0$)

3.3. Calculation procedure

$t_{2,j} = t_{SUP,j} - \Delta t_{FAN2,j} - \Delta t_{SH,j}$

$x_{2,j} = x_{1,j}$

Calculate heating output

IF S = W water heating coil

$$\mathbf{P_{h(W),j} = \rho_s \cdot q_{V2,j} \cdot (t_{2,j} - t_{1,j})}$$

IF S = E electric heater

$$\mathbf{P_{h(E),j} = \rho_s \cdot q_{V2,j} \cdot (t_{2,j} - t_{1,j})}$$

Annual values

Determination of annual energy for heating

Add the hourly $P_{H(S),j}$ value to the sum of energy consumption for heating from the preceding hour.

IF S = W	water heating coil
$E_{TH,j} = E_{TH,j-1} + P_{H(W),j}$	-> see also section 3.5.2.1
IF S = E	electric heater
$E_{EH,j} = E_{EH,j-1} + P_{H(E),j}$	-> see also section 3.5.1.2

4.5 Function CC – Cooling coil

Function	Cooling coil (water and direct expansion)
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V2,j}$	m^3/s	Supply air flow rate in j hour	O1.2
$t_{1,j}$	°C	Inlet air temperature in *j* hour	
$x_{1,j}$	kg/kg	Air Inlet moisture content in *j* hour	

Auxiliary parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$x_{SUP,j}$	kg/kg	Supply air moisture content in *j* hour	O3.2
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{1,j}$	%	Air Inlet relative humidity in *j* hour	Instead of $x_{1,j}$
$\phi_{SUP,j}$	%	Supply air relative humidity in *j* hour	Instead of $x_{SUP,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Input source / remarks
CMC	Logic	Moisture content control mode 1 = Yes (set temperature and moisture control) 0 = No (only set temperature control)	AHU.17
Sr	Logic	Type of heating source for re-heater (moisture control)	AHU.18

		W = water E = electric	
S	Logic	Type of cooling energy source W = water DX = direct expansions	AHU.19 information only used for energy cost calculation

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{2,j}$	°C	Air outlet temperature in *j* hour	08.1
$x_{2,j}$	kg/kg	Air outlet moisture content in *j* hour	08.2
$P_{c,j}$	kW	Cooling output in *j* hour	08.3
$P_{RH\ (Sr),j}$	kW	Thermal or electric power to re-heater in *j* hour for moisture control mode (of 'Sr' type)	O8.4 Only for CMC = 1
DWO	Logic	Dry or wet cooling coil operation 1 = dry coil operation 2 = wet coil operation	O8.5

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$t_{d1,j}$	°C	Dew point of inlet air in *j* hour	

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
x	kg/kg	Moisture content	**Moisture content (t, ϕ)**	t, ϕ
ϕ	dec.	Relative humidity	**Relative humidity (t,x)**	t, x
t_d	°C	Dew point temperature	**Dew point (t, ϕ)**	t, ϕ
h	kJ/kg	Moist air specific enthalpy	**Enthalpy (t,x)**	t, x

4. Description of calculation procedure – no moisture content in supply air control mode

CASE 1: CMC = 0 (no moisture control) power of cooler controlled to maintain only the set t_{sup}

4.1. Assign input parameters

If **ϕ** values are given as input data, recalculate them to **x** values using Moisture content (t, **ϕ**)

IF no heat recovery (unidirectional supply unit): Only for the SUP configuration

$t_{1,j} = t_{ODA,j}$

$x_{1,j} = x_{ODA,j}$

IF heat recovery For PHE, ROT and RAC configurations

$t_{1,j} = t_{22,j}$ of a heat recovery section upstream

$x_{1,j} = x_{22,j}$ of a heat recovery section upstream

$t_{2,j} = t_{SUP,j} - \Delta t_{FAN2,j}$

4.2. Logical conditions to start calculations

Proceed with calculations IF

$t_{ODA,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{1,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$

Condition 2: e.g. if adiabatic cooling is ON and capable to maintain t_{SUP}

ELSE jump to END without changing input parameters ($t_{2,j} = t_{1,j}$ and $x_{2,j} = x_{1,j}$)

4.3. Calculation procedure

Calculate dew point of inlet air

$t_{d1,j}$ = **Dew point** ($t_{1,j}$, $x_{1,j}$)

IF $t_{2,j} > t_{d1,j}$ Dry operation

THEN

$x_{2,j} = x_{1,j}$

DWO = 1

ELSE Wet operation

$x_{2,j}$ = **Moisture content** (t_2 , 1) Moisture content for t_2 at saturation ($\phi = 1$)

DWO = 2

Calculate cooling output

$P_{c,j} = \rho_s \cdot q_{V2,j} \cdot$ (**Enthalpy** ($t_{1,j}$,$x_{1,j}$) - **Enthalpy** ($t_{2,j}$,$x_{2,j}$))

<u>Annual values</u>

Determination of annual energy for cooling

Add the hourly $P_{C,j}$ value to the sum of energy consumption for cooling from the preceding hour.

$E_{C,j} = E_{C,j-1} + P_{c,j}$ -> see also section 3.5.3

5. Description of calculation procedure – control of moisture content in supply air mode

CASE 2: CMC = 1 (moisture control) power of cooler and re-heater controlled to maintain t_{sup} and x_{SUP}

5.1. Assign input parameters

If ϕ values are given as input data, recalculate them to x values using **Moisture content (t, ϕ)**

IF no heat recovery (unidirectional supply unit): Only for the SUP configuration

$t_{1,j} = t_{ODA,j}$

$x_{1,j} = x_{ODA,j}$

IF heat recovery For PHE, ROT and RAC configurations

$t_{1,j} = t_{22,j}$ of a heat recovery section upstream

$x_{1,j} = x_{22,j}$ of a heat recovery section upstream

$x_{2,j} = x_{SUP,j}$

5.2. Logical conditions to start calculations

Proceed with calculations IF

$x_{1,j} > x_{SUP,j}$

IF $x_{1,j} \leq x_{SUP,j}$ AND $t_{ODA,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{1,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$ GO TO PROCEDURE AS IN CASE 1

ELSE: jump to END without changing input / output parameters

5.3. Calculation procedure

No dry operation expected

Determine $t_{2,j}$ using an iteration method assuming that end point of cooling process is on saturation curve ϕ = 1 for given $x_{2,j}$

$$x = 0.622 \cdot \frac{\varphi \cdot p_{ws}(t)}{p_{atm} - \varphi \cdot p_{ws}(t)} \qquad \{1\}$$

$$p_{ws}(t) = f(t) \qquad \{2\}$$

Calculate $t_{2,j}$ from {1} and {2} for ϕ = 1 and $x = x_{2,j}$

Calculate cooling output:

$P_{c,j} = \rho_s \cdot q_{v2,j} \cdot$ (**Enthalpy** $(t_{1,j}, x_{1,j})$ - **Enthalpy** $(t_{2,j}, x_{2,j})$)

Calculate thermal power to re-heater

IF Sr = E electric re-heater

$P_{RH(E),j} = \rho_s \cdot c_P \cdot q_{v2,j} \cdot (t_{SUP,j} - \Delta t_{FAN2,j} - t_{2,j})$

IF Sr = W water re-heater

$P_{RH(W),j} = \rho_s \cdot c_P \cdot q_{v2,j} \cdot (t_{SUP,j} - \Delta t_{FAN2,j} - t_{2,j})$

DWO = 2

<u>Annual values</u>

Determination of annual energy for cooling

Add the hourly $P_{C,j}$ value to the sum of energy consumption for cooling from the preceding hour.

$E_{C,j} = E_{C,j-1} + P_{c,j}$ -> see also section 3.5.3

Determination of annual energy consumption for heating (re-heating)

Add the hourly $P_{RH(S),j}$ value to the sum of energy consumption for heating from the preceding hour.

IF Sr = W water coil

$E_{TH,j} = E_{TH,j-1} + P_{RH(W),j}$ -> see also section 3.5.2.1

IF Sr = E electric heater

$E_{EH,j} = E_{EH,j-1} + P_{RH(E),j}$ -> see also section 3.5.1.2

4.6 Function HUM-AD – Adiabatic humidifier

Function	Adiabatic humidifier
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Data from climatic database, scenarios or another component upstream.

Main parameters for calculations

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
$x_{1,j}$	kg/kg	Air Inlet moisture content in *j* hour	

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$x_{SUP,j}$	°C	Supply air moisture content in *j* hour	O3.2

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{SUP,j}$	%	Supply air relative humidity in *j* hour	Instead of $x_{SUP,j}$

1.2. Input data from AHU calculation software

Symbol	UOM	Description	Input source / remarks
x_{ODA_DW}	kg/kg	Design outdoor air moisture content in winter	AHU.19
P_{el_nom}	kW	Humidifier pump nominal electric power input	AHU.10
F	-	Water consumption factor	AHU.7 based on values from Table 7.4 of Eurovent 6/8

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$x_{2,j}$	kg/kg	Air outlet moisture content in *j* hour	O9.1
$P_{t\_hu,j}$	kW	Thermal power for humidification in *j* hour	O9.2
$Wc_{,j}$	kg	Water consumption in *j* hour	O9.3

$P_{el\_pump,j}$	kW	Pump electric energy consumption in *j* hour	O9.4

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$q_{H,j}$	kg/s	Humidification load in *j* hour	

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
x	kg/kg	Moisture content	**Moisture content (t, ϕ)**	t, ϕ

4. Description of calculation procedure

4.1. Assign input parameters

If t_{SUP} and ϕ_{SUP} values are given as input data, convert them to x_{SUP} values using function Moisture content

$x_{2,j} = x_{SUP,j}$

IF no heat recovery (unidirectional supply unit):

$x_{1,j} = x_{ODA,j}$

IF heat recovery

$x_{1,j} = x_{22,j}$ of a heat recovery section upstream

4.2. Logical conditions to start calculations

Start calculations IF

$\mathbf{x_{1,j} < x_{2,j}}$

4.3. Calculation procedure

Thermal power for humidification in *j* hour

$P_{t\_hu,j} = \rho_s \cdot q_{V2,j} \cdot (x_{2,j} - x_{1,j}) \cdot 2450$

Comment: thermal power for heating the supply air to the set t_{SUP} is considered in the heater calculation (Function H). P_{t_hu} is only the power associated with the humidification process.
If two heating coils are used – upstream and downstream the humidifier – the entire power calculated will be assigned to the type (water, electric, steam) of the first coil (even if the second is of a different type e.g. first water, second electric).

Humidification load in *j* hour (i.e. water evaporated in the air)

$q_{H,j} = \rho_s \cdot q_{V2,j} \cdot (x_{2,j} - x_{1,j})$

Water consumption in *j* hour

$Wc_{,j} = q_{H,J} \cdot F \cdot 3600$

Pump electric energy consumption in *j* hour

$P_{el\_pump,j} = P_{el\_nom} \cdot (x_{2,j} - x_{1,j}) / (x_{2,j} - x_{ODA\_DW})$

<u>Annual values</u>

Determination of annual thermal energy for adiabatic humidification

Add the hourly $P_{t\_hu,j}$ value to the sum of thermal energy consumption for humidification. This energy is considered as thermal, if the master heating coil (Function H) is water, or as electric, if the master heater is electric.

$E_{THU,j} = E_{THU,j-1} + P_{t\_hu,j}$ -> see also section 3.5.2.3 and 3.5.1.7

Determination of annual water consumption for adiabatic humidification

Add the hourly $Wc_{,j}$ value to the sum of water consumption from the preceding hour.

$AWc_{,j} = AWc_{,j-1} + Wc_{,j}$ -> see also section 3.5.4.1

Determination of annual electricity consumption by the adiabatic humidifier pump

Add the hourly $P_{el\_pump,j}$ value to the sum of electricity consumption from the preceding hour.

$E_{AUX,j} = E_{AUX,j-1} + P_{el\_pump,j}$ -> see also section 3.5.1.4

4.7 Function HUM-ST – Steam humidifier

Function	Steam humidifier
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components.

Main parameters for calculation

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V2,j}$	m³/s	Supply air flow rate in *j* hour	O1.2
$x_{1,j}$	kg/kg	Air Inlet moisture content in *j* hour	

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$x_{SUP,j}$	°C	Supply air moisture content in *j* hour	O3.2

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{SUP,j}$	%	Supply air relative humidity in *j* hour	Instead of $x_{SUP,j}$

1.2. Input data from AHU calculation software

Symbol	UOM	Description	Input source / remarks
HT	Logic	Type of humidifier E = electric (electrode / resistance) C= central steam system G = gas fired	AHU.20
F	-	Water consumption factor	AHU.7 based on values from Table 7.4 of Eurovent 6/8

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$x_{2,j}$	kg/kg	Air outlet moisture content in *j* hour	O10.1

$\Delta t_{SH,j}$	°C	Air temperature increase in *j* hour	O10.2
$Wc_{,j}$	kg/h	Water consumption in *j* hour	O10.3
$P_{e\_hu,j}$	kW	Electric power input for humidification in *j* hour	O10.4 if HT = E (electric)
$P_{t\_hu,j}$	kW	Thermal power input for humidification in *j* hour	O10.5 If HT = C or G

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$q_{S,j}$	kg/s	Steam capacity required in j hour	

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
x	kg/kg	Moisture content	**Moisture content (t, ϕ)**	t, ϕ

4. Description of calculation procedure

4.1. Assing input parameters

If t_{SUP} and ϕ_{SUP} values are given as input data, convert them to x_{SUP} values using function **Moisture content**

$x_{2,j} = x_{SUP,j}$

IF no heat recovery (unidirectional supply unit):

$x_{1,j} = x_{ODA,j}$

IF heat recovery

$x_{1,j} = x_{22,j}$ of a heat recovery section upstream

4.2. Logical conditions to start calculations

Start calculations IF

$x_{1,j} < x_{2,j}$

Calculation procedure

Steam capacity required in *j* hour, kg/s

$q_{S,j} = \rho_s \cdot q_{V2,j} \cdot (x_{2,j} - x_{1,j})$

Air temperature increase in *j* hour

$\Delta t_{SH,j} = 150 \cdot (x_{2,j} - x_{1,j}) + 0.15$

Water consumption in *j* hour

$Wc_{,j} = q_{S,J} \cdot F \cdot 3600$

Calculation of power input (electric or thermal)

IF HT = E electric power source (immersed electrodes or immersed heaters humidifier)

Electric power input in *j* hour

$P_{el\_hum,j} = q_{S,j} \cdot (\Delta t_w \cdot c_{pw} + r) + P_{diss\_h} \approx 2700 \cdot q_{S,j}$

IF HT = G gas power source (gas fired humidifier)

$P_{t\_hum,j} = [\ q_{S,j} \cdot (\Delta t_w \cdot c_{pw} + r) + P_{diss\_h}\ ] \approx 2600 \cdot q_{S,j}$

IF HT = C (centralized steam boiler)

$P_{t\_hum,j} = q_{S,j} \cdot [\Delta t_w \cdot c_{pw} + r + (p_{temp} - 100) \cdot c_{pv}] = q_{S,j} \cdot [80 \cdot 1.87 + 2501 + (200 - 100) \cdot 2.2] = 2870.6 \cdot q_{S,j}$

<u>Annual values</u>

Determination of annual electricity consumption for steam humidification

If HT = E, add the hourly $P_{el\_hum,j}$ value to the sum of electric energy consumption for steam humidification.

$E_{EHU,j} = E_{EHU,j-1} + P_{el\_hum,j}$ -> see also section 3.5.1.6

Determination of annual thermal energy for steam humidification

If HT = G or C, add the hourly $P_{t\_hum,j}$ value to the sum of thermal energy consumption for steam humidification.

$E_{THUs,j} = E_{THUs,j-1} + P_{t\_hum,j}$ -> see also section 3.5.2.4

Determination of annual water consumption for steam humidification

Add the hourly $Wc_{,j}$ value to the sum of water consumption from the preceding hour.

$AWc_{,j} = AWc_{,j-1} + Wc_{,j}$ -> see also section 3.5.4.1

4.8 Function ADC – Adiabatic cooling

Function	Adiabatic cooling (adiabatic humidifier on exhaust side + plate exchanger or RAC or condensation rotary heat exchanger)
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components

Main parameters for calculation

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m^3/s	Exhaust air flow rate in *j* hour	O1.1
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
$t_{1,j}$	kg/kg	Air Inlet temperature content in *j* hour	Adiabatic humidifier
$x_{1,j}$	kg/kg	Air Inlet moisture content in *j* hour	Adiabatic humidifier
$t_{21,j}$	°C	Supply side air Inlet temperature in *j* hour	Heat recovery exchanger
$x_{21,j}$	kg/kg	Supply side air Inlet moisture content in *j* hour	Heat recovery exchanger

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$t_{ETA,j}$	°C	Extract air temperature in j hour	O3.3
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in *j* hour	O13.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in *j* hour	O2.2
$x_{ETA,j}$	kg/kg	Extract air moisture content in *j* hour	O3.4

Alternative UOM inputs

Symbol	UOM	Description	Remarks
$\phi_{21,j}$	%	Supply air Inlet relative humidity in *j* hour	Instead of $x_{21,j}$
$\phi_{ETA,j}$	%	Extract air relative humidity in *j* hour	Instead of $x_{ETA,j}$

1.2. Input data from the AHU calculation software

Symbol	UOM	Description	Input source / remarks
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1 if η_{h_j} would be calculated
η_{h_nom}	%	Nominal humidifier efficiency at q_{v1nom}	AHU.21
P_{el_nom}	kW	Humidifier pump nominal electric power input	AHU.10
F	-	Water consumption factor	AHU.7 based on values from Table 7.4 of Eurovent 6/8
EFP	Logic	Exhaust fan position 0 = Upstream 1 = Downstream	AHU.4

2. Output data for energy calculation

Symbol	UOM	Description	Output number / remarks
$t_{22,j}$	°C	Supply air outlet temperature in *j* hour Heat recovery exchanger	O11.1
$x_{22,j}$	kg/kg	Supply air outlet moisture content in *j* Head recovery exchanger	O11.2
$Wc_{,j}$	kg	Water consumption in *j* hour	O11.3
$P_{el\_pump,j}$	kW	Pump electric energy consumption in *j* hour	O11.4
$P_{AC,j}$	kW	Adiabatic cooling output in *j* hour	O11.5

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$t_{2,j}$	kg/kg	Air outlet temperature content in *j* hour	Adiabatic humidifier
$x_{2,j}$	kg/kg	Air outlet moisture content in *j* hour	Adiabatic humidifier
$t_{11,j}$	°C	Exhaust air Inlet temperature in *j* hour	Heat recovery exchanger
η_{h_j}	%	Actual humidifier efficiency in *j* hour at $q_{v1,j}$	
$x_{2(\eta max),j}$	kg/kg	Max possible moisture content downstream humidifier (no capacity reduction) in *j* hour	

x_{sat}	kg/kg	moisture content at saturation point for adiabatic humidification process (ϕ = 1)	
t_{sat}	°C	temperature at saturation point for adiabatic humidification process (ϕ = 1)	

Related psychrometric functions (see section 3.2)

Output	UOM	Name	Notation	Inputs
x	kg/kg	Moisture content	**Moisture content (t, ϕ)**	t, ϕ
h	kJ/kg	Moist air specific enthalpy	**Enthalpy (t,x)**	t, x

External functions called during computing:

ROT (Rotary heat exchanger) to calculate: $t_{22,j}$, $x_{22,j}$, $P_{e\_drv,j}$

PHE (Plate heat exchanger) to calculate $t_{22,j}$, $x_{22,j}$

RAC (Run-around coils) to calculate $t_{22,j}$, $x_{22,j}$, $P_{PUMP,j}$

4. Description of calculation procedure

4.1. Assign input parameters

If **ϕ** values are given as input data, recalculate them to **x** values using Moisture content (t, **ϕ**)

$x_{1,j} = x_{ETA,j}$

IF EFP = 0 Exhaust fan upstream humidifier

$t_{1,j} = t_{ETA,j} + \Delta t_{FAN1,j}$

ELSE Exhaust fan downstream humidifier

$t_{1,j} = t_{ETA,j}$

$x_{21,j} = x_{ODA,j}$ Input to ROT/PHE/RAC function

$t_{21,j} = t_{ODA,j}$ Input to ROT/PHE/RAC function

Humidification efficiency of adiabatic humidifier

Nominal humidifier efficiency (η_{h_nom}) is retrieved from the AHU selection software for the nominal exhaust air flow rate q_{v1nom}. For simplification, it was assumed that the impact of variation in the air flow rate ($q_{v1,j} << q_{v1nom}$) on humification efficiency is negligible

$\eta_{h\_j} = \eta_{h\_nom}$

4.2. Logical conditions to start calculations

Depending on the applied exchanger type, call function ROTc, PHE or RAC (with standard input data – without considering impact of adiabatic humidifier) to find out the actual value of $t_{22,j}$

Comment: do not start adiabatic cooling if cool recovery is enough to meet the t_{SUP} setpoint.

Start calculations IF

$t_{ODA,j} > t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{22,j} > t_{SUP,j} - \Delta t_{FAN2,j}$

ELSE – exit function and substitute outputs as follows:

$t_{22,j} = t_{22,j}$ derived from the called in a previous step ROTc, PHE or RAC function

$x_{22,j} = x_{22,j}$ derived from the called in a previous step ROTc, PHE or RAC function

$P_{AC,j} = 0$

$Wc_{,j} = 0$

$P_{el\_pump,j} = 0$

4.3. Calculation procedure

Determination of outlet air parameters of humidifier on the exhaust side

$h_{1,j} =$ **Enthalpy** $(t_{1,j}, x_{1,j}) = 1{,}006 \cdot t_{1,j} + x_{1,j} \cdot (2501 + 1{,}86 \cdot t_{1,j})$

$h_{1,j} = h_{2,j} = h_{sat,j}$ Adiabatic process

Calculation of temperature at saturation point $\phi = 1$

$$x = 0.62198 \cdot \frac{\varphi \cdot p_{ws}(t)}{p_{atm} - \varphi \cdot p_{ws}(t)}$$

Solve $t_{sat,}$ using the iterative method and the following equations

$$p_{ws} = 601.78 \cdot e^{(tsat,j / (tsat,j + 228.3) \cdot 17.2694)} \quad \{1\}$$

$$x_{sat,j} = 0.622 \cdot \frac{1 \cdot p_{ws}(t_{sat,j})}{p_{atm} - 1 \cdot p_{ws}(t_{sat,j})} \quad \{2\}$$

$$h_{1,j} = h_{sat,j} = 1{,}006 \cdot t_{sat,j} + x_{sat,j} \cdot (2501 + 1{,}86 \cdot t_{sat,j}) \quad \{3\}$$

} $t_{sat,j}$

Optionally, for simplification, assume $t_{sat} \approx$ wet bulb temperature and use the following experimental formula[1] to calculate the wet bulb temperature

$$T_w = T \operatorname{atan}[0.151977(RH\% + 8.313659)^{1/2}] + \operatorname{atan}(T + RH\%) - \operatorname{atan}(RH\% - 1.676331) + 0.00391838(RH\%)^{3/2} \operatorname{atan}(0.023101 RH\%) - 4.686035.$$

Where for our case applies:

$T_w \approx t_{sat}$

$RH = \phi_1$

$T = t_1$

Calculation of $x_{sat,j}$

[1] Stull. R, Wet-Bulb Temperature from Relative Humidity and Air Temperature, Journal of applied meteorology and climatology, Volume 50, November 2011.

$x_{sat,j} = (h_{sat,j} - 1{,}006 \cdot t_{sat,j}) / (2501 + 1{,}86 \cdot t_{sat,j})$

Calculation of $x_{2,j}$

$x_{2,j} = \eta_h \cdot (x_{sat,j} - x_{1,j}) + x_{1,j}$

$x_{2(\eta max),j} = x_{2,j}$

Calculation of $t_{2,j}$

$$t_{2,j} = \frac{h_{2,j} - x_{2,j} \cdot 2501}{1{,}006 + x_{2,j} \cdot 1{,}86}$$

Heat recovery exchanger outlet temperature in *j* hour, supply air side

Depending on the type applied exchanger type, call function ROT (condensation only), PHE or ERC-RAC setting as the input data for the exchanger calculation the following:

$t_{11,j} = t_{2,j}$

$x_{11,j} = x_{2,j}$

$t_{21,j} = t_{ODA,j}$

$x_{21,j} = x_{ODA,j}$

And calculate:

$t_{22,j}$ and $\eta_{t,j}$ — $t_{22,j} = t_{ODA,j} + \eta_{t,j} \cdot (t_{2,j} - t_{ODA,j})$

Moreover, calculate

for ROT: $P_{e\_drv,j}$

for RAC: $P_{PUMP,j}$

Check if t_{22} is not lower than set t_{SUP}

IF $t_{22,j} < t_{SUP,j} - \Delta t_{FAN2,j}$

THEN

$t_{2,j} = t_{21,j} + (t_{SUP,j} - \Delta t_{FAN2,j} - t_{21,j}) / \eta_{t,j}$ — Operation with reduced humidifier efficiency

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{2,j} - t_{21,j}) = t_{SUP,j} - \Delta t_{FAN2,j}$

$x_{2,j} = (h_{sat,j} - 1{,}006 \cdot t_{2,j}) / (2501 + 1{,}86 \cdot t_{2,j})$ — moisture content at reduced η_h

ELSE

$t_{22,j} = t_{21,j} + \eta_{t,j} \cdot (t_{2,j} - t_{21,j})$ — Humidifier operates with full capacity

Heat recovery exchanger outlet moisture content in *j* hour, supply air side

$x_{22,j} = x_{ODA,j}$

Adiabatic cooling output in *j* hour, supply air side, kW

$P_{AC,j} = \rho_s \cdot q_{V2,j} \cdot (t_{21,j} - t_{22,j})$

Water consumption in *j* hour

$Wc_{,j} = \rho_s \cdot q_{V1,j} \cdot (x_{2,j} - x_{1,j}) \cdot F \cdot 3600$

Electric energy consumption for pump in *j* hour

$P_{el\_pump,j} = P_{el\_nom} \cdot (x_{2,j} - x_{1,j}) / (x_{2(\eta max),j} - x_{1,j})$

Annual values

Determination of annual water consumption for adiabatic cooling

Add the hourly $Wc_{,j}$ value to the sum of water consumption from the preceding hour.

$AWc_{AC,j} = AWc_{AC,j-1} + Wc_{,j}$ -> see also section 3.5.4.2

Determination of the annual auxiliary electric energy consumption

For Rotary Heat exchanger

Add the hourly $P_{el\_pump,j}$ and $P_{e\_drv,j}$ values to the sum of auxiliary electric energy consumption for adiabatic cooling from the preceding hour.

$E_{EAUX\_AC,j} = E_{EAUX\_AC,j-1} + (P_{el\_pump,j} + P_{e\_drv,j})$ -> see also section 3.5.1.5

For Run-around coil

Add the hourly $P_{el\_pump,j}$ and $P_{pump,j}$ values to the sum of auxiliary electric energy consumption for adiabatic cooling from the preceding hour.

$E_{EAUX\_AC,j} = E_{EAUX\_AC,j-1} + (P_{el\_pump,j} + P_{pump,j})$ -> see also section 3.5.1.5

Determination of annual adiabatic cooling energy

Add the hourly $P_{AC,j}$ value to the sum of adiabatic cooling energy from the preceding hour.

$E_{AC,j} = E_{AC,j-1} + P_{AC,j}$

4.9 Function HRS+MIX – Heat recovery and mixing section

Function	Mixing section with a recuperative heat recovery exchanger
Revision number	F1
Date	12/31/2018

LIMITATIONS OF THE PROCEDURE

Due to the excessive complexity of calculations for the 'mixing section – heat recovery' set-up, (variability of temperature/moisture efficiency, HRS freezing, difficulty with finding the mixing point at enthalpy control mode), the following limitations apply to this calculation procedure:

- The AHU operates only at nominal and balanced supply and extract air flow rates,
- The AHU is equipped with a mixing section and with a recuperative heat exchanger with no moisture recovery (only plate heat exchanger)
- Actual outdoor air flow rate is calculated assuming that the temperature control mode (no enthalpy control) is applied.
- Variations of the fan static pressure and fan temperature rise due to changing of the ODA rate are not considered

1. Input data

1.1. Input from climate data, scenarios or other components

Main parameters for calculation

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m³/s	Exhaust air flow rate in *j* hour	$q_{V1,j} = q_{v1nom} = q_{v2nom}$ or 0
$q_{V2,j}$	m³/s	Supply air flow rate in *j* hour	$q_{V2,j} = q_{v2nom} = q_{v1nom}$ or 0

Auxiliary Parameters for calculations, boundaries and logical conditions

Symbol	UOM	Description	Input source / remarks
$t_{ODA,j}$	°C	Outdoor air temperature in j hour	O2.1
$t_{SUP,j}$	°C	Supply air temperature in *j* hour	O3.1
$t_{ETA,j}$	°C	Extract air temperature in j hour	O3.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4
$x_{ODA,j}$	kg/kg	Outdoor air moisture content in *j* hour	O2.2
$x_{ETA,j}$	kg/kg	Extract air moisture content in *j* hour	O3.4

1.2. Input data from AHU calculation software

Symbol	UOM	Description	Input source / remarks
q_{VODA_min}	m^3/s	Min. fresh air flow rate	AHU.35
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
All other data applicable for the PHE function			

2. Output data

Symbol	UOM	Description	Output number / remarks
$t_{mix,j}$	°C	Mixing temperature in j hour	O12.1
$x_{mix,j}$	kg/kg	mixing moisture content in *j* hour	O12.2

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$t_{22\_qv2nom,j}$	°C	t_{22} at $q_{v1nom} = q_{v2nom}$	From the PHE function
$t_{22\_ODA\_min,j}$	°C	t_{22} at q_{VODA_min}	From the PHE function
η_{t_v2nom}	dec	HRS temperature efficiency at $q_{v1nom} = q_{v2nom}$	From the PHE function
η_{t_ODAmin}	dec	HRS temperature efficiency at q_{VODA_min}	From the PHE function
$t_{mix\_ODAmin,j}$	°C	mixing temperature at q_{VODA_min} in *j* hour	
$q_{VODA,j}$	m^3/s	ODA rate in *j* hour	

4. Description of calculation procedure

Assumptions

- No consideration of internal pressure drop, and fan temperature rise variations
- Constant and balanced supply and exhaust air flow rate.

4.1. Mixing section + recuperative heat recovery (no moisture recovery). Temperature control

4.1.1. Heating mode

IF $t_{SUP,j} - \Delta t_{FAN2,j} > t_{ODA,j}$ AND $t_{ETA,j} > t_{ODA,j}$

Call the PHE function to calculate the actual t_{22} at q_{v2nom} and q_{VODA_min}

$t_{22\_qv2nom,j,} = PHE\ (q_{v1nom}\ ,\ q_{v2nom})$

$t_{22\_ODA\_min,j,} = PHE\ (q_{VODA\_min}\ ,\ q_{VODA\_min})$

For auxiliary calculations retrieve the corresponding exchanger efficiencies from the PHE function:

η_{t_ODAmin} at q_{VODA_min}

η_{t_v2nom} at q_{v2nom}

Calculate the mixing temperature at q_{VODA_min}

$t_{mix\_ODAmin,j} = (t_{22\_ODA\_min,j} \cdot q_{VODA\_min} + t_{ETA,j} \cdot (q_{v2nom} - q_{VODA\_min})) / q_{v2nom}$

CASE 1 $t_{mix\_ODAmin,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{22\_qv2nom,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$

Even the HRS alone, operating at nominal supply air flow can meet the required supply air temperature. No recirculation. Moreover, if needed, the efficiency of HRS must be reduced by controls to avoid overheating. Re-heater is OFF.

$t_{mix,j} = t_{SUP,j} - \Delta t_{FAN2,j}$

$x_{mix,j} = x_{ODA,j}$

CASE 2 $t_{mix\_ODAmin,j} \geq t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{22\_qv2nom,j} < t_{SUP,j} - \Delta t_{FAN2,j}$

Mixing temperature (at ODA_min) is higher than required supply temperature, but the HRS alone (operating at the nominal supply air flow rate) can't meet the required supply temperature. This means that to maintain required supply air temperature, the recirculation rate must be reduced (down to zero) and HRS operates at maximum efficiency (due to IAQ reasons). Re-heater is OFF.

To assess energy effect, we don't need to know neither actual recirculation rate nor actual efficiency of HRS (dependent on air flow rate). We simply assume that t_{sup} is met. Mixing rate is needed to find x_{mix} (in case of humidification)

$t_{mix,j} = t_{SUP,j} - \Delta t_{FAN2,j}$

$x_{mix,j} = (x_{ODA,j} \cdot q_{Voda,j} + x_{ETA,j} \cdot (q_{v2nom} - q_{Voda,j})) / q_{v2nom}$

Where

$q_{Voda,j} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ (positive solution)

$a = (\eta_{t\_v2nom} - \eta_{t\_ODAmin})$

$b = q_{VODA\_min} \cdot (1 - \eta_{t\_v2nom}) + q_{v2nom} \cdot (\eta_{t\_ODAmin} - 1)$

$c = q_{v2nom} \cdot (t_{mix,j} - t_{ETA,j}) \cdot (q_{v2nom} - q_{VODA\_min}) / (t_{ODA,j} - t_{ETA,j})$

CASE 3 $t_{mix\_ODAmin,j} < t_{SUP,j} - \Delta t_{FAN2,j}$

Despite the maximum recirculation rate and heat recovery efficiency at ODA_min through HRS, the required supply temperature cannot be met. Re-heater must be switched on.

$t_{mix,j} = t_{mix\_ODAmin,j}$

$x_{mix,j} = (x_{ODA,j} \cdot q_{VODA\_min} + x_{ETA,j} \cdot (q_{v2nom} - q_{VODA\_min})) / q_{v2nom}$

4.1.2. NEUTRAL MODE

IF $t_{SUP,j} - \Delta t_{FAN2,j} = t_{ODA,j}$ OR $t_{ETA,j} = t_{ODA,j}$

Neither recirculation nor heat recovery is needed, Use ODA

$t_{mix,j} = t_{ODA,j}$

$x_{mix,j} = x_{ODA,j}$

4.1.3. COOLING MODE

IF $t_{SUP,j} - \Delta t_{FAN2,j} < t_{ODA,j}$ AND $t_{ETA,j} < t_{ODA,j}$

Call the PHE function to calculate the actual t_{22} at q_{v2nom} and q_{VODA_min}

$t_{22\_qv2nom,j,} = \text{ERC-PHE}(q_{v1nom}, q_{v2nom})$

$t_{22\_ODA\_min,j,} = \text{ERC-PHE}(q_{VODA\_min}, q_{VODA\_min})$

For auxiliary calculations retrieve the corresponding exchanger efficiencies from the PHE function:

η_{t_ODAmin} at q_{VODA_min}

η_{t_v2nom} at q_{v2nom}

Calculate the mixing temperature at q_{VODA_min}

$t_{mix\_ODAmin,j} = (t_{22\_ODA\_min,j} \cdot q_{VODA\_min} + t_{ETA,j} \cdot (q_{v2nom} - q_{VODA\_min})) / q_{v2nom}$

CASE 1 $t_{mix\_ODAmin,j} \le t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{22\_qv2nom,j} \le t_{SUP,j} - \Delta t_{FAN2,j}$

The HRS alone, operating at nominal supply air flow rate can meet the required supply air temperature. No recirculation needed. Moreover, the efficiency of HRS may be reduced by controls to avoid overcooling. Cooler is OFF (This CASE is unlikely to occur except for specific applications such as a cold storage chamber).

$t_{mix,j} = t_{SUP,j} - \Delta t_{FAN2,j}$

$x_{mix,j} = x_{ODA,j}$

CASE 2 $t_{mix\_ODAmin,j} \le t_{SUP,j} - \Delta t_{FAN2,j}$ AND $t_{22\_qv2nom,j} > t_{SUP,j} - \Delta t_{FAN2,j}$

Mixing temperature (at ODA_min) is lower than the required supply temperature, but the HRS alone (operating at the nominal supply air flow rate) cannot meet the required supply temperature. This means that in order to maintain the required supply air temperature, recirculation must be reduced (down to zero) and HRS operates at the maximum efficiency (due to IAQ reasons). Cooler is OFF. (This CASE is unlikely to occur except for specific applications such as a cold storage chamber).

To assess energy effect, there is no need to know neither the actual recirculation rate nor actual efficiency of HRS (dependent on air flow rate). We simply assume that t_{sup} is met.

$t_{mix,j} = t_{SUP,j} - \Delta t_{FAN2,j}$

$x_{mix,j} = (x_{ODA,j} \cdot q_{Voda,j} + x_{ETA,j} \cdot (q_{v2nom} - q_{Voda,j})) / q_{v2nom}$

Where

$q_{Voda,j} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ (positive solution)

$a = (\eta_{t\_v2nom} - \eta_{t\_ODAmin})$

$b = q_{VODA\_min} \cdot (1 - \eta_{t\_v2nom}) + q_{v2nom} \cdot (\eta_{t\_ODAmin} - 1)$

$c = q_{v2nom} \cdot (t_{mix,j} - t_{ETA,j}) \cdot (q_{v2nom} - q_{VODA\_min}) / (t_{ODA,j} - t_{ETA,j})$

CASE 3 $t_{mix\_ODAmin,j} > t_{SUP,j} - \Delta t_{FAN2,j}$

This means, despite max. recirculation rate and max. heat recovery at ODA_min over HRS, required supply temperature is not met. Cooler must be used.

$t_{mix,j} = t_{mix\_ODAmin,j}$

$x_{mix,j} = (x_{ODA,j} \cdot q_{VODA\_min} + x_{ETA,j} \cdot (q_{v2nom} - q_{VODA\_min})) / q_{v2nom}$

IF $t_{SUP,j} - \Delta t_{FAN2,j} < t_{ODA,j}$ AND $t_{ETA,j} > t_{ODA,j}$

No recirculation and heat recovery. Use free-cooling.

$t_{mix,j} = t_{ODA,j}$
$x_{mix,j} = x_{ODA,j}$

4.10 Function FAN – Supply and Exhaust fan

Function	Supply and exhaust fan
Revision number	F1
Date	12/31/2018

1. Input data

1.1. Input from climate data, scenarios or other components

Symbol	UOM	Description	Input source / remarks
j	-	Hour of the year	
$q_{V1,j}$	m^3/s	Exhaust air flow rate in *j* hour	O1.1
$q_{V2,j}$	m^3/s	Supply air flow rate in *j* hour	O1.2
DWO	Logic	Dry or wet cooling coil operation in *j* hour 1 = dry cooling coil operation 2 = wet cooling coil operation	O8.5

1.2. Input data from AHU calculation software

Symbol	UOM	Description	Remarks
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
$P_{mot\_rated\_1}$	kW	Rated motor shaft power, exhaust fan	AHU.22
$P_{mot\_rated\_2}$	kW	Rated motor shaft power, supply fan	AHU.23
MT1	Logic	Type of motor, exhaust fan 1 = PM 2 = other type	AHU.24
MT2	Logic	Type of motor, supply fan 1 = PM 2 = other type	AHU.25
WPC	Logic	Working point at q_{v2nom} from AHU software given for dry or wet cooling coil conditions 1 = DRY 2 = WET	AHU.26
Δp_{ext1_nom}	Pa	external static pressure drop at q_{v1nom}, exhaust side	AHU.27

Δp_{int1_nom}	Pa	Internal static pressure drop at q_{v1nom}, exhaust side (internal components + average filter Δp)	AHU.28
Δp_{ext2_nom}	Pa	external static pressure drop at q_{v2nom}, supply side	AHU.29
Δp_{int2_nom}	Pa	Internal static pressure drop at q_{v2nom}, supply side (internal components + average filters Δp) at dry cooling coil (WPC=1) or wet cooling coil conditions (WPC=2)	AHU.30
Δp_{C}	Pa	Additional air pressure drop on the cooling coil due to wet operation (at q_{v2nom} and t_{ODA_DS} , x_{ODA_DS} , t_{SUP_DS})	AHU.31
$P_{el\_FAN1(nom)}$	kW	electrical power input of exhaust air fan from mains at nominal air flow q_{v1nom} and nominal static pressure ($\Delta p_{ext1\_nom} + \Delta p_{int1\_nom}$)	AHU.32 Acc. to EN 13053
$P_{el\_FAN2(nom)}$	kW	electrical power input of supply air fan from mains at nominal air flow q_{v2nom}, and nominal static pressure ($\Delta p_{ext2\_nom} + \Delta p_{int2\_nom}$) for **dry** cooling coils (WPC=1)	AHU.33 IF WPC=1
$P_{el\_FAN2\mathbf{w}(nom)}$	kW	electrical power input of supply air fan from mains at nominal air flow q_{v2nom}, and nominal static pressure ($\Delta p_{ext2\_nom} + \Delta p_{int2\_nom}$) for **wet** cooling coils (WPC=2)	AHU.34 IF WPC=2

2. Output data for electric energy consumption

Symbol	UOM	Description	Output number / remarks
$P_{el\_FAN1,j}$	kW	Electrical power input of exhaust air fan from mains in *j* hour	O13.1
$P_{el\_FAN2,j}$	kW	Electrical power input of supply air fan from mains in *j* hour	O13.2
$\Delta t_{FAN1,j}$	°C	Temperature rise in exhaust air fan in *j* hour	O13.3
$\Delta t_{FAN2,j}$	°C	Temperature rise in supply air fan in *j* hour	O13.4

3. Parameters for internal calculation within function

Symbol	UOM	Description	Remarks
$\Delta p_{s\_FAN1,j}$	Pa	Exhaust fan static pressure at reduced air flow rate $q_{V1,j}$ in j hour	
$\Delta p_{s\_FAN2,j}$	Pa	Supply fan static pressure at reduced air flow rate $q_{V2,j}$ in j hour	
$P_{el,2\_j}$	kW	Power supplied from mains to fan in secondary point	

4. Logical conditions to start calculations

Start calculations IF

$q_{V1,j}$ <> 0 AND $q_{V2,j}$ <> 0

5. Calculation procedure

5.1. Calculations at nominal air flows ($q_{V1,j} = q_{V1nom}$ and $q_{V2,j} = q_{V2nom}$)

For consecutive *j* hour of the year:

CASE 1: $q_{V2,j} = q_{V2nom}$ **AND** $q_{V1,j} = q_{V1nom}$ — nominal air flow rate

AND DWO = 1 — DRY cooling coil operating condition

AND WPC = 1 — fan power input from AHU software for DRY cooling coil

$P_{el\_FAN2,j} = P_{el\_FAN2\,(nom)}$

$P_{el\_FAN1,j} = P_{el\_FAN1(nom)}$

CASE 2: $q_{V2,j} = q_{V2nom}$ AND $q_{V1,j} = q_{V1nom}$ — nominal air flow rate

AND DWO = 2 — WET cooling coil operating condition

AND WPC = 1 — fan power input from AHU software for DRY cooling coil

$P_{el\,FAN2,j} = P_{el\_FAN2(nom)} \cdot (\Delta p_{ext2\_nom} + \Delta p_{int2\_nom} + \Delta p_C) / (\Delta p_{ext2\_nom} + \Delta p_{int2\_nom})$

Comment: assumed that the controls system adjusts fan speed to maintain the set air flow rate (fan efficiency constant)

$P_{el\_FAN1,j} = P_{el\_FAN1(nom)}$

CASE 3: $q_{V2,j} = q_{V2nom}$ AND $q_{V1,j} = q_{V1nom}$ — nominal air flow rate

AND DWO = 1 — DRY cooling coil operating condition

AND WPC = 2 — fan power input from AHU software for WET cooling coil

$P_{el\_FAN2,j} = P_{el\_FAN2W(nom)} \cdot (\Delta p_{ext2\_nom} + \Delta p_{int2\_nom}) / (\Delta p_{ext2\_nom} + \Delta p_{int2\_nom} + \Delta p_C)$

$P_{el\_FAN1,j} = P_{el\_FAN1(nom)}$

CASE 4: $q_{V2,j} = q_{V2nom}$ AND $q_{V1,j} = q_{V1nom}$ — nominal air flow rate

AND DWO = 2 — WET cooling coil operating condition

AND WPC = 2 — fan power input from AHU software for WET cooling coil

$P_{el\_FAN2,j} = P_{el\_FAN2W(nom)}$

$P_{el\_FAN1,j} = P_{el\_FAN1(nom)}$

FOR CASE 1 to 4

$\Delta t_{FAN2,j} = P_{el\_FAN2,j} / (q_{V2,j} \cdot \rho_s \cdot c_P)$

$\Delta t_{FAN1,j} = P_{el\_FAN1,j} / (q_{V1,j} \cdot \rho_s \cdot c_P)$

5.2. Calculations for air flow rates lower than nominal ($q_{V1,j} < q_{V1nom}$ and $q_{V2,j} < q_{V2nom}$)

Comment: Internal static pressure drop (Δp_{int_nom}) at nominal air flow rate is retrieved from the AHU selection software and calculated as a sum of pressure drops over internal components and average pressure drop of all filtration stages. Average pressure drop of filters is defined as a mean average of the initial and the final pressured drop. The final pressure drop is determined as per EN 13053

For ISO course class:	The smaller value of either adding 50 Pa to the clean filter pressure drop or three times the pressure drop of clean filters.
For ePM_1, $ePM_{2,5}$, ePM_{10}	The smaller value of either adding 100 Pa to the clean filter pressure drop or three times the pressure drop of clean filters.

Calculation for Exhaust air fan

Calculate exhaust fan static pressure at a reduced air flow rate $q_{V1,j}$ in *j* hour

$\Delta p_{s\_FAN1,j} = \Delta p_{ext1\_nom} \cdot (q_{V1,j} / q_{v1nom})^2 + \Delta p_{int1\_nom} (q_{V1,j} / q_{v1nom})^{1.4}$

Calculate power supplied from mains to a fan in secondary point $P_{el,2\_j}$ based on a procedure described in Section 6 of this Annex.

Substitute the variable symbols originally used in the procedure as follows:

Type of electrical motor = MT1

$q_1 = q_{v1nom}$

$p_1 = \Delta p_{ext1\_nom} + \Delta p_{int1\_nom}$

$P_{el,1} = P_{el\_FAN1(nom)}$

$P_{motor} = P_{mot\_rated\_1}$

$q_2 = q_{V1,j}$

$p_2 = \Delta p_{s\_FAN1,j}$

Electrical power input of exhaust air fan from mains in *j* hour

$P_{el\_FAN1,j} = P_{el,2\_j}$

Momentary air temperature rise

$\Delta t_{FAN1,j} = P_{el\_FAN1,j} / (q_{V1,j} \cdot \rho_s \cdot c_P)$

Calculation for Supply air fan

Calculate supply fan static pressure at reduced air flow rate $q_{V2,j}$ in j hour

$\Delta p_{s\_FAN2,j} = \Delta p_{ext2\_nom} \cdot (q_{V2,j} / q_{v2nom})^2 + \Delta p_{int2\_nom} (q_{V2,j} / q_{v2nom})^{1.4}$

Calculate power supplied from mains to a fan in secondary point $P_{el,2\_j}$ based on a procedure described in Section 6 of this Annex.

Substitute the variable symbols originally used in the procedure as follows:

Type of electrical motor = MT2

$q_1 = q_{v2nom}$

$p_1 = \Delta p_{ext2\_nom} + \Delta p_{int2\_nom}$

$P_{el,1}$

IF WPC = 1 THEN $P_{el,1} = P_{el\_FAN2(nom)}$
IF WPC = 2 THEN $P_{el,1} = P_{el\_FAN2W(nom)}$

$P_{motor} = P_{mot\_rated\_2}$

$q_2 = q_{V2,j}$

$p_2 = \Delta p_{s\_FAN2,j}$

Calculate supply fan electrical power input in j hour

For consecutive *j* hour of the year:

CASE 1

AND DWO = 1 — DRY cooling coil operating condition

AND WPC = 1 — fan power input from AHU software for DRY cooling coil

$P_{el\_FAN2,j} = P_{el,2\_j}$

CASE 2

AND DWO = 2 — WET cooling coil operating condition

AND WPC = 1 — fan power input from AHU software for DRY cooling coil

$P_{el\ FAN2,j} = P_{el,2\_j} \cdot (\Delta p_{s\_FAN2,j} + \Delta p_C \cdot (q_{V2,j} / q_{v2nom})^{1.4}) / \Delta p_{s\_FAN2,j}$

Comment: assumed that controls system adjusts fan speed to maintain set air flow rate (fan efficiency constant)

CASE 3

AND DWO = 1 — DRY cooling coil operating condition

AND WPC = 2 fan power input from AHU software for WET cooling coil

$P_{el\_FAN2,j} = P_{el,2\_j} \cdot \Delta p_{s\_FAN2,j} / (\Delta p_{s\_FAN2,j} + \Delta p_C \cdot (q_{V2,j} / q_{v2nom})^{1.4})$

CASE 4

AND DWO = 2 WET cooling coil operating condition

AND WPC = 2 fan power input from AHU software for WET cooling coil

$P_{el\_FAN2,j} = P_{el,2\_j}$

FOR CASE 1 to 4

$\Delta t_{FAN2,j} = P_{el\_FAN2,j} / (q_{V2,j} \cdot \rho_s \cdot c_P)$

<u>Annual values</u>

Determination of annual electric energy consumed by fans

Add the hourly $P_{el\_FAN1,j}$ and $P_{el\_FAN2,j}$ values to the sum of electricity consumption from the preceding hour.

$E_{EF,j} = E_{EF,j-1} + P_{el\_FAN1,j} + P_{el\_FAN2,j}$ -> see also section 3.5.1.1

6. Fan electrical power calculation – secondary point

Description of how to calculate a secondary point of fan electrical power consumption out of given prerequisites.

The electrical motor shall be connected to a speed control, VSD (variable frequency drive).

The methodology and data in ISO / DIS 12759-2 (standard losses for drive components) have been used as a fundamental source.

Following data in the standard have been made equations by curve-fitting:

- 4-pole, IE3, motor efficiencies
- 4-pole motor constants (a and b) when fed from VSD
- VFD performance constants (d, e), constant is omitted.

The rated motor powers in the standard are between 1 to 375 kW. Curve-fitting is extended downwards and upwards to be fail-safe.

No accuracy can be promised due to the simplification of highly complex calculations. The formulas and taken figures from the standard are expected to be normative but this application and the curve-fitting based on the numbers are not within expected use.

However, if we always go from the design point (the maximum point) to a lower point the electrical power will decrease rapidly and then it is less sensitive if the calculations have deviations.

Permanent magnet motors (PM) are considered to have about half of the losses compared to alternating current motors (AC).

The calculations are somewhat compensated for changes in fan efficiency due to deviation between fan working lines for the reference and calculated working point. The reference point is assumed to be located on the working line with maximum fan efficiency.

Data to be given

Type of electrical motor: AC (alternating current) or PM (permanent magnet)

Origin working point of fan:

- Air flow: q_1 in m^3/s
- Fan static pressure: p_1 in Pa
- Power supplied from mains to fan: $P_{el,1}$ in kW
- Rated motor shaft power: P_{motor}

Secondary working point of fan:

- Air flow: q_2 in m^3/s
- Fan static pressure: p_2 in Pa

Calculation result

Power supplied from mains to fan in secondary point: $P_{el,2}$ in kW

Calculations

Calculate nominal motor efficiency at rated shaft power: η_{mreg}

$$\eta_{mreg} := \begin{cases} \left[0.1678\cdot(P_{motor}-0.2)+\dfrac{(1.1-P_{motor})\cdot(P_{motor}-0.2)}{6.2308}+0.69\right] & \text{if } P_{motor}\le 1.1 \\ \left[0.009844\cdot(P_{motor}-1.1)+\dfrac{(7.5-P_{motor})\cdot(P_{motor}-1.1)}{620.606}+0.841\right] & \text{if } 1.1<P_{motor}\le 7.5 \\ \left[0.001013\cdot(P_{motor}-7.5)+\dfrac{(45-P_{motor})\cdot(P_{motor}-7.5)}{35874}+0.904\right] & \text{if } 7.5<P_{motor}\le 45 \\ \left[0.00011613\cdot(P_{motor}-45)+\dfrac{(200-P_{motor})\cdot(P_{motor}-45)}{1540064}+0.942\right] & \text{if } 45<P_{motor}\le 200 \\ 0.96 & \text{otherwise} \end{cases}$$

Calculate approximate motor shaft power at origin working point: $P_{mo,1}$

$$P_{mo,1} = \eta_{mreg} * P_{el,1}$$

Calculation of approximate motor shaft power in the secondary point: P_{mo_2}

$$P_{mo\_2} = \frac{q_2 * p_2}{q_1 * p_1} * P_{mo\_1}$$

Calculate motor load ratio: L_m

$$L_m = \frac{P_{mo\_2}}{P_{motor}}$$

Calculation coefficient: a

$$a := \begin{cases} 1.04 & \text{if } P_{motor} \le 5.5 \\ \left[\left[\left(2.66125 \cdot \frac{1}{P_{motor}} - 1.6656\right) \cdot \frac{1}{P_{motor}} + 0.3596\right] \cdot \frac{1}{P_{motor}} + 1.0137\right] & \text{if } 5.5 < P_{motor} < 135.7 \\ 1.01626 & \text{otherwise} \end{cases}$$

Calculation coefficient: b

$$b := \begin{cases} 1 & \text{if } P_{motor} \le 0.22 \\ \left[\left[\left(0.02072 \cdot \frac{1}{P_{motor}} - 0.064\right) \cdot \frac{1}{P_{motor}} + 0.0727\right] \cdot \frac{1}{P_{motor}} + 0.0025\right] & \text{if } 0.22 < P_{motor} \le 75 \\ 0.00269 + 8.9 \cdot 10^{-6} \cdot (P_{motor} - 75) & \text{if } 75 < P_{motor} < 150 \\ 0.0336 & \text{otherwise} \end{cases}$$

Calculation coefficient: c

$$c = 1 - \frac{a}{b+1}$$

Calculation of the motor efficiency: η_m

$$\eta_m = \eta_{mreg} * \left(\frac{a * L_m}{b + L_m} + c * L_m^2\right)$$

Set motor controller rated output power: P_{crat}

$$P_{crat} = 1.02 * \frac{P_{motor}}{\eta_{mreg}}$$

Calculate controller load ratio: L_m

$$L_c = \frac{P_{mo\_2}}{\eta_m * P_{crat\_}}$$

Calculation coefficient: d

$$d = 0.982$$

Calculation coefficient: e

$$e := \begin{cases} 0.04 & \text{if } P_{crat} \leq 1 \\ \left[\left[\left(0.06065 \cdot \frac{1}{P_{crat}} - 0.1314\right) \cdot \frac{1}{P_{crat}} + 0.0993\right] \cdot \frac{1}{P_{crat}} + 0.0109\right] & \text{if } 1 < P_{crat} \leq 150 \\ 0.0098 & \text{otherwise} \end{cases}$$

Calculation of the combined motor and motor control efficiency; η_{mc}

$$\eta_{mc} = \eta_m * \left(\frac{d * L_c}{e + L_c}\right)$$

If PM motor - recalculate the motor and control efficiency; η_{mc}

$$\eta_{mc} = \frac{\eta_{mc} + 0.98}{2}$$

Calculate relative deviation in fan working lines:

$$RWL = 1 - \frac{q_2}{q_1} * \sqrt{\frac{p_1}{p_2}}$$

Calculate the relative fan efficiency change: Reff

$$Reff := \begin{cases} 1 & \text{if } RWL \leq 0 \\ 1 - 0.088252 \cdot RWL & \text{if } 0 < RWL \leq 0.25 \\ [[[(-1.88664 \cdot RWL + 4.62522) \cdot RWL - 4.4458] \cdot RWL + 1.328] \cdot RWL + 0.8589] & \text{otherwise} \end{cases}$$

Calculate the power supplied from mains to fan in the secondary point including changes in fan efficiency: $P_{el,2}$ in kW

$$P_{el\_2} = \frac{P_{mo\_2}}{\eta_{mc} * Reff}$$

4.11 Input data from AHU technical specification and data assignment chart

Input data from AHU technical specification

Symbol	UOM	Description	AHU input number
q_{v1nom}	m^3/s	Nominal (design) exhaust air flow rate	AHU.1
q_{v2nom}	m^3/s	Nominal (design) supply air flow rate	AHU.2
$\eta_{t(nom)}$	%	Nominal (design) temperature efficiency (dry) at q_{v1nom} and q_{v2nom} for EN308 reference temperature conditions	AHU.3
EFP	Logic	Exhaust fan position 0 = Upstream the heat recovery exchanger 1 = Downstream the heat recovery exchanger	AHU.4
$\upsilon_{hr;nom}$	m/s	Air velocity over exchanger at nominal conditions according EN 16798-5-1	AHU.5
x_{ETA_DW}	kg/kg	Design extract air moisture content in winter	AHU.6
F	-	Water consumption factor based on values from Table 7.4 of Eurovent 6/8	AHU.7
t_{ETA_DW}	°C	Design extract air temperature in winter	AHU.8
S	Logic	Type of heating source for the heater W = water E = electric	AHU.9
P_{el_nom}	kW	Humidifier pump nominal electric power input	AHU.10
PH	Logic	Type of the pre-heater applied. 0 = no preheater (other frost protection measures) E = electric W = water coil	AHU.11
PHE	Logic	Type of plate heat exchanger 1 = counterflow 2 = crossflow	AHU.12
$\eta_{x\,(nom)}$	%	Nominal (design) humidity efficiency at q_{V1nom} and q_{V2nom} for winter design conditions. at t_{ETA_DW} , x_{ETA_DW} , t_{ODA_DW} and x_{ODA_DW}	AHU.13
P_{e_drv}	kW	Rotor drive nominal power input from mains	AHU.14
ROTyp	Logic	Type of rotary heat exchanger	AHU.15

Symbol	UOM	Description	AHU input number
		C = condensation H = hygroscopic S = sorption	
P_{el_pump}	kW	Electric power input of the RAC circulation pomp at selected system working point (fluid flow rate and fluid side pressure drop – coils + pipes + valve)	AHU.16
CMC	Logic	Moisture content control mode for a cooling coil 1 = Yes (set temperature and moisture control) 0 = No (only set temperature control)	AHU.17
Sr	Logic	Type of heating source for re-heater (moisture control) W = water E = electric	AHU.18
S	Logic	Type of cooling energy source for a cooling coil W = water DX = direct expansions	AHU.19
HT	Logic	Type of humidifier E = electric (electrode / resistance) C= central steam system G = gas fired	AHU.20
η_{h_nom}	%	Nominal humidifier efficiency at q_{v1nom}	AHU.21
$P_{mot\_rated\_1}$	kW	Rated motor shaft power, exhaust fan	AHU.22
$P_{mot\_rated\_2}$	kW	Rated motor shaft power, supply fan	AHU.23
MT1	Logic	Type of motor, exhaust fan 1 = PM 2 = other type	AHU.24
MT2	Logic	Type of motor, supply fan 1 = PM 2 = other type	AHU.25
WPC	Logic	Working point at q_{v2nom} from AHU software given for dry or wet cooling coil conditions 1 = DRY 2 = WET	AHU.26
Δp_{ext1_nom}	Pa	external static pressure drop at q_{v1nom}, exhaust side	AHU.27
Δp_{int1_nom}	Pa	Internal static pressure drop at q_{v1nom}, exhaust side (internal components + average filter Δp)	AHU.28

Symbol	UOM	Description	AHU input number
Δp_{ext2_nom}	Pa	external static pressure drop at q_{v2nom}, supply side	AHU.29
Δp_{int2_nom}	Pa	Internal static pressure drop at q_{v2nom}, supply side (internal components + average filters Δp) at dry cooling coil (WPC=1) or wet cooling coil conditions (WPC=2)	AHU.30
Δp_{C}	Pa	Additional air pressure drop on the cooling coil due to wet operation (at q_{v2nom} and t_{ODA_DS} , x_{ODA_DS} , t_{SUP_DS})	AHU.31
$P_{el\_FAN1(nom)}$	kW	electrical power input of exhaust air fan from mains at nominal air flow q_{v1nom} and nominal static pressure ($\Delta p_{ext1\_nom} + \Delta p_{int1\_nom}$) Acc. to EN 13053	AHU.32
$P_{el\_FAN2(nom)}$	kW	electrical power input of supply air fan from mains at nominal air flow q_{v2nom}, and nominal static pressure ($\Delta p_{ext2\_nom} + \Delta p_{int2\_nom}$) for **dry** cooling coils (WPC=1)	AHU.33
$P_{el\_FAN2\mathbf{w}(nom)}$	kW	electrical power input of supply air fan from mains at nominal air flow q_{v2nom}, and nominal static pressure ($\Delta p_{ext2\_nom} + \Delta p_{int2\_nom}$) for **wet** cooling coils (WPC=2)	AHU.34
q_{VODA_min}	m^3/s	Minimum fresh air flow rate	AHU.35

Function – AHU input data assignment chart

AHU input	Function									
number	PHE	ROT	RAC	H	CC	HUM-AD	HUM-ST	ADC	FANS	MIX
AHU.1	q_{v1nom}	q_{v1nom}	q_{v1nom}					q_{v1nom}	q_{v1nom}	
AHU.2	q_{v2nom}	q_{v2nom}	q_{v2nom}						q_{v2nom}	
AHU.3	$\eta_{t(nom)}$	$\eta_{t(nom)}$	$\eta_{t(nom)}$							
AHU.4	EFP	EFP	EFP					EFP		
AHU.5	$\upsilon_{hr;nom}$	$\upsilon_{hr;nom}$	$\upsilon_{hr;nom}$							
AHU.6	x_{ETA_DW}	x_{ETA_DW}	x_{ETA_DW}							
AHU.7						F	F	F		
AHU.8	t_{ETA_DW}		t_{ETA_DW}							
AHU.9				S	S					
AHU.10						P_{el_nom}		P_{el_nom}		
AHU.11	PH									
AHU.12	PHE									
AHU.13		$\eta_{x(nom)}$								
AHU.14		P_{e_drv}								
AHU.15		ROTyp								
AHU.16			P_{el_pump}							
AHU.17					CMC					
AHU.18					Sr					
AHU.19						x_{ODA_DW}				
AHU.20							HT			
AHU.21								η_{h_nom}		
AHU.22									$P_{mot\_rated\_1}$	
AHU.23									$P_{mot\_rated\_2}$	
AHU.24									MT1	
AHU.25									MT2	
AHU.26									WPC	
AHU.27									Δp_{ext1_nom}	
AHU.28									Δp_{int1_nom}	
AHU.29									Δp_{ext2_nom}	
AHU.30									Δp_{int2_nom}	
AHU.31									Δp_{C}	
AHU.32									$P_{el\_FAN1(nom)}$	
AHU.33									$P_{el\_FAN2(nom)}$	
AHU.34									$P_{el\_FAN2W(nom)}$	
AHU.35										q_{VODA_min}

4.12 Data-flow chart for Configuration 1 (PHE) - HR+H

CONFIG 1 (PHE) HR(PHE)+H

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_{C} AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	PH AHU.11	PHE AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.13 Data-flow chart for Configuration 2 (PHE) - HR+H+C

CONFIG 2 (PHE) HR(PHE)+H+C

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr,nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	PH AHU.11	PHE AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

EUROVENT EUROPEAN INDUSTRY ASSOCIATION

4.14 Data-flow chart for Configuration 3 (PHE) - HR+H+SH

CONFIG 3 (PHE) HR(PHE)+H+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	WPC=1	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	PH	PHE
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.11	AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	10	HUM-ST	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	HT	F													
				counter	O1.2	O3.2	O4.2	AHU.20	AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_{j}	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O4.1	O10.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.15 Data-flow chart for Configuration 4 (PHE) - HR+H+C+SH

CONFIG 4 (PHE) HR(PHE)+H+C+SH

Calculation Sequence	FUNCTION			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
				INPUT/OUTPUT NUMBER																		
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	PH AHU.11	PHE AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O4.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	$Wc_{,j}$	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O4.1	$x_{1,j}$ O10.1	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.16 Data-flow chart for Configuration 5 (PHE) - HR+H+AH

CONFIG	5 (PHE)	HR(PHE)+H+AH																				
Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	PH	PHE
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.11	AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O4.1	O4.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O4.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	$Wc_{,j}$	$P_{el\_pump,j}$															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.17 Data-flow chart for Configuration 6 (PHE) - HR+H+C+AH

CONFIG	6 (PHE)		HR(PHE)+H+C+AH																			
Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	PH	PHE
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.11	AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O4.1	O4.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O4.1	O4.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O4.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	$Wc_{,j}$	$P_{el\_pump,j}$															
9	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.18 Data-flow chart for Configuration 7 (PHE) - AC+HR+H+C

CONFIG 7 (PHE) AC+HR(PHE)+H+C

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	PH	PHE
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.11	AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	11	ADC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	η_{h_nom}	P_{el_nom}	F	EFP				
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.21	AHU.10	AHU.7	AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	$Wc_{,j}$	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O11.1	O11.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O4.1	O4.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.19 Data-flow chart for Configuration 8 (PHE) - AC+HR+H+C+SH

CONFIG 8 (PHE) AC+HR(PHE)+H+C+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	PH AHU.11	PHE AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_j	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O4.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
9	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
10	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 10

4.20 Data-flow chart for Configuration 9 (PHE) - AC+HR+H+C+AH

CONFIG 9 (PHE) **AC+HR(PHE)+H+C+AH**

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_{C} AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	4	PHE	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	PH AHU.11	PHE AHU.12
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{PH(s),j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_{j}	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O4.1	$x_{1,j}$ O4.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O4.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_{j}	$P_{el\_pump,j}$															
10	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_{C} AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 10

4.21 Data-flow chart for Configuration 10 (PHE) - HR+MIX+H

CONFIG 10 (PHE) **HR(PHE)+MIX+H** limited application - see description of function HRS-MIX

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	q_{vODA_min} AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
				Important: Function PHE called within HRS+MIX (see procedure description)																		
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O12.1	$x_{1,j}$ O12.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.22 Data-flow chart for Configuration 11 (PHE) - HR+MIX+H+C

CONFIG 11 (PHE) **HR(PHE)+MIX+H+C** limited application - see description of function HRS-MIX

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	q_{vODA_min}							
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.4	AHU.1	AHU.2	AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
			Important: Function PHE called inside HRS+MIX (see procedure description)																			
6	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O12.1	O12.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O12.1	O12.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

4.23 Data-flow chart for Configuration 12 (PHE) - HR+MIX+H+SH

CONFIG 12 (PHE) HR(PHE)+MIX+H+SH — limited application - see description of function HRS-MIX

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	q_{vODA_min} AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
				Important: Function PHE called inside HRS+MIX (see procedure description)																		
6	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O12.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	$Wc_{,j}$	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O12.1	$x_{1,j}$ O12.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.24 Data-flow chart for Configuration 13 (PHE) - HR+MIX+H+C+SH

CONFIG 13 (PHE) HR(PHE)+MIX+H+C+SH — limited application - see description of function HRS-MIX

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	q_{vODA_min}							
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.4	AHU.1	AHU.2	AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
				Important: Function PHE called inside HRS+MIX (see procedure description)																		
6	10	HUM-ST	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	HT	F													
				counter	O1.2	O3.2	O12.2	AHU.20	AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	$Wc_{,j}$	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O12.1	O12.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O12.1	O12.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.25 Data-flow chart for Configuration 14 (PHE) - HR+MIX+H+AH

CONFIG 14 (PHE) — **HR(PHE)+MIX+H+AH** — limited application - see description of function HRS-MIX

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_{C} AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	q_{vODA_min} AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
				Important: Function PHE called inside HRS+MIX (see procedure description)																		
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O12.1	$x_{1,j}$ O12.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O12.1	$x_{1,j}$ O12.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O12.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_{j}	$P_{el\_pump,j}$															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.26 Data-flow chart for Configuration 15 (PHE) - HR+MIX+H+C+AH

CONFIG 15 (PHE) **HR(PHE)+MIX+H+C+AH** limited application - see function description

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	12	HRS+MIX	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	q_{vODA_min}							
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.4	AHU.1	AHU.2	AHU.35							
			O	$t_{mix,j}$	$x_{mix,j}$																	
				Important: Function PHE called inside HRS+MIX (see procedure description)																		
7	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O12.1	O12.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O12.1	O12.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O12.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_j	$P_{el\_pump,j}$															
10	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input in performed in step 9

4.27 Data-flow chart for Configuration 1 (ROT) - HR+ H

CONFIG 1 (ROT) HR(ROT)+H

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	WPC=1	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	$\eta_{x(nom)}$	P_{e_drv}	ROTyp
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.13	AHU.14	AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O5.1	O5.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.28 Data-flow chart for Configuration 2 (ROT) - HR+H+C

CONFIG 2 (ROT) HR(ROT)+H+C

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr,nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

4.29 Data-flow chart for Configuration 3 (ROT) - HR+H+SH

CONFIG 3 (ROT) HR(ROT)+H+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O5.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O5.1	$x_{1,j}$ O10.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.30 Data-flow chart for Configuration 4 (ROT) - HR+H+C+SH

CONFIG 4 (ROT) **HR(ROT)+H+C+SH**

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O5.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	$Wc_{,j}$	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O5.1	$x_{1,j}$ O10.1	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.31 Data-flow chart for Configuration 5 (ROT) - HR+H+AH

CONFIG	5 (ROT)	HR(ROT)+H+AH																				
Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER																		
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2w(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O5.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	$Wc_{,j}$	$P_{el\_pump,j}$															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.32 Data-flow chart for Configuration 6 (ROT) - HR+H+C+AH

CONFIG 6 (ROT) HR(ROT)+H+C+AH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O5.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_j	$P_{el\_pump,j}$															
9	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.33 Data-flow chart for Configuration 7 (ROTc) - AC-HR+H+C

CONFIG 7 (ROT) **AC+HR(ROTc)+H+C** **Only condensation rotor**

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	$Wc_{,j}$	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.34 Data-flow chart for Configuration 8 (ROTc) - AC-HR+H+C+SH

CONFIG 8 (ROTc) AC+HR(ROTc)+H+C+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	$\eta_{x(nom)}$ AHU.13	P_{e_drv} AHU.14	ROTyp AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_j	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O5.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
9	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O5.1	$x_{1,j}$ O5.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
10	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT

Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)

Essential calculation of power input is performed in step 10

4.35 Data-flow chart for Configuration 9 (ROTc) - AC-HR+H+C+AH

CONFIG 9 (ROT) AC+HR(ROTc)+H+C+AH **Only condensation rotor**

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
				INPUT/OUTPUT NUMBER																		
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	5	ROT	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	$\eta_{x(nom)}$	P_{e_drv}	ROTyp
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.13	AHU.14	AHU.15
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{e\_drv,j}$														
6	11	ADC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	η_{h_nom}	P_{el_nom}	F	EFP				
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.21	AHU.10	AHU.7	AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_j	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O11.1	O11.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O5.1	O5.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O5.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_j	$P_{el\_pump,j}$															
10	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 10

4.36 Data-flow chart for Configuration 1 (RAC) - HR+H

CONFIG 1 (RAC) HR(RAC)+H

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_{C} AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	P_{el_pump} AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O6.1	$x_{1,j}$ O6.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.37 Data-flow chart for Configuration 2 (RAC) - HR+H+C

2 (RAC) **HR(RAC)+H+C**

	FUNCTION		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			INPUT/OUTPUT NUMBER																		
1	operating mode scenario	I	j																		
			counter																		
		O	$q_{v1,j}$	$q_{v2,j}$																	
2	outdoor climatic data	I	j																		
			counter																		
		O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
			counter	O2.1	O2.2																
		O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
			counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
		O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
6	RAC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	P_{el_pump}	
			counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.16	
		O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
			counter	O1.2	O3.1	O2.1	O13.4	O10.2	O6.1	O6.2	AHU.9										
		O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
			counter	O1.2	O3.1	O3.2	O2.1	O13.4	O6.1	O6.2	AHU.9	AHU.17	AHU.18								
		O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
			counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
		O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

4.38 Data-flow chart for Configuration 3 (RAC) - HR+H+SH

CONFIG 3 (RAC) HR(RAC)+H+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	WPC=1	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	P_{el_pump} AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O6.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O6.1	$x_{1,j}$ O10.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.39 Data-flow chart for Configuration 4 (RAC) - HR+H+C+SH

CONFIG 4 (RAC) HR(RAC)+H+C+SH

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
				INPUT/OUTPUT NUMBER																		
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	P_{el_pump}	
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	10	HUM-ST	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	HT	F													
				counter	O1.2	O3.2	O6.2	AHU.20	AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	$Wc_{,j}$	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
7	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O6.1	O10.1	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
8	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O6.1	O6.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
9	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.40 Data-flow chart for Configuration 5 (RAC) - HR+H+AH

CONFIG 5 (RAC) HR(RAC)+H+AH

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	P_{el_pump} AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O6.1	$x_{1,j}$ O6.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O6.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	$Wc_{,j}$	$P_{el\_pump,j}$															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.41 Data-flow chart for Configuration 6 (RAC) - HR+H+C+AH

CONFIG	6 (RAC)		HR(RAC)+H+C+AH																			
Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	P_{el_pump}	
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	~~O10.2~~	O6.1	O6.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O6.1	O6.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O6.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	$Wc_{,j}$	$P_{el\_pump,j}$															
9	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_C	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 9

4.42 Data-flow chart for Configuration 7 (RAC) - AC+HR+H+C

CONFIG 7 (RAC) AC+HR(RAC)+H+C

Calculation Sequence	FUNCTION			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	P_{el_pump} AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_j	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ ~~O10.2~~	$t_{1,j}$ O6.1	$x_{1,j}$ O6.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT

Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)

Essential calculation of power input is performed in step 9

4.43 Data-flow chart for Configuration 8 (RAC) - AC+HR+H+C+SH

CONFIG 8 (RAC) AC+HR(RAC)+H+C+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$\eta_{t(nom)}$ AHU.3	$\upsilon_{hr;nom}$ AHU.5	EFP AHU.4	x_{ETA_DW} AHU.6	t_{ETA_DW} AHU.8	P_{el_pump} AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	11	ADC	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	$t_{ETA,j}$ O3.3	$x_{ETA,j}$ O3.4	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2	$t_{SUP,j}$ O3.1	$\Delta t_{FAN1,j}$ O13.3	$\Delta t_{FAN2,j}$ O13.4	q_{v1nom} AHU.1	η_{h_nom} AHU.21	P_{el_nom} AHU.10	F AHU.7	EFP AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_j	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O11.1	$x_{1,j}$ O11.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{C,j}$	$P_{RH(Sr),j}$	DWO														
8	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O6.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
9	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O6.1	$x_{1,j}$ O6.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
10	13	FANS	I	j counter	$q_{v1,j}$ O1.1	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} AHU.1	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ AHU.22	$P_{mot\_rated\_2}$ AHU.23	MT1 AHU.24	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} AHU.27	Δp_{int1_nom} AHU.28	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ AHU.32	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 10

4.44 Data-flow chart for Configuration 9 (RAC) - AC+HR+H+C+AH

CONFIG 9 (RAC) AC+HR(RAC)+H+C+AH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j																		
				counter																		
			O	$q_{v1,j}$	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j																		
				counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j	$t_{ODA,j}$	$x_{ODA,j}$																
				counter	O2.1	O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	DWO=1	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O			$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$															
5	6	RAC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	q_{v2nom}	$\eta_{t(nom)}$	$\upsilon_{hr;nom}$	EFP	x_{ETA_DW}	t_{ETA_DW}	P_{el_pump}	
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.2	AHU.3	AHU.5	AHU.4	AHU.6	AHU.8	AHU.16	
			O	$t_{22,j}$	$x_{22,j}$	$P_{HRS\_H,j}$	$P_{HRS\_C,j}$	$P_{pump,j}$														
6	11	ADC	I	j	$q_{v1,j}$	$q_{v2,j}$	$t_{ETA,j}$	$x_{ETA,j}$	$t_{ODA,j}$	$x_{ODA,j}$	$t_{SUP,j}$	$\Delta t_{FAN1,j}$	$\Delta t_{FAN2,j}$	q_{v1nom}	η_{h_nom}	P_{el_nom}	F	EFP				
				counter	O1.1	O1.2	O3.3	O3.4	O2.1	O2.2	O3.1	O13.3	O13.4	AHU.1	AHU.21	AHU.10	AHU.7	AHU.4				
			O	$t_{22,j}$	$x_{22,j}$	Wc_{j}	$P_{el\_pump,j}$	$P_{AC,j}$														
7	8	CC	I	j	$q_{v2,j}$	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$t_{1,j}$	$x_{1,j}$	S	CMC	Sr								
				counter	O1.2	O3.1	O3.2	O2.1	O13.4	O11.1	O11.2	AHU.9	AHU.17	AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	7	H	I	j	$q_{v2,j}$	$t_{SUP,j}$	$t_{ODA,j}$	$\Delta t_{FAN2,j}$	$\Delta t_{SH,j}$	$t_{1,j}$	$x_{1,j}$	S										
				counter	O1.2	O3.1	O2.1	O13.4	O10.2	O6.1	O6.2	AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
9	9	HUM-AD	I	j	$q_{v2,j}$	$x_{SUP,j}$	$x_{1,j}$	x_{ODA_DW}	P_{el_nom}	F												
				counter	O1.2	O3.2	O6.2	AHU.19	AHU.10	AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_{j}	$P_{el\_pump,j}$															
10	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	O1.2	O8.5	AHU.1	AHU.2	AHU.22	AHU.23	AHU.24	AHU.25	AHU.26	AHU.27	AHU.28	AHU.29	AHU.30	AHU.31	AHU.32	AHU.33	AHU.34
			O	$P_{el\_FAN1,j}$	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 10

4.45 Data-flow chart for Configuration 16 (SUP) - H

CONFIG 16 (SUP) H

Calculation Sequence	FUNCTION			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
				INPUT/OUTPUT NUMBER																		
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C ~~AHU.31~~	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2w(nom)}$ ~~AHU.34~~
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

Eurovent AISBL / IVZW / INPA
European Industry Association
EU Trans. Reg.: 89424237848-89

80 Bd A. Reyers Ln
1030 Brussels
BELGIUM

www.eurovent.eu
+32 (0)466 90 04 01
secretariat@eurovent.eu

Fortis Bank
IBAN: BE 31 210043999555
BIC: GEBABEBB

4.46 Data-flow chart for Configuration 17 (SUP) - H+SH

CONFIG 17 (SUP) H+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C ~~AHU.31~~	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ ~~AHU.34~~
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O2.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.47 Data-flow chart for Configuration 18 (SUP) - H+AH

CONFIG 18 (SUP) H+AH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC WPC=1	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C ~~AHU.31~~	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ ~~AHU.34~~
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
6	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O2.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_j	$P_{el\_pump,j}$															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

4.48 Data-flow chart for Configuration 19 (SUP) - H+C

CONFIG 19 (SUP) H+C

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
6	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
7	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 7

4.49 Data-flow chart for Configuration 20 (SUP) - H+C+SH

CONFIG 20 (SUP) H+C+SH

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	10	HUM-ST	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O2.2	HT AHU.20	F AHU.7													
			O	$x_{2,j}$	$\Delta t_{SH,j}$	Wc_j	$P_{e\_hu,j}$	$P_{t\_hu,j}$														
6	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
7	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
8	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

4.50 Data-flow chart for Configuration 21 (SUP) - H+C+AH

CONFIG 21 (SUP) H+C+AH

Calculation Sequence	FUNCTION		I/O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
				INPUT/OUTPUT NUMBER																		
1	1	operating mode scenario	I	j counter																		
			O	~~$q_{v1,j}$~~	$q_{v2,j}$																	
2	2	outdoor climatic data	I	j counter																		
			O	$t_{ODA,j}$	$x_{ODA,j}$																	
3	3	t-x scenario	I	j counter	$t_{ODA,j}$ O2.1	$x_{ODA,j}$ O2.2																
			O	$t_{SUP,j}$	$x_{SUP,j}$	$t_{ETA,j}$	$x_{ETA,j}$															
4	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO DWO=1	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O			~~$\Delta t_{FAN1,j}$~~	$\Delta t_{FAN2,j}$															
5	7	H	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$\Delta t_{SH,j}$ O10.2	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9										
			O	$t_{2,j}$	$x_{2,j}$	$P_{h(s),j}$																
6	8	CC	I	j counter	$q_{v2,j}$ O1.2	$t_{SUP,j}$ O3.1	$x_{SUP,j}$ O3.2	$t_{ODA,j}$ O2.1	$\Delta t_{FAN2,j}$ O13.4	$t_{1,j}$ O2.1	$x_{1,j}$ O2.2	S AHU.9	CMC AHU.17	Sr AHU.18								
			O	$t_{2,j}$	$x_{2,j}$	$P_{c,j}$	$P_{RH(Sr),j}$	DWO														
7	9	HUM-AD	I	j counter	$q_{v2,j}$ O1.2	$x_{SUP,j}$ O3.2	$x_{1,j}$ O2.2	x_{ODA_DW} AHU.19	P_{el_nom} AHU.10	F AHU.7												
			O	$x_{2,j}$	$P_{t\_hu,j}$	Wc_j	$P_{el\_pump,j}$															
8	13	FANS	I	j counter	$q_{v1,j}$ ~~O1.1~~	$q_{v2,j}$ O1.2	DWO O8.5	q_{v1nom} ~~AHU.1~~	q_{v2nom} AHU.2	$P_{mot\_rated\_1}$ ~~AHU.22~~	$P_{mot\_rated\_2}$ AHU.23	MT1 ~~AHU.24~~	MT2 AHU.25	WPC AHU.26	Δp_{ext1_nom} ~~AHU.27~~	Δp_{int1_nom} ~~AHU.28~~	Δp_{ext2_nom} AHU.29	Δp_{int2_nom} AHU.30	Δp_C AHU.31	$P_{el\_FAN1(nom)}$ ~~AHU.32~~	$P_{el\_FAN2(nom)}$ AHU.33	$P_{el\_FAN2W(nom)}$ AHU.34
			O	~~$P_{el\_FAN1,j}$~~	$P_{el\_FAN2,j}$	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

COMMENT
Fans are calculated for the first time in step 4 only to determine temperature rise over fans to avoid the loop with cooling coil (CC)
Essential calculation of power input is performed in step 8

4.51 Data-flow chart for Configuration 22 (EHA) - Fan

CONFIG 22 (EHA) Fan

Calculation Sequence	FUNCTION			INPUT/OUTPUT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	operating mode scenario	I	j counter																		
			O	$q_{v1,j}$	~~$q_{v2,j}$~~																	
2	13	FANS	I	j	$q_{v1,j}$	$q_{v2,j}$	DWO	q_{v1nom}	q_{v2nom}	$P_{mot\_rated\_1}$	$P_{mot\_rated\_2}$	MT1	MT2	WPC	Δp_{ext1_nom}	Δp_{int1_nom}	Δp_{ext2_nom}	Δp_{int2_nom}	Δp_{C}	$P_{el\_FAN1(nom)}$	$P_{el\_FAN2(nom)}$	$P_{el\_FAN2W(nom)}$
				counter	O1.1	~~O1.2~~	~~DWO=1~~	AHU.1	~~AHU.2~~	AHU.22	~~AHU.23~~	AHU.24	~~AHU.25~~	~~WPC=1~~	AHU.27	AHU.28	~~AHU.29~~	~~AHU.30~~	~~AHU.31~~	AHU.32	~~AHU.33~~	~~AHU.34~~
			O	$P_{el\_FAN1,j}$	~~$P_{el\_FAN2,j}$~~	~~$\Delta t_{FAN1,j}$~~	~~$\Delta t_{FAN2,j}$~~															

DYNAMICALLY ASSIGNED VARIABLES (DEPENDING ON CONFIGURATION)
FIXED VALUE
AHU SOFTWARE INPUTS
OUTCOME ADDED TO ANNUAL SUM
AUXILIARY CALCULATIONS

5 Annexes – economic and price factors for LCC calculation

5.1 General factors - Eurovent reference values

Item	UoM	Description	Value
n	years	AHU life span (assumed LCC calculation period)	15
r_R	decimal	Discount rate	0.03
PDR_E	decimal	Price development rate for electricity, thermal energy, cooling energy and water price	0.00
PDR_L	decimal	Price development rate for labour cost	0.00

5.2 Energy and utility calculations - Eurovent reference values

Item	UoM	Description	Value
C_{EL}	€/kWh	Electric energy price	
C_{TH}	€/kWh	Heating energy price for water heating coils	
C_{TS}	€/kWh	Thermal energy price for steam generation	
C_C	€/kWh	Cooling energy price	
C_W	€/kg	Water price	

6 Annex – presentation of LCC calculation results

The structure and list of items to be presented as LCC calculation outcomes.

LCC values

- LCC value (total)
- LCC share accounting for RC_{EU} (Running costs – Energy & Utilities)
  - Separately LCC value for electrical energy
  - Separately LCC value for heating energy
  - Separately LCC value for cooling energy
  - Separately LCC value for water consumption
- LCC share accounting for RC_{RM} (Running costs – Regular maintenance)
  - Separately LCC value for labour cost
  - Separately LCC value for spare parts
- LCC value for OC (ORR) (Occasional Costs – Occasional Repair and Replacement)
  - Separately LCC value for labour cost
  - Separately LCC value parts / material cost
- LCC value for FC (final costs)
  - Separately LCC value for Residual value
  - Separately LCC value for disposal
- LCC value for IC (Investment costs)
  - Acquisition cost
  - Assembling cost
  - Start-up, commissioning

Energy calculation

- Annual electrical energy consumption (kWh/a)
  - Annual electrical energy consumption for fans (kWh/a)
  - Annual electrical energy consumption for heaters, including the HRS pre-heater (kWh/a)
  - Annual electrical energy consumption for Rotary Exchanger drive (kWh/a)
  - Annual electrical energy consumption for pumps RAC, adiabatic humidifiers (kWh/a)
  - Annual electrical energy consumption for electric steam humidifiers (kWh/a)
  - Annual electrical energy consumption for control system (kWh/a) (fixed value)
  - Other?

- Annual heating energy consumption (kWh/a)
  - Annual consumption for heating coils (total for all) (kWh/a)
  - Thermal energy consumption for adiabatic humidification (kWh/a)

- Annual cooling energy consumption (kWh/a)
  - Annual consumption for cooling coils (no type distinction) (kWh/a)

- Annual water consumption for humidification & adiabatic cooling (dm^3/a)

- Annual heat recovery by HRS
  - Sensible energy recovery (kWh/a)
  - Total energy recovery (kWh/a)
  - Moist recovery (kg/a)

- Annual cooling energy delivered by Adiabatic cooling (kWh/a)

Regular maintenance and ORR related costs

- Regular maintenance
    - Annual labour cost for regular maintenance measures (respectively for each year)
    - Annual cost of spare parts for regular maintenance measures (respectively for each year)
    - Annual time for regular maintenance measures (respectively for each year)
- Occasional repairs and replacements
    - Annual ORR cost respectively for each year

Eurovent AISBL / IVZW / INPA
European Industry Association
EU Trans. Reg.: 89424237848-89

80 Bd A. Reyers Ln
1030 Brussels
BELGIUM

www.eurovent.eu
+32 (0)466 90 04 01
secretariat@eurovent.eu

Fortis Bank
IBAN: BE 31 210043999555
BIC: GEBABEBB

About Eurovent

Eurovent is Europe's Industry Association for Indoor Climate (HVAC), Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe represent more than 1.000 organisations, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn EUR, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level playing field for the entire industry independent from organisation sizes or membership fees.

Our Member Associations

Our Member Associations are major national sector associations from Europe that represent manufacturers in the area of Indoor Climate (HVAC), Process Cooling, Food Cold Chain, and Industrial Ventilation technologies.

The more than 1.000 manufacturers within our network (Eurovent 'Affiliated Manufacturers' and 'Corresponding Members') are represented in Eurovent activities in a democratic and transparent manner.

→ For in-depth information and a list of all our members, visit www.eurovent.eu