Heat Exchanger with Water Vapour Condensation / Wet Coils in AHU

4.6.2. Kreislaufverbundsysteme (KVS)

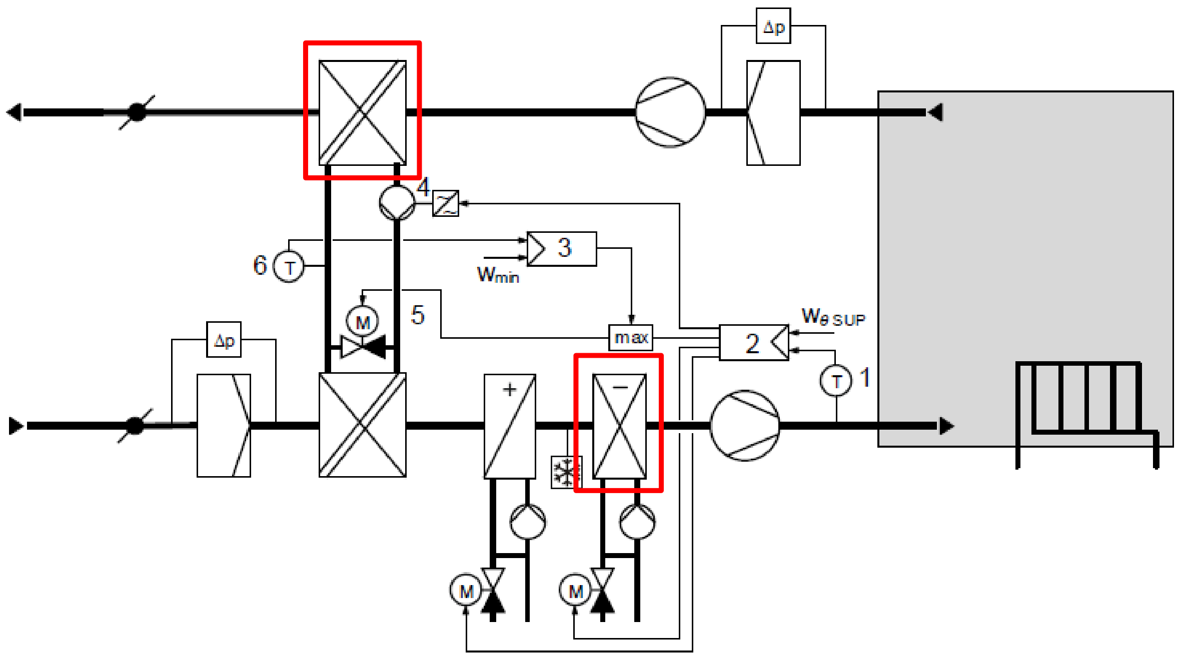


Fig. 4-10 KVS-WRG-Regelung

1	Zulufttemperaturfühler	4	Umwälzpumpe (drehzahlgeregelt)
2	Zulufttemperaturregler	5	Bypass-Regelventil
3	Vereisungsschutzregler	6	Vereisungsschutzfühler

Quelle: Regeln und Steuern von Lüftungs-/Klimaanlagen / Siemens

Heat Exchanger with Water Vapour Condensation

Bypass - Effekt

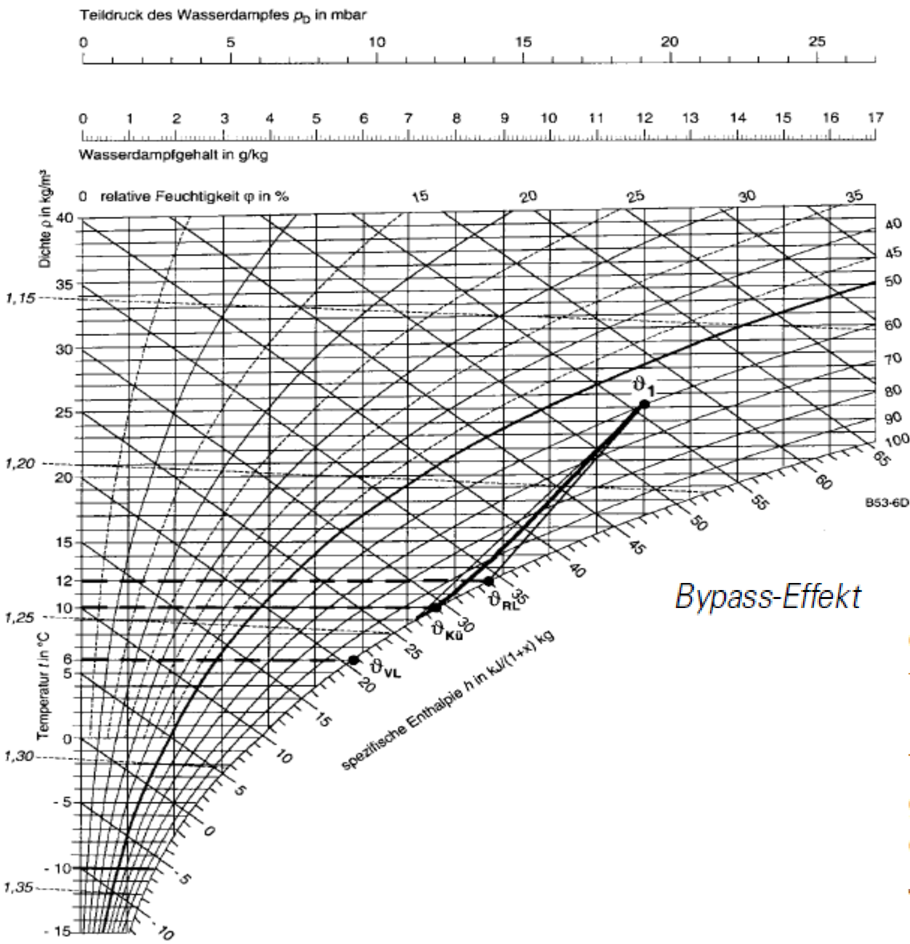


Fig. 3-6 Wirklicher Abkühlungsverlauf bei nasser Kühlfläche

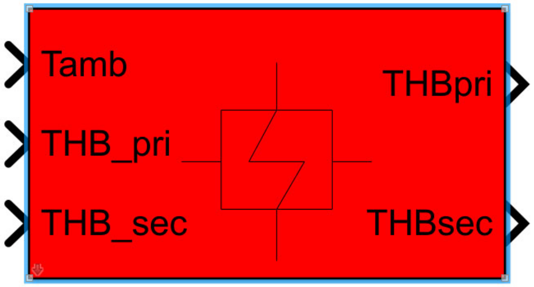
Quelle: Siemens Grundlagen hx-Diagramm

Bypass-Effekt

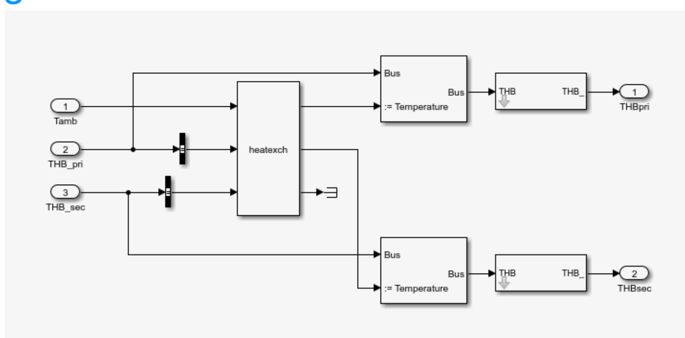
Mit Bypass-Effekt bezeichnet man den Umstand, dass im Kühler nur der Teil der Luft Wasser ausscheidet, der mit den Kühlflächen in engen thermischen Kontakt kommt. Der andere Teil der Luft, die «Bypass-Luft», verlässt den Kühler praktisch unverändert. Die am Kühler austretende Luft ist also eine Mischung von ungesättigter warmer Luft und gesättigter kalter Luft, so dass die Zustandsänderung im Kühler entlang einer nach unten gekrümmten Kurve verläuft.

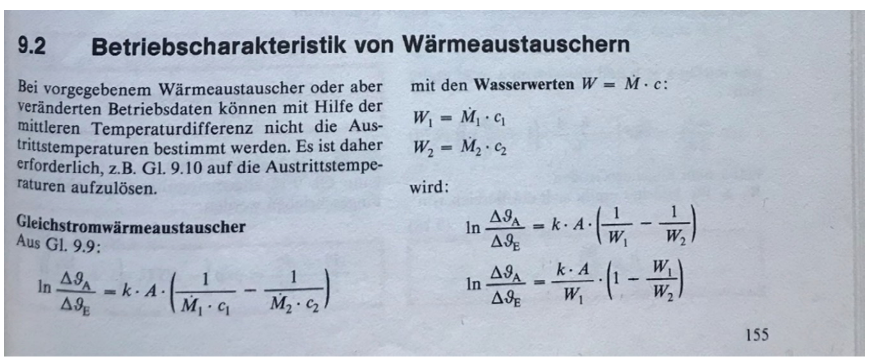
Je enger die Lamellenabstände und je zahlreicher die Rohrreihen des Kühlers sind, umso flacher wird die Krümmung der Kurve. Bei der Berechnung der benötigten Kühlleistung eines Kühlers muss der Bypass-Effekt nicht berücksichtigt werden.

HeatExchanger (NTU / Effectivness-Method) Carnot



HeatExchanger





9.2 Betriebscharakteristik von Wärmeaustauschern

Bei vorgegebenem Wärmeaustauscher oder aber veränderten Betriebsdaten können mit Hilfe der mittleren Temperaturdifferenz nicht die Austrittstemperaturen bestimmt werden. Es ist daher erforderlich, z.B. Gl. 9.10 auf die Austrittstemperaturen aufzulösen.

Gleichstromwärmeaustauscher
Aus Gl. 9.9:

$$\ln \frac{\Delta\vartheta_A}{\Delta\vartheta_E} = k \cdot A \cdot \left(\frac{1}{\dot{M}_1 \cdot c_1} - \frac{1}{\dot{M}_2 \cdot c_2}\right)$$

mit den **Wasserwerten** $W = \dot{M} \cdot c$:

$$W_1 = \dot{M}_1 \cdot c_1$$

$$W_2 = \dot{M}_2 \cdot c_2$$

wird:

$$\ln \frac{\Delta\vartheta_A}{\Delta\vartheta_E} = k \cdot A \cdot \left(\frac{1}{W_1} - \frac{1}{W_2}\right)$$

$$\ln \frac{\Delta\vartheta_A}{\Delta\vartheta_E} = \frac{k \cdot A}{W_1} \cdot \left(1 - \frac{W_1}{W_2}\right)$$

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Aus: Wärmeübertrager, W. Wagner, Vogel-Fachbuch

```
/* heat capacity flow */
cp = heat_capacity(FLUID_HOT, PERCENT_HOT, T_HOT, P_HOT);
whot = MDOT_HOT*cp;
wcold = MDOT_COLD*heat_capacity(FLUID_COLD,PERCENT_COLD,T_COLD,P_COLD);

/* heat capacity flow characteristic number w1to2 */
if (whot <= wcold) {
    w1 = whot;
    w1to2 = w1/wcold;
    normal = 1;
} else {
    w1 = wcold;
    w1to2 = w1/whot;
    normal = 0;
}

/* heat transfer characteristic number  ntu = Number of Transfer Units */
ua = UA_0 *  (pow(MDOT_HOT/MDOTNOMH,UA_EXPH)+pow(MDOT_COLD/MDOTNOMC,UA_EXPC))*0.5;
ntu = ua/w1;

/* heat exchanger characteristics: dimensionless temperature change */
p1 = exp(-ntu*(1.0 + w1to2*(1.0 - 2.0*flowtype)));

denom = (1.0+w1to2*(1.0-flowtype*(1.0+p1)));
/* denominator = 0, if w1to2 = 1, i.e. if (m*cp)hot = (m*cp)cold */

/* equations from Renz: Kalorische Apparate, Vorlesungsumdruck RWTH Aachen */
if (fabs(denom) < 1.0e-10)
    psi = ua/(ua+1);  /* equation for psi in case of w1to2=1  */
else
    psi = (1.0-p1)/(1.0+w1to2*(1.0-flowtype*(1.0+p1)));

/* not yet corrected for crossflow exchangers, equation is
   correct only for NTU <= 2, for NTU = 4 error is about 5% */

/* set outputs */
if (normal) {
    y0[0] = T_HOT - psi*(T_HOT-T_COLD);     /* outlet T hot part */
    y1[0] = T_COLD + w1to2*(T_HOT-y0[0]);   /* outlet T cold part */
} else {
    y1[0] = T_COLD - psi*(T_COLD-T_HOT);    /* outlet T cold part */
    y0[0] = T_HOT + w1to2*(T_COLD-y1[0]);   /* outlet T hot part */
```

Ausschnitt S-Function

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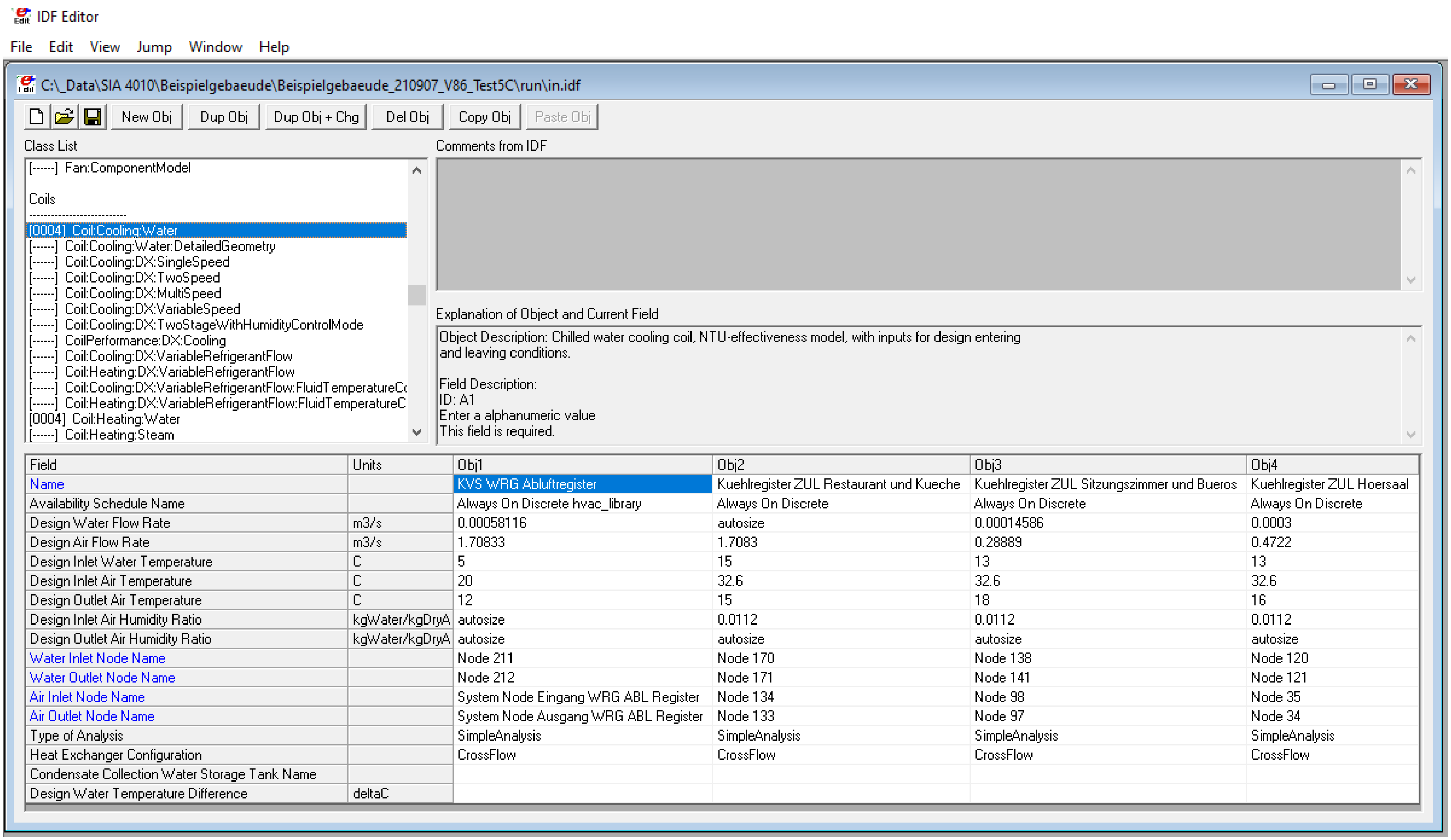
Heat Exchanger with Condensation (Energy Plus)



Field	Units	Obj1	Obj2	Obj3	Obj4
Name		KVS WRG Abluftregister	Kuehlregister ZUL Restaurant und Kueche	Kuehlregister ZUL Sitzungszimmer und Bueros	Kuehlregister ZUL Hoersaal
Availability Schedule Name		Always On Discrete hvac_library	Always On Discrete	Always On Discrete	Always On Discrete
Design Water Flow Rate	m3/s	0.00058116	autosize	0.00014586	0.0003
Design Air Flow Rate	m3/s	1.70833	1.7083	0.28889	0.4722
Design Inlet Water Temperature	C	5	15	13	13
Design Inlet Air Temperature	C	20	32.6	32.6	32.6
Design Outlet Air Temperature	C	12	15	18	16
Design Inlet Air Humidity Ratio	kgWater/kgDryA	autosize	0.0112	0.0112	0.0112
Design Outlet Air Humidity Ratio	kgWater/kgDryA	autosize	autosize	autosize	autosize
Water Inlet Node Name		Node 211	Node 170	Node 138	Node 120
Water Outlet Node Name		Node 212	Node 171	Node 141	Node 121
Air Inlet Node Name		System Node Eingang WRG ABL Register	Node 134	Node 98	Node 35
Air Outlet Node Name		System Node Ausgang WRG ABL Register	Node 133	Node 97	Node 34
Type of Analysis		SimpleAnalysis	SimpleAnalysis	SimpleAnalysis	SimpleAnalysis
Heat Exchanger Configuration		CrossFlow	CrossFlow	CrossFlow	CrossFlow
Condensate Collection Water Storage Tank Name					
Design Water Temperature Difference	deltaC				

Quelle: Energy Plus

Heat Exchanger with Condensation (Energy Plus)

15.2 Coils
15.2.1 Chilled-Water-Based Air Cooling Coil

The input object Coil:Cooling:Water is simpler than the detailed geometry model.

The simple model provides a good prediction of the air and water outlet conditions without requiring the detailed geometric input required for the detailed model. A greatly simplified schematic of enthalpy and temperature conditions in a counter flow cooling/dehumidifying coil is shown in the schematic Figure 15.1. The input required to model the coil includes only a set of thermodynamic design inputs, which require no specific manufacturer's data.

The coil simulation model is essentially a modification of one presented by Elmahdy and Mitalas (1977), TRNSYS, 1990 and Threlkeld, J.L. 1970. The model calculates the UA values required for a Dry, Wet and Part Wet & Part Dry Coil and iterates between the Dry and Wet Coil to output the fraction wet. There are two modes of flow operation for this model: CrossFlow or CounterFlow. The default mode is CounterFlow.

Quelle: Engineering Reference

Heat Exchanger with Condensation (Energy Plus)

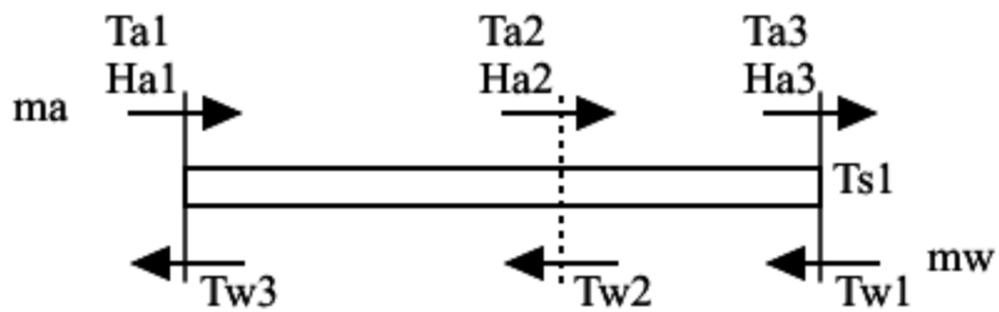


Figure 15.1: Simplified Schematic of Cooling/Dehumidifying Coil

15.2.1.1 Heat Transfer and Energy Balance

The cooling coil may be completely dry, completely wet with condensation, or it may have wet and dry sections. The actual condition of the coil surface depends on the humidity and temperature of the air passing over the coil and the coil surface temperature. The part-dry part-wet case represents the most general scenario for the coil surface conditions. There are subroutines present in the model for both the dry and wet regions of the coil, and a subroutine that iterates between the dry and wet subroutines to calculate the fraction of the coil surface that is wet. For each region the heat transfer rate from air to water may be defined by the rate of enthalpy change in the air and in the water. The rates must balance between each medium for energy to be conserved.

Quelle: Engineering Reference

Heat Exchanger with Condensation (Energy Plus)

$h_{air,in}$ = PsyHFnTdbW($T_{air,in;}w_{air,in}$) (15.17)
$h_{air,out}$ = PsyHFnTdbW($T_{air,out;}w_{air,out}$) (15.18)
$h_{w,sat,in}$ = PsyHFnTdbW($T_{w,in}$; PsyWFnTdpPb($T_{w,in}$; P_{atm})) (15.19)

$\dot{Q}_{coil} = \dot{m}_{air} * (h_{air,in} – h_{air,out})$ (15.20)

$T_{w,out} = T_{w,in} + \dot{Q}_{coil} / (\dot{m}_{w,max} * C_{p,w})$ (15.21)

$h_{w,sat,out}$ = PsyHFnTdbW($T_{w,out}$; PsyWFnTdpPb($T_{w,out}$; P_{atm})) (15.22)

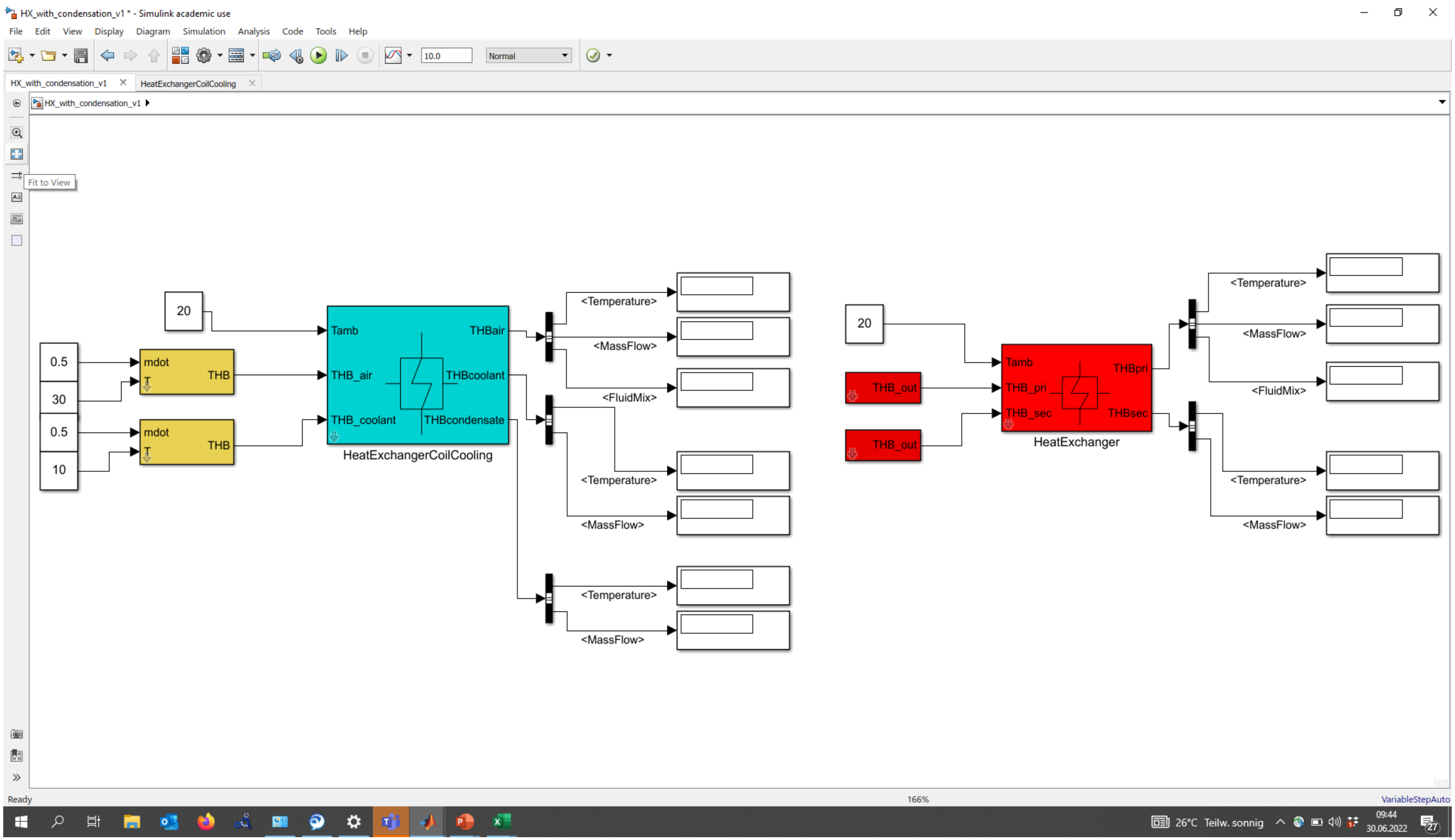
We now calculate the design coil bypass factor. The bypass factor is not used in subsequent calculations. It is calculated solely to use as check on the reasonableness of the user-input design inlet and outlet conditions. First we make an initial estimate of the apparatus dew point temperature:
$T_{air,dp,app}$ = PsyTdpFnWPb($w_{air,out}$; P_{atm}) (15.23)

We also need the “slope” of temperature versus humidity ratio on the psych chart between the inlet and outlet air conditions:

$S_{T,w} = (T_{air;in} - T_{air;out}) / (w_{air,in} - w_{air;out})$ (15.24)

Quelle: Engineering Reference

Heat Exchanger with Condensation (Carnot)



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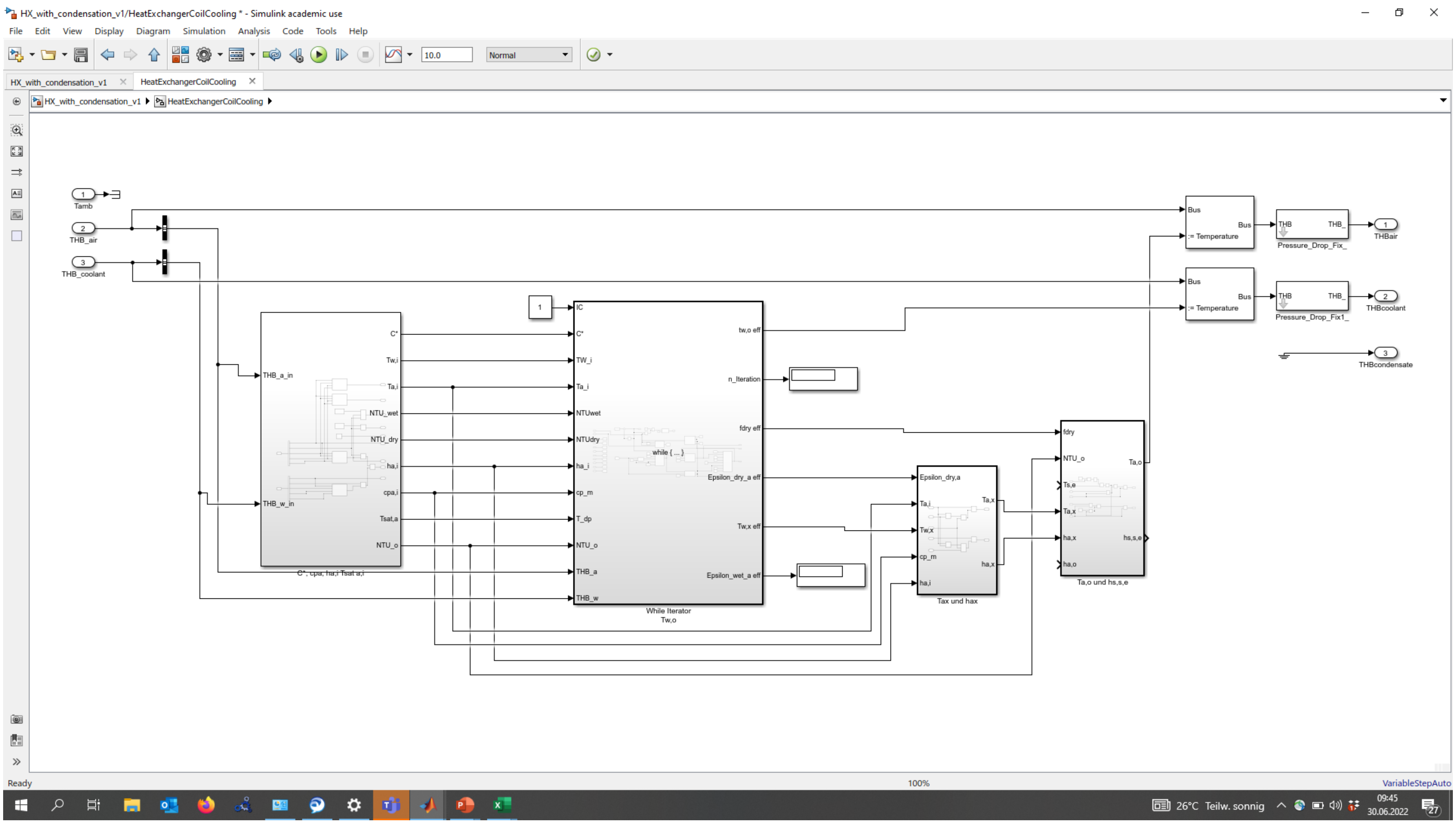
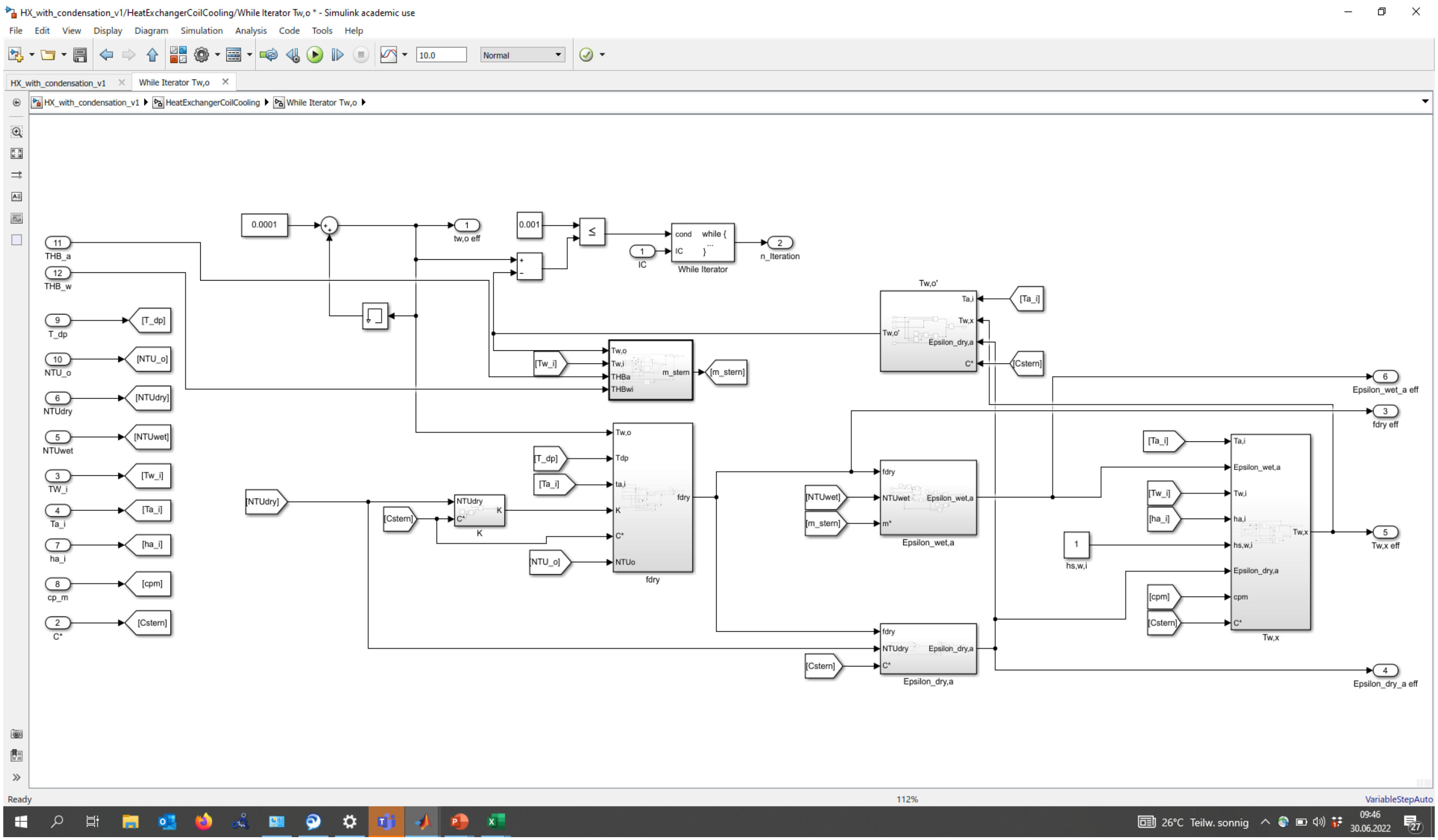
Heat Exchanger with Condensation (Carnot)



Heat Exchanger with Condensation (Carnot)



Heat Exchanger with Condensation (Carnot)

Next Steps

- Validation of the block
- Speed evaluation
- Consideration of a timer

- Evaluation of a Look-up table variant based on the standard HX