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Introduction

Included in this tutorial are 12 step by step examples that you can follow to create either a drying flowsheet, or an evaporation flowsheet or a combined drying and evaporation flowsheet.

All the 12 examples data can be loaded into Simprosys from the “samples” folder installed with Simprosys.

You can also modify any of the samples installed with Simprosys to create your own flowsheet.

Example 1 - Drying Gas Stream

Problem 1

Moist air has the following conditions:

Pressure = 1 atm
Temperature (dry-bulb) = 25 ^{o}C
Absolute humidity = 0.009 kg/kg (dry air)

Calculate wet-bulb temperature, dew point temperature, relative humidity, humid heat, specific enthalpy and density.

Solution Steps:

1. Start Simprosys. By default, a new empty flowsheet is created with the default generic material of the software. The name of the default material is “Generic Drying Material”. The specific heat of the material is 1.26 kJ/kg·^{o}C when it is absolutely dry.
2. Go to ‘Edit | Unit Systems’. Select SI-3 and click **Set Current** button to set SI-3 unit system as current unit system. Then close the dialog.
3. Go to ‘Edit | Numeric Format’ to change Decimal Places to 3.
4. Select ‘Flowsheet | Add | Streams | Drying Gas’, then click anywhere on the flowsheet to add a stream. Double click the stream icon to bring up the editor.
5. Input 1.0 atm in the *Pressure* field.
6. Input 25 ^{o}C in the *Dry-bulb Temperature* field.
7. Input 0.009 kg/kg in the *Absolute Humidity* field
8. After the enter key of last input is hit, wet-bulb temperature, dew point temperature, relative humidity, humid heat, specific enthalpy and density are automatically calculated and displayed on the stream’s editor as in Figure 1.1.

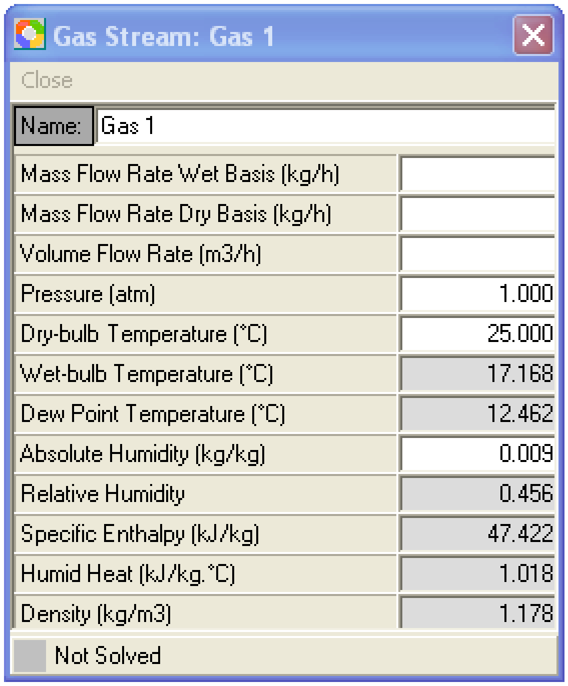


Figure 1.1

Problem 2

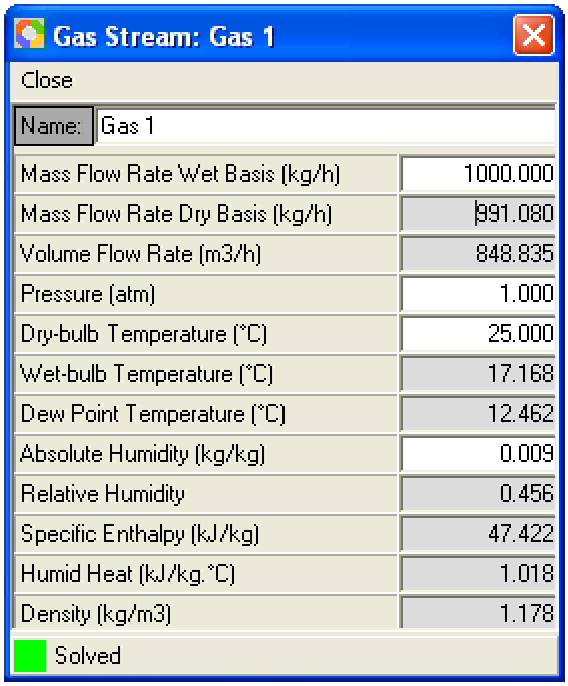
Moist air has the following conditions:

Pressure = 1 atm
Temperature (dry-bulb) = 25 ^{o}C
Absolute humidity = 0.009 kg/kg (dry air)
Mass flow rate wet basis = 1000 kg/hr

Calculate the wet-bulb temperature, dew point temperature, relative humidity, humid heat, specific enthalpy, density, mass flow rate dry basis and volume flow rate.

Solution Steps

1. Follow solution steps 1 through 7 in problem 1.
2. Input 1000 kg/hr in *Mass Flow Rate Wet Basis* field
3. After the enter key of the last input is hit, the stream is completely solved and the result is as shown in Figure 1.2.



Gas Stream: Gas 1

Close

Name: Gas 1

Mass Flow Rate Wet Basis (kg/h)	1000.000
Mass Flow Rate Dry Basis (kg/h)	991.080
Volume Flow Rate (m3/h)	848.835
Pressure (atm)	1.000
Dry-bulb Temperature (°C)	25.000
Wet-bulb Temperature (°C)	17.168
Dew Point Temperature (°C)	12.462
Absolute Humidity (kg/kg)	0.009
Relative Humidity	0.456
Specific Enthalpy (kJ/kg)	47.422
Humid Heat (kJ/kg.°C)	1.018
Density (kg/m3)	1.178

Solved

Figure 1.2

Summary

1. When pressure, one of the three temperature parameters (either Dry-bulb Temperature, or Wet-bulb Temperature or Dew Point Temperature) and one of two humidity parameters (either Absolute Humidity or Relative Humidity) are specified, the state of the moist air is determined and can be calculated, and therefore all the thermal physical properties at this state can also be calculated and automatically displayed on the stream's editor.
2. When one of the flow rate parameters (either Mass Flow Rate Wet Basis, or Mass Flow Rate Dry Basis, or Volume Flow Rate) is specified and the state of the moist air is determined, the other flow rates are automatically calculated and displayed on the stream's editor.

Example 2 - Solid Dryer

Problem 1

Material has the following conditions:

Type: solid particles
Feed moisture content = 3% wet basis
Feed temperature = 20 ^{o}C
Product moisture content = 0.2% wet basis
Product temperature = 50 ^{o}C
Specific heat of the absolute dry material = 1.26 kJ/kg·^{o}C
Mass flow rate wet basis = 2000 kg/hr

Drying air has the following conditions:

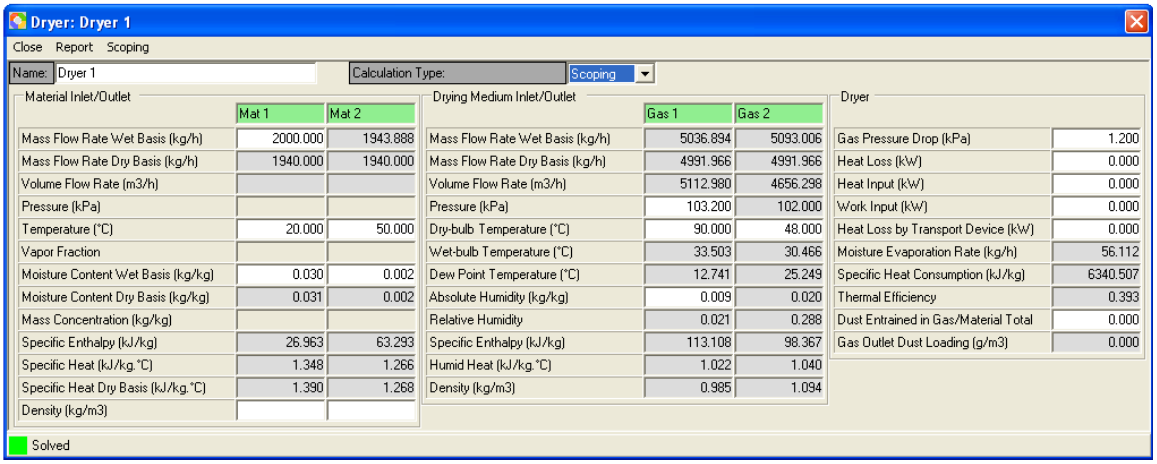
Pressure at dryer inlet = 103.2 kPa
Temperature (dry-bulb) at dryer inlet = 90 ^{o}C
Absolute humidity at dryer inlet = 0.009 kg/kg
Temperature (dry-bulb) at dryer outlet = 48 ^{o}C
Pressure drop of air in dryer = 1.2 kPa

Calculate how much drying air is needed as well as what is the outlet humidity of the drying air.

Solution Steps

1. Save and close current flowsheet if you currently work on a flowsheet. Otherwise start Simprosys and close the new empty flowsheet created automatically by Simprosys.
2. Go to 'Edit | Unit Systems' to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to 'Edit | Numeric Format' to change Decimal Places to 3.
4. Go to 'Materials | Set Default Flowsheet Settings' to bring up the Set Default Flowsheet Settings dialog. Select "Generic Drying Material" in the Select Drying Material list box. Then click **Set** button to set this material as the drying material of the new flowsheet to be created. Close this dialog.
5. Create a new flowsheet by clicking the first icon  in the toolbar or selecting 'File | New'.
6. Select 'Flowsheet | Add | Unit Operations | Solid Material Dryer' and click anywhere on the flowsheet. Double click the dryer icon to bring up the editor.
7. Input in "Mat 1" column 2000 kg/hr in the *Mass Flow Rate Wet Basis* field, 20^{o}C in the *Temperature* field and 0.03 kg/kg in the *Moisture Content Wet Basis* field.
8. Input in "Mat 2" column 50^{o}C in the *Temperature* field and 0.002 kg/kg in the *Moisture Content Wet Basis* field.

9. Input in “Gas 1” column 103.2 kPa in the *Pressure* field, 90 °C in the *Dry-bulb Temperature* field and 0.009 kg/kg in the *Absolute Humidity* field.
10. Input in “Gas 2” column 48 °C in the *Dry-bulb Temperature* field.
11. Input in *Gas Pressure Drop* field of the “Dryer” group box 1.2 kPa.
12. After the enter key of the last input is hit, the dryer is solved and all the calculated variable values are displayed as in Figure 2.1.



Dryer: Dryer 1

Close Report Scoping

Name: Dryer 1 Calculation Type: Scoping

Material Inlet/Outlet

	Mat 1	Mat 2
Mass Flow Rate Wet Basis (kg/h)	2000.000	1943.888
Mass Flow Rate Dry Basis (kg/h)	1940.000	1940.000
Volume Flow Rate (m3/h)		
Pressure (kPa)		
Temperature (°C)	20.000	50.000
Vapor Fraction		
Moisture Content Wet Basis (kg/kg)	0.030	0.002
Moisture Content Dry Basis (kg/kg)	0.031	0.002
Mass Concentration (kg/kg)		
Specific Enthalpy (kJ/kg)	26.963	63.293
Specific Heat (kJ/kg.°C)	1.348	1.266
Specific Heat Dry Basis (kJ/kg.°C)	1.390	1.268
Density (kg/m3)		

Drying Medium Inlet/Outlet

	Gas 1	Gas 2
Mass Flow Rate Wet Basis (kg/h)	5036.894	5093.006
Mass Flow Rate Dry Basis (kg/h)	4991.966	4991.966
Volume Flow Rate (m3/h)	5112.980	4656.298
Pressure (kPa)	103.200	102.000
Dry-bulb Temperature (°C)	90.000	48.000
Wet-bulb Temperature (°C)	33.503	30.466
Dew Point Temperature (°C)	12.741	25.249
Absolute Humidity (kg/kg)	0.009	0.020
Relative Humidity	0.021	0.288
Specific Enthalpy (kJ/kg)	113.108	98.367
Humid Heat (kJ/kg.°C)	1.022	1.040
Density (kg/m3)	0.985	1.094

Dryer

Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	56.112
Specific Heat Consumption (kJ/kg)	6340.507
Thermal Efficiency	0.393
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000

Solved

Figure 2.1

Problem 2

All conditions are the same as those in Problem 1 except that the outlet gas relative humidity is known as 0.288 rather than the outlet air temperature is known.

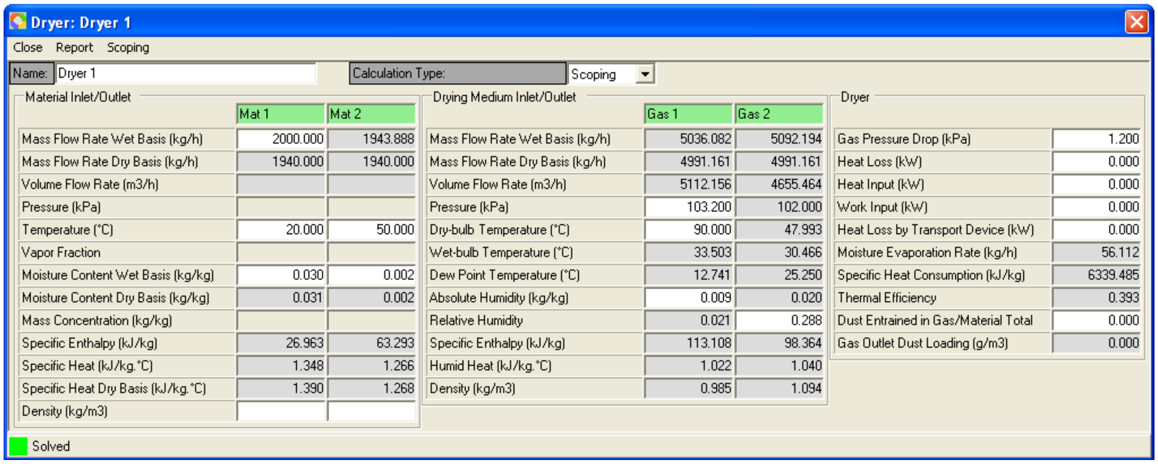
Solution Steps

All the steps are the same as in Problem 1 except that step 10 is replaced by the following

10. Input in “Gas 2” column 0.288 in the *Relative Humidity* field.

A shortcut of the solution steps for this problem is to use the established flowsheet from problem 1 and then delete 48 °C in the *Dry-bulb Temperature* field, and enter 0.288 in the *Relative Humidity* field in “Gas 2”.

The calculated results are displayed in Figure 2.2.



Material Inlet/Outlet

	Mat 1	Mat 2
Mass Flow Rate Wet Basis (kg/h)	2000.000	1943.888
Mass Flow Rate Dry Basis (kg/h)	1940.000	1940.000
Volume Flow Rate (m3/h)		
Pressure (kPa)		
Temperature (°C)	20.000	50.000
Vapor Fraction		
Moisture Content Wet Basis (kg/kg)	0.030	0.002
Moisture Content Dry Basis (kg/kg)	0.031	0.002
Mass Concentration (kg/kg)		
Specific Enthalpy (kJ/kg)	26.963	63.293
Specific Heat (kJ/kg.°C)	1.348	1.266
Specific Heat Dry Basis (kJ/kg.°C)	1.390	1.268
Density (kg/m3)		

Drying Medium Inlet/Outlet

	Gas 1	Gas 2
Mass Flow Rate Wet Basis (kg/h)	5036.082	5092.194
Mass Flow Rate Dry Basis (kg/h)	4991.161	4991.161
Volume Flow Rate (m3/h)	5112.156	4655.464
Pressure (kPa)	103.200	102.000
Dry-bulb Temperature (°C)	90.000	47.993
Wet-bulb Temperature (°C)	33.503	30.466
Dew Point Temperature (°C)	12.741	25.250
Absolute Humidity (kg/kg)	0.009	0.020
Relative Humidity	0.021	0.288
Specific Enthalpy (kJ/kg)	113.108	98.364
Humid Heat (kJ/kg.°C)	1.022	1.040
Density (kg/m3)	0.985	1.094

Dryer

Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	56.112
Specific Heat Consumption (kJ/kg)	6339.485
Thermal Efficiency	0.393
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000

Figure 2.2

Please be noted that the calculated gas outlet temperature and mass flow rates are slightly different from those in problem 1. This is caused by the truncation error of the outlet relative humidity. The more accurate value of the outlet relative humidity in problem 1 is 0.28787887 (To see more decimal digits of each field in the dryer's editor you need to go to 'Edit | Numeric Format' Decimal Places field to increase decimal digits).

Problem 3

All conditions are the same as in problem 1 except that inlet gas mass flow rate wet basis is known as 5036.894 kg/hr rather than the outlet gas temperature is known.

Solution Steps

All the steps are the same as in Problem 1 except that steps 9 and 10 are replaced by the following one step

9. Input in "Gas 1" column 5036.894 kg/hr in *Mass Flow Rate Wet Basis*, 103.2 kPa in the *Pressure* field, 90 ^{o}C in the *Dry-bulb Temperature* field and 0.009 kg/kg in the *Absolute Humidity* field.

A shortcut of the solution steps for this problem is to use the established flowsheet from problem 1 and then delete 48 ^{o}C in the *Dry-bulb Temperature* field in "Gas 2", and enter 5036.894 kg/hr in the *Mass Flow Rate Wet Basis* field of "Gas 1".

The calculated results are displayed in Figure 2.3.

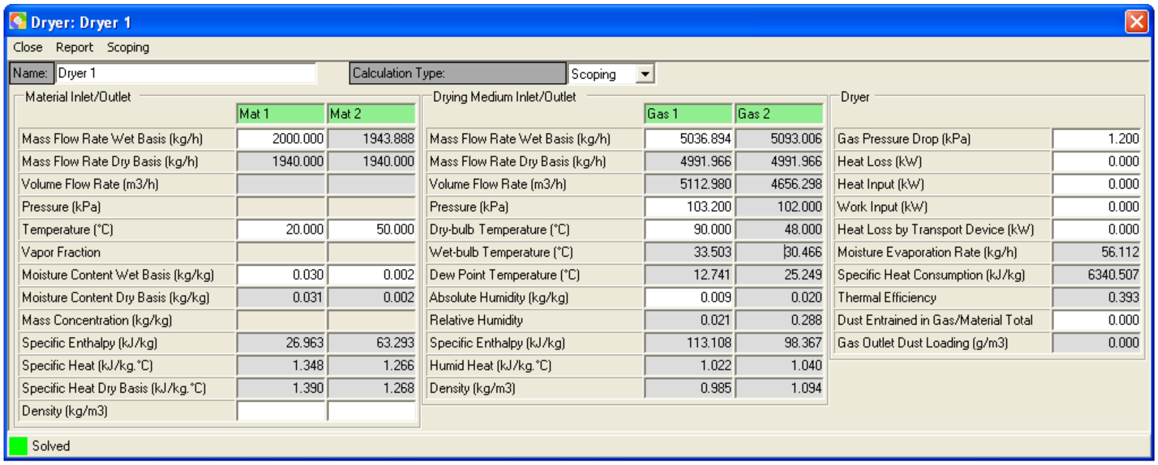


Figure 2.3

Problem 4

This problem is an extension of Problem 1. All material and drying air conditions are the same as in Problem 1.

Suppose this is a rotary dryer. The gas velocity in the dryer is 2.0 m/s. The length to diameter ratio is 8.0. Calculate the dimensions of the dryer using the simple scoping model.

Solution Steps

1. After the dryer balance calculation is solved following steps 1 through 11 in problem 1, go to *Calculation Type* combo box on the dryer's editor and select "Scoping" entry.
2. Click "Scoping" menu on the dryer's editor to bring up the scoping editor.
3. Select "Circle" for the cross section type because the cross section of a rotary dryer is circular.
4. Input in the *Gas Velocity* field 2.0 m/s and in the *Length/Diameter Ratio* field 8.0.
5. After the enter key of the last input is hit, the dryer scoping is solved and the calculated variable values are displayed as in Figure 2.4.

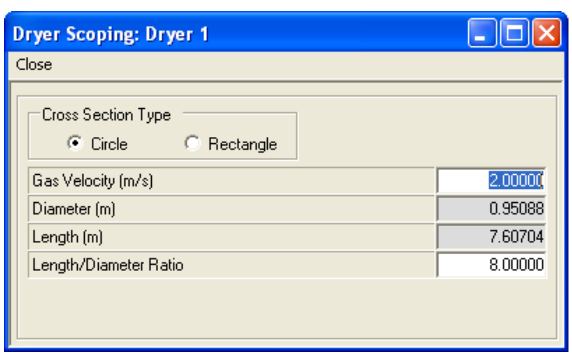


Figure 2.4

Please be noted that you can change the balance calculation specification. After the changed values are input into the dryer's editor the calculated dimension variables in the scoping editor is automatically recalculated and updated.

Summary

1. If the dryer has heat loss, heat input in addition to the heat from the drying gas, work input and heat loss by transport device for some specific dryers, you can input a specified value in each of the corresponding field. The dryer model will take them into account.
2. In addition to the 3 cases of problems 1 to 3, you can also know one of the outlet temperatures (either dry-bulb, or web-bulb or dew point) and one of the two outlet humidity parameters (either absolute humidity or relative humidity) rather than the corresponding inlet variables to satisfy the dryer's balance calculation conditions and get the dryer solved.

Example 3 - Liquid Dryer

Problem 1

Material is know as follows

Type: liquid solution
Feed mass solid content = 58%
Feed temperature = 85 ^{o}C
Feed pressure = 102 kPa
Product moisture content = 5% wet basis
Product temperature = 65 ^{o}C
Specific heat of the absolute dry material = 1.26 kJ/kg·^{o}C
Mass flow rate wet basis = 5000 kg/hr

Drying air has the following conditions:

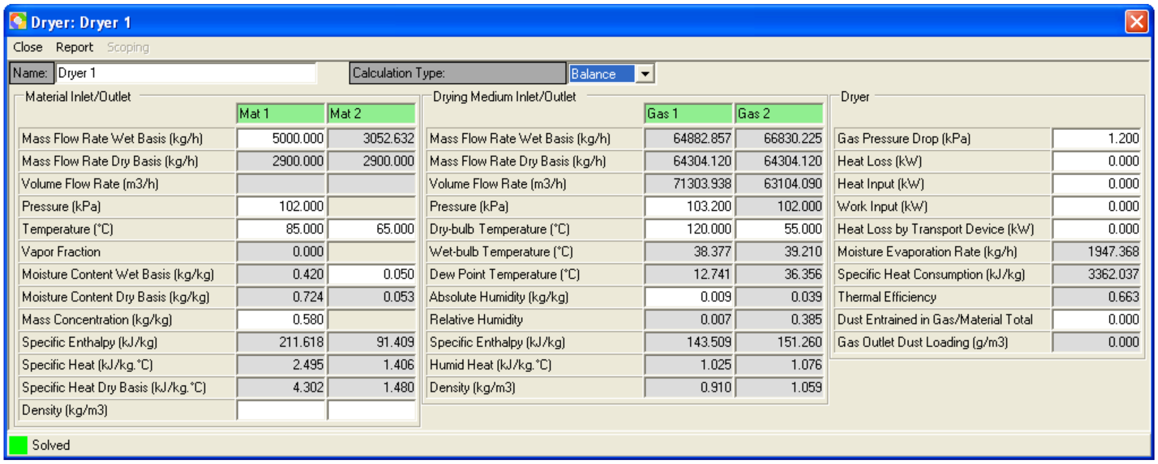
Pressure at dryer inlet = 103.2 kPa
Temperature (dry-bulb) at dryer inlet = 120 ^{o}C
Absolute Humidity at dryer inlet = 0.009 kg/kg dry air
Temperature (dry-bulb) at dryer outlet = 55 ^{o}C
Pressure drop of air in dryer = 1.2 kPa

Calculate how much drying air is needed as well as what is the outlet humidity of the drying air.

Solution Steps

1. Save and close current flowsheet if you currently work on a flowsheet. Otherwise start Simprosys and close the new empty flowsheet created automatically by Simprosys.
2. Go to 'Edit | Unit Systems' to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to 'Edit | Numeric Format' to change Decimal Places to 3.
4. Neglect this step if you come from Example 2. Go to 'Materials | Set Default Flowsheet Settings' to bring up the Set Default Flowsheet Settings dialog. Select "Generic Drying Material" in the Select Drying Material list box. Then click **Set** button to set this material as the drying material of the new flowsheet to be created. Close this dialog.
5. Create a new flowsheet by clicking the first icon  in the toolbar or selecting 'File | New'.
6. Select 'Flowsheet | Add | Unit Operations | Liquid Material Dryer' and click anywhere on flowsheet. Double click the dryer icon to bring up the editor.

7. Input in "Mat 1" column 5000 kg/hr in the *Mass Flow Rate Wet Basis* field, 102 kPa in the *Pressure* field, 85°C in the *Temperature* field and 0.58 in the *Mass Concentration* field.
8. Input in "Mat 2" column 65°C in the *Temperature* field and 0.05 in the *Moisture Content Wet Basis* field.
9. Input in "Gas 1" column 103.2 kPa in the *Pressure* field, 120 °C in the *Dry-bulb Temperature* field and 0.009 kg/kg in the *Absolute Humidity* field.
10. Input in "Gas 2" column 55 °C in the *Dry-bulb Temperature* field.
11. Input in *Gas Pressure Drop* field of the "Dryer" group box 1.2 kPa.
12. After the enter key of last input is hit, the dryer is solved and all the calculated variable values are displayed as shown in Figure 3.


Dryer: Dryer 1

Close Report Scoping

Name: Dryer 1 Calculation Type: Balance

Material Inlet/Outlet

	Mat 1	Mat 2
Mass Flow Rate Wet Basis (kg/h)	5000.000	3052.632
Mass Flow Rate Dry Basis (kg/h)	2900.000	2900.000
Volume Flow Rate (m3/h)		
Pressure (kPa)	102.000	
Temperature (°C)	85.000	65.000
Vapor Fraction	0.000	
Moisture Content Wet Basis (kg/kg)	0.420	0.050
Moisture Content Dry Basis (kg/kg)	0.724	0.053
Mass Concentration (kg/kg)	0.580	
Specific Enthalpy (kJ/kg)	211.618	91.409
Specific Heat (kJ/kg.°C)	2.495	1.406
Specific Heat Dry Basis (kJ/kg.°C)	4.302	1.480
Density (kg/m3)		

Drying Medium Inlet/Outlet

	Gas 1	Gas 2
Mass Flow Rate Wet Basis (kg/h)	64882.857	66830.225
Mass Flow Rate Dry Basis (kg/h)	64304.120	64304.120
Volume Flow Rate (m3/h)	71303.938	63104.090
Pressure (kPa)	103.200	102.000
Dry-bulb Temperature (°C)	120.000	55.000
Wet-bulb Temperature (°C)	38.377	39.210
Dew Point Temperature (°C)	12.741	36.356
Absolute Humidity (kg/kg)	0.009	0.039
Relative Humidity	0.007	0.385
Specific Enthalpy (kJ/kg)	143.509	151.260
Humid Heat (kJ/kg.°C)	1.025	1.076
Density (kg/m3)	0.910	1.059

Dryer

Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	1947.368
Specific Heat Consumption (kJ/kg)	3362.037
Thermal Efficiency	0.663
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000

Solved

Figure 3

Example 4 – Combined Dryer and Heater

Problem

Drying material is solid food particles with a composition of Carbohydrate 60%, Protein 22%, Fat 10%, Fiber 5% and Ash 3%. Inlet and outlet conditions of the material are as follows:

Feed moisture content = 3% wet basis
Feed temperature = 20 ^{o}C
Product moisture content = 0.2% kg/kg wet basis
Product temperature = 50 ^{o}C
Mass flow rate wet basis = 2000 kg/hr

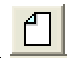
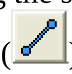
Drying air has the following conditions:

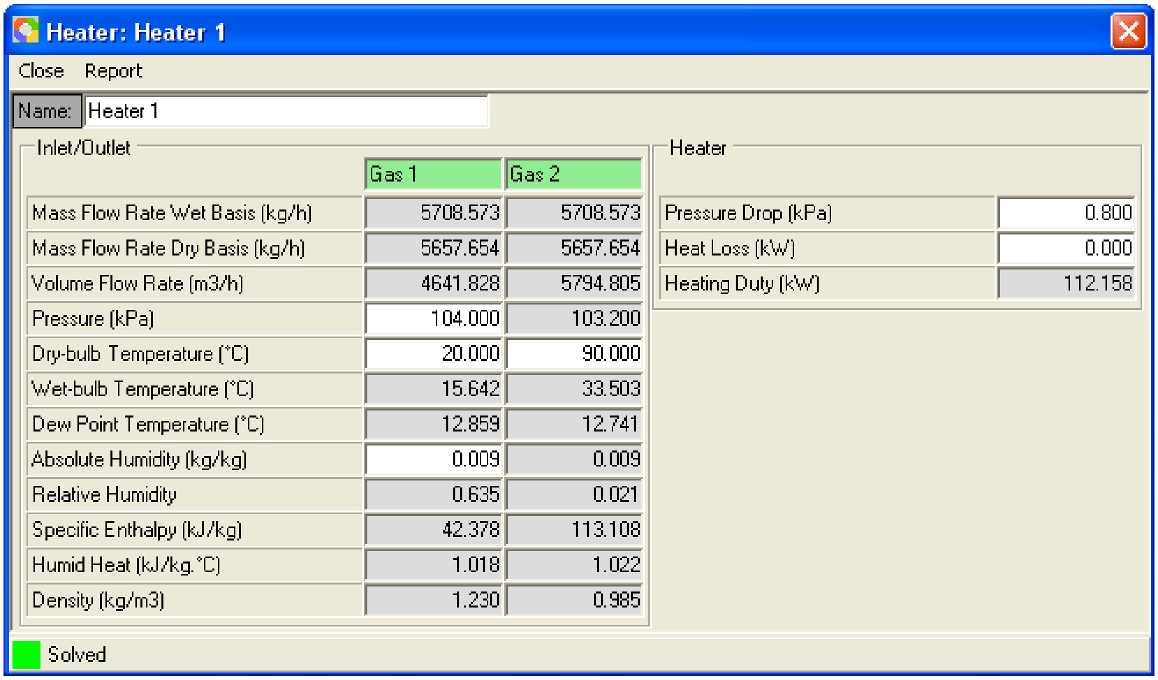
Pressure at heater inlet = 104 kPa
Temperature (dry-bulb) at heater inlet = 20 ^{o}C
Absolute Humidity at heater inlet = 0.009 kg/kg dry air
Temperature (dry-bulb) at heater outlet = 90 ^{o}C
Temperature (dry-bulb) at dryer outlet = 48 ^{o}C
Pressure drop of air in heater = 0.8 kPa
Pressure drop of air in dryer = 1.2 kPa

Calculate the required mass flow rate of the drying air, the thermal energy to heat the air as well as the outlet humidity of the drying air from the dryer.

Solution Steps

1. Save and close current flowsheet if you currently work on a flowsheet. Otherwise start Simprosys and close the new empty flowsheet created automatically by Simprosys.
2. Go to 'Materials | Drying Material Catalog'. Click **Add** button to bring up the 'New Drying Material' dialog. Give the material a name of "Food Material 1". Select 'Generic Food' from the **Type** combo box. Then specify the 'Drying Material Components' table with Carbohydrate 60, Protein 22, Fat 10, Fiber 5 and Ash 3. Click **Normalize** button and then click **OK** button to close the 'New Drying Material' dialog. Close 'Drying Material Catalog'.
3. Go to 'Materials | Set Default Flowsheet Settings'. Select "Food Material 1" and click **Set** button to set this material as the drying material of the to-be-created new flowsheet.
4. Go to 'Edit | Unit Systems' to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
5. Go to 'Edit | Numeric Format' tab to change Decimal Places to 3.

6. Create a new flowsheet by clicking the first icon  in the toolbar or selecting 'File | New'.
7. Go to 'Flowsheet | Options' group box "Unit Operation Creation" and choose radio button "With Input and Output".
8. Select 'Flowsheet | Add | Unit Operations | Heater' and click anywhere on flowsheet to create a heater.
9. Delete the outlet gas stream of the heater by selecting the stream, right clicking mouse and hitting the 'Delete' in the pop-up menu.
10. Create a solid dryer using the same way as in step 7.
11. Press down the **Connect** () button in the toolbar. Click on the gas input stream of the dryer and then click at the middle of the right border (the connection port) of the heater. You will get the heater and the dryer connected.
12. Double click the heater icon to bring up the heater's editor.
13. Input in "Gas 1" column 104 kPa in the *Pressure* field, 20^{o}C in the *Dry-bulb Temperature* field and 0.009 kg/kg in the *Absolute Humidity* field.
14. Input in "Gas 2" column 90^{o}C in the *Dry-bulb Temperature* field.
15. Input in *Pressure Drop* field of the "Heater" group box 0.8 kPa.
16. Double click the dryer icon to bring up the dryer's editor.
17. Input in "Mat 1" column 2000 kg/hr in the *Mass Flow Rate Wet Basis* field, 20^{o}C in the *Temperature* field and 0.03 in the *Moisture Content Wet Basis* field.
18. Input in "Mat 2" column 50^{o}C in the *Temperature* field and 0.002 in the *Moisture Content Wet Basis* field.
19. Input in "Gas 3" column 48 ^{o}C in the *Dry-bulb Temperatur*e field.
20. Input in *Gas Pressure Drop* field of the "Dryer" group box 1.2 kPa.
21. After the enter key of last input is hit, both the dryer and the heater are solved and all the calculated variable values are displayed as shown in Figure 4a and 4b.



Heater: Heater 1

Close Report

Name: Heater 1

Inlet/Outlet

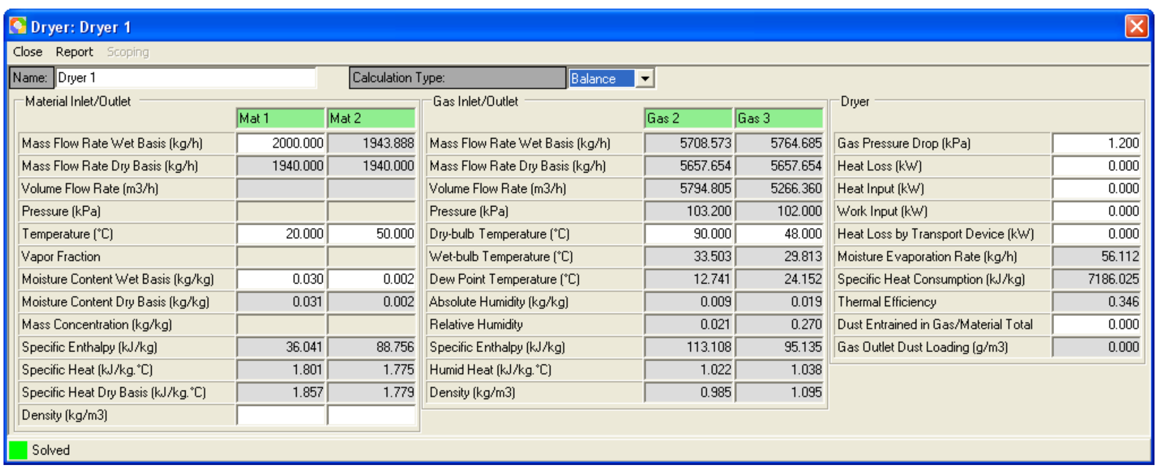
	Gas 1	Gas 2
Mass Flow Rate Wet Basis (kg/h)	5708.573	5708.573
Mass Flow Rate Dry Basis (kg/h)	5657.654	5657.654
Volume Flow Rate (m3/h)	4641.828	5794.805
Pressure (kPa)	104.000	103.200
Dry-bulb Temperature (°C)	20.000	90.000
Wet-bulb Temperature (°C)	15.642	33.503
Dew Point Temperature (°C)	12.859	12.741
Absolute Humidity (kg/kg)	0.009	0.009
Relative Humidity	0.635	0.021
Specific Enthalpy (kJ/kg)	42.378	113.108
Humid Heat (kJ/kg.°C)	1.018	1.022
Density (kg/m3)	1.230	0.985

Heater

Pressure Drop (kPa)	0.800
Heat Loss (kW)	0.000
Heating Duty (kW)	112.158

Solved

Figure 4a



Dryer: Dryer 1

Close Report Scoping

Name: Dryer 1 Calculation Type: Balance

Material Inlet/Outlet

	Mat 1	Mat 2
Mass Flow Rate Wet Basis (kg/h)	2000.000	1943.888
Mass Flow Rate Dry Basis (kg/h)	1940.000	1940.000
Volume Flow Rate (m3/h)		
Pressure (kPa)		
Temperature (°C)	20.000	50.000
Vapor Fraction		
Moisture Content Wet Basis (kg/kg)	0.030	0.002
Moisture Content Dry Basis (kg/kg)	0.031	0.002
Mass Concentration (kg/kg)		
Specific Enthalpy (kJ/kg)	36.041	88.756
Specific Heat (kJ/kg.°C)	1.801	1.775
Specific Heat Dry Basis (kJ/kg.°C)	1.857	1.779
Density (kg/m3)		

Gas Inlet/Outlet

	Gas 2	Gas 3
Mass Flow Rate Wet Basis (kg/h)	5708.573	5764.685
Mass Flow Rate Dry Basis (kg/h)	5657.654	5657.654
Volume Flow Rate (m3/h)	5794.805	5266.360
Pressure (kPa)	103.200	102.000
Dry-bulb Temperature (°C)	90.000	48.000
Wet-bulb Temperature (°C)	33.503	29.813
Dew Point Temperature (°C)	12.741	24.152
Absolute Humidity (kg/kg)	0.009	0.019
Relative Humidity	0.021	0.270
Specific Enthalpy (kJ/kg)	113.108	95.135
Humid Heat (kJ/kg.°C)	1.022	1.038
Density (kg/m3)	0.985	1.095

Dryer

Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	56.112
Specific Heat Consumption (kJ/kg)	7186.025
Thermal Efficiency	0.346
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000

Solved

Figure 4b

Alternative Solution Steps

1. Following the above solution steps 1 through 10.
2. Go to ‘Edit | Flowsheet Data’ to bring up the global editor
3. Input the known values in the variable fields of Gas 1, Gas 2, Gas 3, Mat 1, Mat 2. Input the pressure drop values for the heater and dryer in Heater 1 and Dryer 1 in the global editor.
4. After the enter key of last input is hit, both the dryer and the heater are solved and all the calculated variable values are displayed as in Figure 4c.

Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3
Mass Flow Rate Wet Basis (kg/h)	5708.573	5708.573	5764.685
Mass Flow Rate Dry Basis (kg/h)	5657.654	5657.654	5657.654
Volume Flow Rate (m3/h)	4641.828	5794.805	5266.360
Pressure (kPa)	104.000	103.200	102.000
Dry-bulb Temperature (°C)	20.000	90.000	48.000
Wet-bulb Temperature (°C)	15.642	33.503	29.813
Dew Point Temperature (°C)	12.859	12.741	24.152
Absolute Humidity (kg/kg)	0.009	0.009	0.019
Relative Humidity	0.635	0.021	0.270
Specific Enthalpy (kJ/kg)	42.378	113.108	95.135
Humid Heat (kJ/kg.°C)	1.018	1.022	1.038
Density (kg/m3)	1.230	0.985	1.095

Material Streams:	Mat 1	Mat 2
Mass Flow Rate Wet Basis (kg/h)	2000.000	1943.888
Mass Flow Rate Dry Basis (kg/h)	1940.000	1940.000
Volume Flow Rate (m3/h)		
Pressure (kPa)		
Temperature (°C)	20.000	50.000
Vapor Fraction		
Moisture Content Wet Basis (kg/kg)	0.030	0.002
Moisture Content Dry Basis (kg/kg)	0.031	0.002
Mass Concentration (kg/kg)		
Specific Enthalpy (kJ/kg)	36.041	88.756
Specific Heat (kJ/kg.°C)	1.801	1.775
Specific Heat Dry Basis (kJ/kg.°C)	1.857	1.779
Density (kg/m3)		

Dryers:	Dryer 1
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	56.112
Specific Heat Consumption (kJ/kg)	7186.025
Thermal Efficiency	0.346
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000
Heaters:	**Heater 1**
Pressure Drop (kPa)	0.800
Heat Loss (kW)	0.000
Heating Duty (kW)	112.158

Figure 4c

Tip 1:

If the heating duty of the heater (Heater 1) is known as 112.158 kJ/s (the same unit as kW) rather than the temperature of the heater outlet (90 ^{o}C), you can delete the heater's outlet temperature and then input 112.158 in the *Heating Duty* field of the heater. You will get the same results for the solved heater and dryer.

Tip 2:

If the outlet air relative humidity of dryer (Dryer 1) is know as 0.270 rather than the outlet temperature (48 ^{o}C), you can delete the outlet temperature (48 ^{o}C) and then input 0.270 in the *Relative Humidity* field of Gas 3. You will get the same results for the solved heater and dryer.

Tip 3:

If the inlet air flow rate (wet basis) of the dryer (Dryer 1) is know as 5708.573 rather than the outlet temperature (48 ^{o}C), you can delete the outlet temperature (48 ^{o}C) and then input 5708.573 in the *Mass Flow Rate Wet Basis* field of Gas 2. You will get the same results for the solved heater and dryer.

Tip 4:

If the relative humidity at heater inlet is know as 0.635 rather than the absolute humidity 0.009 kg/kg is known, you can delete 0.009 in the *Absolute Humidity* and input 0.635 in the *Relative Humidity* field of Gas 1. You will get the same results for the solved heater and dryer.

Example 5 - A Simple Drying Flowsheet

Problem

Material is known as follows

Type: solid particles
Feed moisture content = 5% wet basis
Feed temperature = 20 ^{o}C.
Product temperature = 50 ^{o}C
Product moisture content = 0.2% wet basis
Specific heat of the absolute dry material = 1.26 kJ/kg·^{o}C
Mass flow rate wet basis = 2000 kg/hr

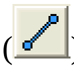
Drying air has the following conditions:

Initial pressure = 101.3 kPa
Initial temperature (dry-bulb) = 20 ^{o}C
Initial absolute humidity = 0.009 kg/kg
Mass flow rate wet basis = 7200 kg/hr

Drying air needs to go through an air filter first. Pressure drop in the air filter is 0.3 kPa. Assume dust volume concentration is 0.1 g/m^3, collection efficiency of the air filter is 99.8% and filtration velocity is 2.5 m/s. Drying air then goes through a fan (the efficiency of the fan is 0.7) to gain 3 kPa static pressure, then through a heater to be heated to 90 ^{o}C before going to the dryer. Pressure drop of air in heater is 0.8 kPa. Pressure drop of air in dryer is 1.2 kPa. The exhaust air entrains 0.1% of the total material. It needs to go through a cyclone to collect the entrained dust material. Collection efficiency of the cyclone is 95%. Pressure drop of the cyclone is 0.6 kPa.

Solution Steps

1. Save and close current flowsheet if you currently work on a flowsheet. Otherwise start Simprosys and close the new empty flowsheet created automatically by Simprosys.
2. Go to ‘Edit | Unit Systems’ to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to ‘Edit | Numeric Format’ tab to change Decimal Places to 4.
4. Go to ‘Materials | Set Default Flowsheet Settings’. Select “Generic Drying Material” and click **Set** button to set this material as the drying material of the to-be-created new flowsheet if you have already created the Generic Drying Material in the material catalog. Otherwise, create the Generic Drying Material and then go to ‘Materials | Set Default Flowsheet Settings’ to set it.
5. Create a new flowsheet by clicking the first icon  in the toolbar or selecting ‘File | New’.

6. Go to ‘Flowsheet | Options’ group box “Unit Operation Creation” and choose radio button “With Input Only”.
7. Select ‘Flowsheet | Add | Unit Operations | Air Filter’ and click anywhere on the flowsheet to create an air filter (AirFilter 1).
8. Use the same way as in step 7 to create a fan (Fan 1), a heater (Heater 1), a solid dryer (Dryer 1), a cyclone (Cyclone 1), a solid material stream (Mat 2) and a gas stream (Gas 6).
9. Press down the **Connect** () button in the toolbar. Click on the Gas 2 and then click at the middle of the right border (the connection port) of AirFilter 1. You will get AirFilter 1 and Fan 1 connected.
10. Use the same way as in step 9 to get Fan 1 and Heater 1, Heater 1 and Dryer 1, Dryer 1 and Cyclone 1, Mat 2 and Dryer 1, Gas 6 and Cyclone 1 connected. The established flowsheet is as displayed in Figure 5a

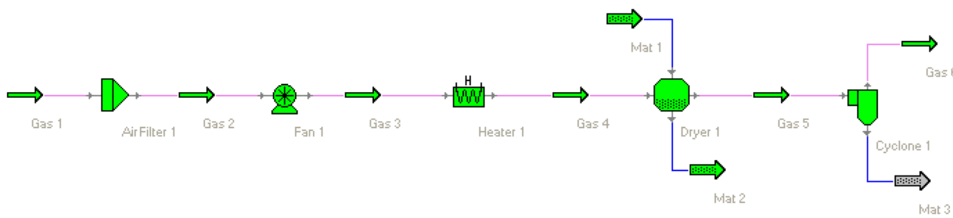
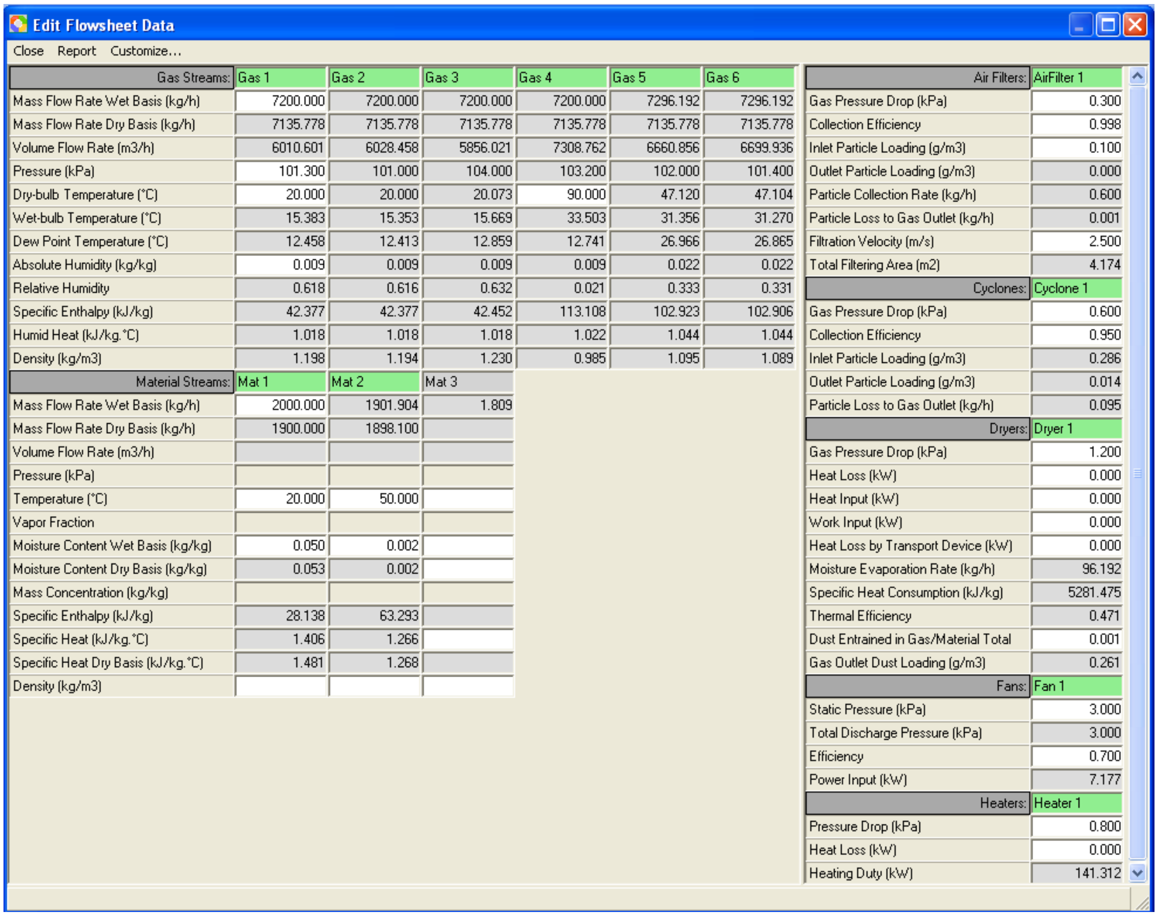


Figure 5a

11. Go to ‘Edit | Flowsheet Data’ to bring up the global editor and input all the known values as follows:
    - Gas 1: *Mass Flow Rate Wet Basis* 7200 kg/hr, *Pressure* 101.3 kPa, *Dry-bulb Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.009 kg/kg.
    - Gas 4: *Dry-bulb Temperature* 90 ^{o}C.
    - Mat 1: *Mass Flow Rate Wet Basis* 2000 kg/hr, *Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.05 kg/kg.
    - Mat 2: *Temperature* 50 ^{o}C, *Moisture Content Wet Basis* 0.002 kg/kg.
    - AirFilter 1: *Gas Pressure Drop* 0.3 kPa; *Collection Efficiency* 0.998, *Inlet Particle Loading* 0.1 g/m^3, *Filtration Velocity* 2.5 m/s.
    - Fan 1: *Static Pressure* 3.0 kPa, *Efficiency* 0.7.
    - Heater 1: *Pressure Drop* 0.8 kPa.
    - Dryer 1: *Gas Pressure Drop* 1.2 kPa, *Dust Entrained in Gas/Material Total* 0.001.
    - Cyclone 1: *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.95.

    You can get the results as in Figure 5b.



Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
Mass Flow Rate Wet Basis (kg/h)	7200.000	7200.000	7200.000	7200.000	7296.192	7296.192
Mass Flow Rate Dry Basis (kg/h)	7135.778	7135.778	7135.778	7135.778	7135.778	7135.778
Volume Flow Rate (m3/h)	6010.601	6028.458	5856.021	7308.762	6660.856	6699.936
Pressure (kPa)	101.300	101.000	104.000	103.200	102.000	101.400
Dry-bulb Temperature (°C)	20.000	20.000	20.073	90.000	47.120	47.104
Wet-bulb Temperature (°C)	15.383	15.353	15.669	33.503	31.356	31.270
Dew Point Temperature (°C)	12.458	12.413	12.859	12.741	26.966	26.865
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.009	0.022	0.022
Relative Humidity	0.618	0.616	0.632	0.021	0.333	0.331
Specific Enthalpy (kJ/kg)	42.377	42.377	42.452	113.108	102.923	102.906
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.022	1.044	1.044
Density (kg/m3)	1.198	1.194	1.230	0.985	1.095	1.089

Material Streams:	Mat 1	Mat 2	Mat 3
Mass Flow Rate Wet Basis (kg/h)	2000.000	1901.904	1.809
Mass Flow Rate Dry Basis (kg/h)	1900.000	1898.100	
Volume Flow Rate (m3/h)			
Pressure (kPa)			
Temperature (°C)	20.000	50.000	
Vapor Fraction			
Moisture Content Wet Basis (kg/kg)	0.050	0.002	
Moisture Content Dry Basis (kg/kg)	0.053	0.002	
Mass Concentration (kg/kg)			
Specific Enthalpy (kJ/kg)	28.138	63.293	
Specific Heat (kJ/kg.°C)	1.406	1.266	
Specific Heat Dry Basis (kJ/kg.°C)	1.481	1.268	
Density (kg/m3)			

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.998
Inlet Particle Loading (g/m3)	0.100
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	0.600
Particle Loss to Gas Outlet (kg/h)	0.001
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	4.174
Cyclones:	**Cyclone 1**
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.286
Outlet Particle Loading (g/m3)	0.014
Particle Loss to Gas Outlet (kg/h)	0.095
Dryers:	**Dryer 1**
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	96.192
Specific Heat Consumption (kJ/kg)	5281.475
Thermal Efficiency	0.471
Dust Entrained in Gas/Material Total	0.001
Gas Outlet Dust Loading (g/m3)	0.261
Fans:	**Fan 1**
Static Pressure (kPa)	3.000
Total Discharge Pressure (kPa)	3.000
Efficiency	0.700
Power Input (kW)	7.177
Heaters:	**Heater 1**
Pressure Drop (kPa)	0.800
Heat Loss (kW)	0.000
Heating Duty (kW)	141.312

Figure 5b

Example 6 - A Combustion Drying Flowsheet

Problem

Material is known as follows

Type: solid particles
Feed moisture content = 22% wet basis
Feed temperature = 20 ^oC
Product temperature = 50 ^oC
Product moisture content = 0.2% wet basis
Specific heat of the absolute dry material = 1.26 kJ/kg·^oC
Mass flow rate wet basis = 2000 kg/hr

Air has the following conditions:

Initial pressure = 101.3 kPa
Initial temperature (dry-bulb) = 20 ^oC
Initial absolute humidity = 0.009 kg/kg

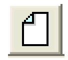
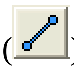
Natural gas as the drying fuel has the following conditions:

Pressure = 101.3 kPa
Temperature = 20 ^oC
Mass flow rate = 34 kg/hr

Drying air needs to go through an air filter first. Pressure drop in the air filter is 0.3 kPa. Assume dust volume concentration is 0.1 g/m^3, collection efficiency of the air filter is 99.8% and filtration velocity is 2.5 m/s. Drying air then goes through a fan (the efficiency of the fan is 0.7) to gain 3 kPa static pressure, then through a burner to be heated before going to the dryer. Excess air % of the burner is 500%. Heat loss of the burner is 10%. Flue gas outlet pressure is 103.2. Pressure drop of air in dryer is 1.2 kPa. The exhaust air entrains 0.1% of the total material. It needs to go through a cyclone to collect the entrained dust material. Collection efficiency of the cyclone is 95%. Pressure drop of the cyclone is 0.6 kPa.

Solution Steps

1. Save and close current flowsheet if you currently work on a flowsheet. Otherwise start Simprosys and close the new empty flowsheet created automatically by Simprosys.
2. Go to ‘Edit | Unit Systems’ to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to ‘Edit | Numeric Format’ tab to change Decimal Places to 4.

4. Go to ‘Materials | Set Default Flowsheet Settings’. Select “Generic Drying Material” and click **Set** button to set this material as the drying material of the to-be-created new flowsheet if you have already created the Generic Drying Material in the material catalog. Otherwise, create the Generic Drying Material and then go to ‘Materials | Set Default Flowsheet Settings’ to set it. Make sure Drying Fuel is selected as Natural Gas.
5. Create a new flowsheet by clicking the first icon  in the toolbar or selecting ‘File | New’.
6. Go to ‘Flowsheet | Options’ group box “Unit Operation Creation” and choose radio button “With Input Only”.
7. Select ‘Flowsheet | Add | Unit Operations | Air Filter’ and click anywhere on the flowsheet to create an air filter (AirFilter 1).
8. Use the same way as in step 7 to create a fan (Fan 1), a Burner (Burner 1), a solid dryer (Dryer 1), a cyclone (Cyclone 1), a solid material stream (Mat 2) and a gas stream (Gas 6).
9. Press down the **Connect** () button in the toolbar. Click on the Gas 2 and then click at the middle of the right border (the connection port) of AirFilter 1. You will get AirFilter 1 and Fan 1 connected.
10. Use the same way as in step 9 to get Fan 1 and Burner 1, Burner 1 and Dryer 1, Dryer 1 and Cyclone 1, Mat 2 and Dryer 1, Gas 6 and Cyclone 1 connected. The established flowsheet is as displayed in Figure 6a

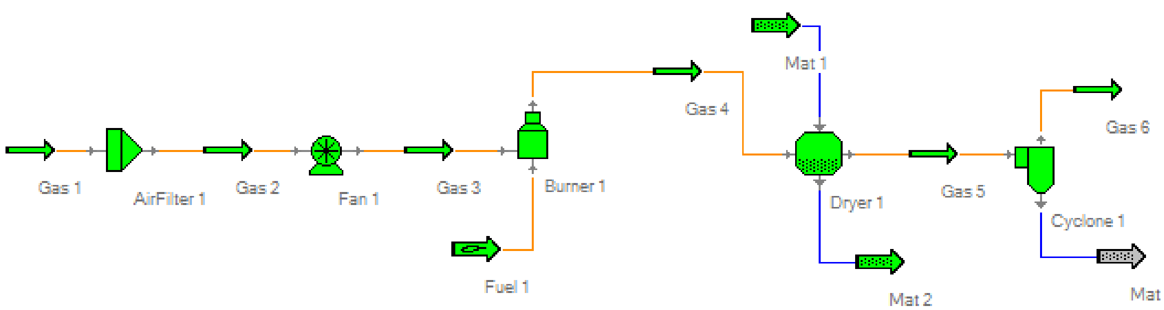


Figure 6a

11. Go to ‘Edit | Flowsheet Data’ to bring up the global editor and input all the known values as follows:
    - Fuel 1: Select “Natural Gas” in the Drying Fuel dropdown list, *Mass Flow Rate Wet Basis* 34 kg/hr, *Pressure* 101.3 kPa, *Temperature* 20 ^{o}C,
    - Gas 1: *Pressure* 101.3 kPa, *Dry-bulb Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.009 kg/kg.
    - Gas 4: *Pressure* 103.2 kPa.
    - Mat 1: *Mass Flow Rate Wet Basis* 2000 kg/hr, *Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.22 kg/kg.
    - Mat 2: *Temperature* 50 ^{o}C, *Moisture Content Wet Basis* 0.002 kg/kg.

- AirFilter 1: *Gas Pressure Drop* 0.3 kPa; *Collection Efficiency* 0.998, *Inlet Particle Loading* 0.1 g/m^3, *Filtration Velocity* 2.5 m/s.
- Fan 1: *Static Pressure* 3.0 kPa, *Efficiency* 0.7.
- Burner 1: *Excess Air %* 500, *Heat Loss %* 10.
- Dryer 1: *Gas Pressure Drop* 1.2 kPa, *Dust Entrained in Gas/Material Total* 0.001.
- Cyclone 1: *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.95.

You can get the results as in Figure 6b.

Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
Mass Flow Rate Wet Basis (kg/h)	3221.948	3221.948	3221.948	3255.948	3692.821	3692.821
Mass Flow Rate Dry Basis (kg/h)	3193.209	3193.209	3193.209	3159.554	3159.554	3159.554
Volume Flow Rate (m3/h)	2689.700	2697.691	2641.909	6420.565	3949.430	3972.809
Pressure (kPa)	101.300	101.000	104.000	103.200	102.000	101.400
Dry-bulb Temperature (°C)	20.000	20.000	22.466	427.815	78.152	78.153
Wet-bulb Temperature (°C)	15.383	15.353	16.542	62.882	62.885	62.762
Dew Point Temperature (°C)	12.458	12.413	12.859	32.365	62.033	61.904
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.031	0.169	0.169
Relative Humidity	0.618	0.616	0.546	0.000	0.498	0.495
Specific Enthalpy (kJ/kg)	42.377	42.377	44.867	527.364	449.397	449.397
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.141	1.326	1.326
Density (kg/m3)	1.198	1.194	1.220	0.507	0.935	0.930

Material Streams:	Mat 1	Mat 2	Mat 3
Mass Flow Rate Wet Basis (kg/h)	2000.000	1561.563	1.485
Mass Flow Rate Dry Basis (kg/h)	1560.000	1558.440	
Volume Flow Rate (m3/h)			
Pressure (kPa)			
Temperature (°C)	20.000	50.000	
Vapor Fraction			
Moisture Content Wet Basis (kg/kg)	0.220	0.002	
Moisture Content Dry Basis (kg/kg)	0.282	0.002	
Mass Concentration (kg/kg)			
Specific Enthalpy (kJ/kg)	38.126	63.293	
Specific Heat (kJ/kg.°C)	1.905	1.266	
Specific Heat Dry Basis (kJ/kg.°C)	2.442	1.268	
Density (kg/m3)			

Fuel Streams:	Fuel 1
Mass Flow Rate (kg/h)	34.000
Mole Flow Rate (kmole/h)	1.864
Volume Flow Rate (m3/h)	44.797
Pressure (kPa)	101.300
Temperature (°C)	20.000
Density (kg/m3)	0.759

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.998
Inlet Particle Loading (g/m3)	0.100
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	0.268
Particle Loss to Gas Outlet (kg/h)	0.001
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	1.868
Burner:	**Burner 1**
Excess Air %	500.000
Total Heat Generated (kW)	432.494
Heat Loss %	10.000
Heat Loss (kW)	43.249
Flue Gas Oxygen Mass Fraction	0.189
Flue Gas Oxygen Mole Fraction	0.170
Cyclones:	**Cyclone 1**
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.396
Outlet Particle Loading (g/m3)	0.020
Particle Collection Rate (kg/h)	1.485
Particle Loss to Gas Outlet (kg/h)	0.078
Dryers:	**Dryer 1**
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	436.874
Initial Gas Temperature (°C)	20.000
Specific Heat Consumption (kJ/kg)	3126.584
Thermal Efficiency	0.814
Dust Entrained in Gas/Material Total	0.001
Gas Outlet Dust Loading (g/m3)	0.423
Fans:	**Fan 1**
Static Pressure (kPa)	3.000
Total Discharge Pressure (kPa)	3.000
Efficiency	0.700
Power Input (kW)	3.212

Figure 6b

Example 7 – Recycle Gas Stream

Problem

This is the same problem as in Example 5 except that half of the gas outlet from the cyclone goes through a fan to gain 1.8 kPa static pressure and then is recycled back to the dryer's gas inlet.

Solution

To model this problem, at first a tee is required to split the gas outlet of the cyclone into two gas streams, one supposed to be discharged into the atmosphere, the other recycled back to the dryer's gas inlet. You might think that the recycled gas stream can go through a fan to gain the required static pressure (1.8 kPa) and then be mixed through a mixer with the fresh hot gas stream coming out of the heater and introduced into the dyer's gas inlet. The possible flowsheet is displayed in Figure 7a.

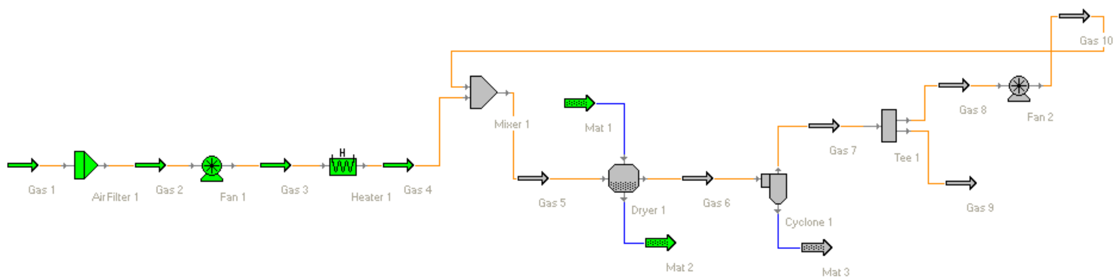


Figure 7a

Such a configuration of the flowsheet can not get the problem solved since it is necessary to know inlet gas conditions to solve the dryer's outlet gas stream. However, a portion of the dryer's gas outlet will be recycled as part of the dryer's gas inlet. This is a nonlinear problem. To solve such a nonlinear problem it is necessary to assume some initial guess values for the recycled stream so that the dryer's gas inlet is known to solve the dryer's gas outlet. This can be achieved by an auxiliary logical unit operation called Recycle.

Solution Steps

1. Follow all solution steps in example 5 you get the flowsheet as in Figure 5a.
2. Go to 'Flowsheet | Options' "Unit Operation Creation" group box to select "With Input and Output" radio button. Choose radio button "Gas" in both group boxes "Tee" and "Mixer" since the tee and mixer in this flowsheet deal with gas streams.
3. Select 'Flowsheet | Add | Unit Operations | Tee' and click anywhere on the flowsheet to create a tee (Tee 1).
4. Use the same way as in step 3 to create a fan (Fan 2), a recycle (Recycle 1) and a mixer (Mixer 1).

5. Delete the input stream of the Tee 1.
6. Delete the input stream of the Fan 2.
7. Delete one of the two input streams (the lower input stream) of Mixer 1.
8. Press down the **Disconnect** ( ) button in the toolbar. Click on the connection line between Gas 4 and Dryer 1 to break up the connection of Gas 4 from the inlet of Dryer 1.
9. Press down the **Connect** ( ) button in the toolbar. Click on Gas 6 and then click at the middle of the left border (the connection port) of Tee 1. You will get Tee 1 and Cyclone 1 connected.
10. Use the same way as in step 9 to connect Gas 8 with Fan 2, Gas 4 with Mixer 1, Gas 12 with Dryer 1.
11. Press down the **Connect** ( ) button in the toolbar. Click on Gas 11 and then click at the middle of the right border (the connection port) of Recycle 1. You will get Tee 1 and Recycle 1's inlet connected.
12. Double click the icon of Tee 1 to bring up the tee editor. Input 0.5 in the *Gas 8* field of the "Outlet Fractions" group box.
13. Bring up Fan 1's editor. Input 1.8 kPa in the *Static Pressure* field and 0.7 in the *Efficiency* field of the Fan group box.
14. Bring up Dryer 1's editor. Input 103.2 in the *Pressure* field of Gas 12.
15. Press down the **Connect** ( ) button in the toolbar. Click on the Gas 13 and then click at the middle of the left border (the connection port) of Recycle 1. You will get Mixer 1 and Recycle 1 connected. Then the flowsheet is automatically solved through multiple loops of iterations.
16. You can rename Gas 6 to Gas 7, Gas 5 to Gas 6, Gas 11 to Gas 10, Gas 12 to Gas 5 and Gas 13 to Gas 11 to get the flowsheet as displayed in Figure 7b.

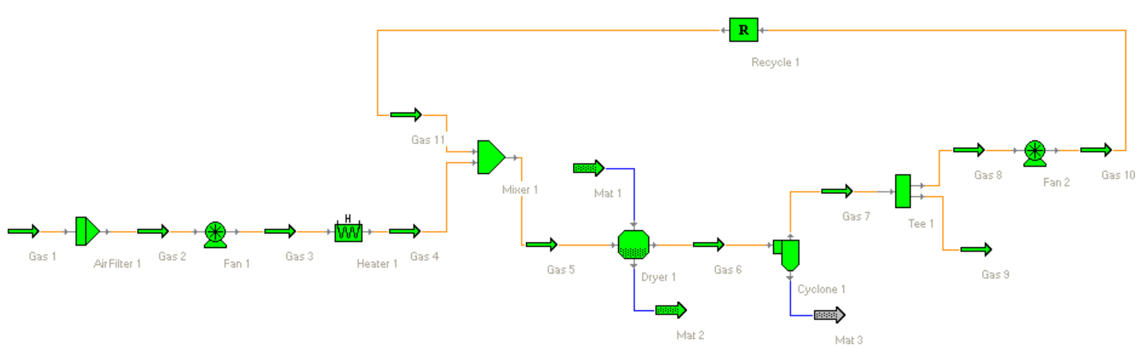
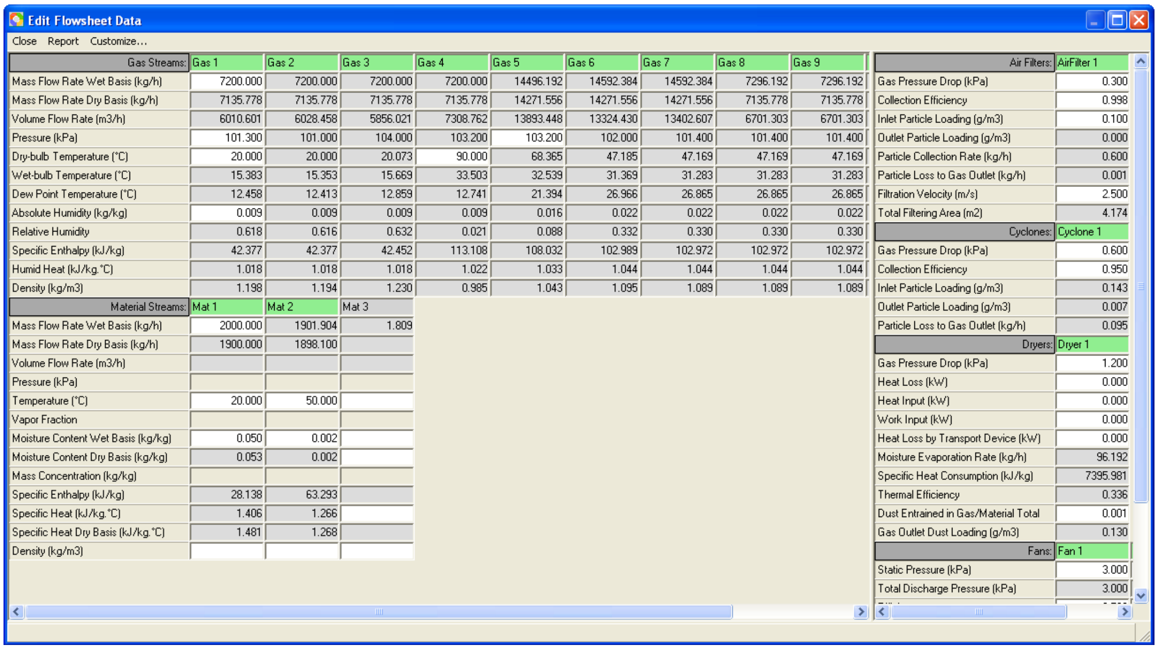


Figure 7b

The solution is shown in the global editor as follows



Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6	Gas 7	Gas 8	Gas 9
Mass Flow Rate Wet Basis (kg/h)	7200.000	7200.000	7200.000	7200.000	14496.192	14592.384	14592.384	7296.192	7296.192
Mass Flow Rate Dry Basis (kg/h)	7135.778	7135.778	7135.778	7135.778	14271.556	14271.556	14271.556	7135.778	7135.778
Volume Flow Rate (m3/h)	6010.601	6028.458	5856.021	7308.762	13893.448	13324.430	13402.607	6701.303	6701.303
Pressure (kPa)	101.300	101.000	104.000	103.200	103.200	102.000	101.400	101.400	101.400
Dry-bulb Temperature (°C)	20.000	20.000	20.073	90.000	68.365	47.185	47.169	47.169	47.169
Wet-bulb Temperature (°C)	15.383	15.353	15.669	33.503	32.539	31.369	31.283	31.283	31.283
Dew Point Temperature (°C)	12.458	12.413	12.859	12.741	21.394	26.966	26.865	26.865	26.865
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.009	0.016	0.022	0.022	0.022	0.022
Relative Humidity	0.618	0.616	0.632	0.021	0.088	0.332	0.330	0.330	0.330
Specific Enthalpy (kJ/kg)	42.377	42.377	42.452	113.108	108.032	102.989	102.972	102.972	102.972
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.022	1.033	1.044	1.044	1.044	1.044
Density (kg/m3)	1.198	1.194	1.230	0.985	1.043	1.095	1.089	1.089	1.089

Material Streams:	Mat 1	Mat 2	Mat 3
Mass Flow Rate Wet Basis (kg/h)	2000.000	1901.904	1.809
Mass Flow Rate Dry Basis (kg/h)	1900.000	1898.100	
Volume Flow Rate (m3/h)			
Pressure (kPa)			
Temperature (°C)	20.000	50.000	
Vapor Fraction			
Moisture Content Wet Basis (kg/kg)	0.050	0.002	
Moisture Content Dry Basis (kg/kg)	0.053	0.002	
Mass Concentration (kg/kg)			
Specific Enthalpy (kJ/kg)	28.138	63.293	
Specific Heat (kJ/kg.°C)	1.406	1.266	
Specific Heat Dry Basis (kJ/kg.°C)	1.481	1.268	
Density (kg/m3)			

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.998
Inlet Particle Loading (g/m3)	0.100
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	0.600
Particle Loss to Gas Outlet (kg/h)	0.001
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	4.174
Cyclones:	**Cyclone 1**
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.143
Outlet Particle Loading (g/m3)	0.007
Particle Loss to Gas Outlet (kg/h)	0.095
Dryers:	**Dryer 1**
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	96.192
Specific Heat Consumption (kJ/kg)	7395.981
Thermal Efficiency	0.336
Dust Entrained in Gas/Material Total	0.001
Gas Outlet Dust Loading (g/m3)	0.130
Fans:	**Fan 1**
Static Pressure (kPa)	3.000
Total Discharge Pressure (kPa)	3.000

Figure 7c

Example 8 – Recycle Material Stream

Problem

Material is known as follows

Type: solid particles
Initial moisture content = 25% wet basis
Initial temperature = 20 ^oC
Product temperature = 75 ^oC
Product moisture content = 0.2% wet basis
Specific heat of the absolute dry material = 1.26 kJ/kg·^oC
Mass flow rate wet basis = 1000 kg/hr

Drying air has the following conditions

Initial pressure = 101.3 kPa
Initial temperature = 20 ^oC.
Initial Absolute Humidity = 0.009 kg/kg
Mass Flow Rate wet basis = 10000 kg/hr

Drying air needs to go through an air filter first. Pressure drop in the air filter is 0.3 kPa. Assume dust volume concentration is 0.1 g/m^3, collection efficiency of the air filter is 99.8% and filtration velocity is 2.5 m/s. Drying air then goes through a fan (the efficiency of the fan is 0.7) to gain 3 kPa static pressure, then through a heater to be heated to 110 ^oC before going to the dryer. Pressure drop of air in heater and dryer is 0.8 kPa and 1.2 kPa respectively. The exhaust air of the dryer entrains 0.1% of the total material into the dryer's gas outlet stream. The gas outlet stream needs to go through a cyclone to collect the entrained dust material. Collection efficiency of the cyclone is 95%. Pressure drop of air in the cyclone is 0.6 kPa.

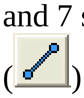
The dryer requires that the feed moisture content (wt basis) can not be greater than 0.15 kg/kg wet basis. As is known, initial moisture content (wet basis) of the material is 0.25 kg/kg. One possible solution is to mix a portion of the dried material product with the fresh material to decrease the moisture content to the required level and then feed the dryer.

A tee is required to split the product material into two halves. One half goes through a Recycle and mixes with the fresh material in a mixer and then introduced into the dryer's material inlet.

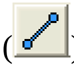
Solution

Similar to recycling a gas stream in Example 6, a portion of the dryer's material outlet stream is recycled in this example. To get this problem solved an auxiliary recycle unit operation is necessary.

Solution Steps

1. Save and close current flowsheet if a flowsheet exists. Otherwise, start Simprosys and close current flowsheet created automatically by Simprosys.
2. Go to 'Edit | Unit Systems' to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to 'Edit | Numeric Format' tab to change Decimal Places to 4.
4. Go to 'Materials | Set Default Flowsheet Settings'. Select "Generic Drying Material" and click **Set** button to set this material as the drying material of the to-be-created new flowsheet if you have already created the Generic Drying Material in the material catalog. Otherwise, create the Generic Drying Material and then go to 'Materials | Set Default Flowsheet Settings' to set it.
5. Create a new flowsheet by clicking the first icon  in the toolbar or clicking 'File | New'.
6. Go to 'Flowsheet | Options' "Unit Operation Creation" and choose radio button "Without Input and Output". Choose radio button "Solid Material" in both group boxes "Tee" and "Mixer" since the tee and mixer in this flowsheet deal with solid material streams.
7. Select 'Flowsheet | Add | Unit Operations | Air Filter' and click anywhere on the flowsheet to create an air filter (AirFilter 1).
8. Use the same way as in step 7 to create a fan (Fan 1), a heater (Heater 1), a solid dryer (Dryer 1), a Tee (Tee 1), a Mixer (Mixer 1), a Cyclone (Cyclone 1), 6 gas streams (Gas 1 to Gas 6) and 7 solid material streams (Mat 1 to Mat 7)
9. Press down the **Connect** () button in the toolbar. Click on the Gas 1 and then click at the middle of the left border (the connection port) of AirFilter 1. You will get Gas 1 and AirFilter 1 connected.
10. Use the same way as in step 9 to get Gas 2 and AirFilter 1, Gas 2 and Fan 1 etc. connected. The connected flowsheet is as displayed in Figure 8a except that Mat 6 is not connected with Recycle 1.
12. Go to Edit | Flowsheet Data to bring up the global editor and input all the known values as follows:
    - Gas 1: *Mass Flow Rate Wet Basis* 10000 kg/hr, *Pressure* 101.3 kPa, *Dry-bulb Temperature* 20 ^{o}C, *Absolute Humidity* 0.009 kg/kg.
    - Gas 4: *Dry-bulb Temperature* 110 ^{o}C.
    - Mat 1: *Mass Flow Rate Wet Basis* 1000 kg/hr, *Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.25 kg/kg.
    - Mat 3: *Temperature* 75 ^{o}C, *Moisture Content Wet Basis* 0.002 kg/kg.
    - AirFilter 1: *Gas Pressure Drop* 0.3 kPa, *Collection Efficiency* 0.998, *Inlet Particle Loading* 0.1 g/m^3, *Filtration Velocity* 2.5 m/s.
    - Fan 1: *Static Pressure* 3.0 kPa, *Efficiency* 0.7.
    - Heater 1: *Pressure Drop* 0.8 kPa.

- Dryer 1: *Gas Pressure Drop* 1.2 kPa, *Dust Entrained in Gas/Material Total* 0.001.
- Cyclone 1: *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.95.

13. Click the icon of Tee 1 to bring up the tee editor. In put 0.5 in the *Mat 4* field of "Outlet Fractions" group box.
14. Press down the **Connect** () button in the toolbar. Click on Mat 6 and then click at the middle of the right border (the connection port) of Recycle 1 to get Mixer 1 and Recycle 1 connected.

The solved flowsheet is as displayed in Figure 8a and the results are shown is Figure 8b.

Please be noted that you can adjust the ratio of the recycled material product to make the moisture content of the dryer material inlet satisfy a specified condition. If, for example, the moisture content of the dryer material inlet has to be less than 0.13 rather the previously specified 0.15, you can increase the ratio of the recycle material product from 0.5 to 0.56 (in the *Mat 4* field of "Outlet Fractions" group box of Tee 1) to get this condition satisfied.

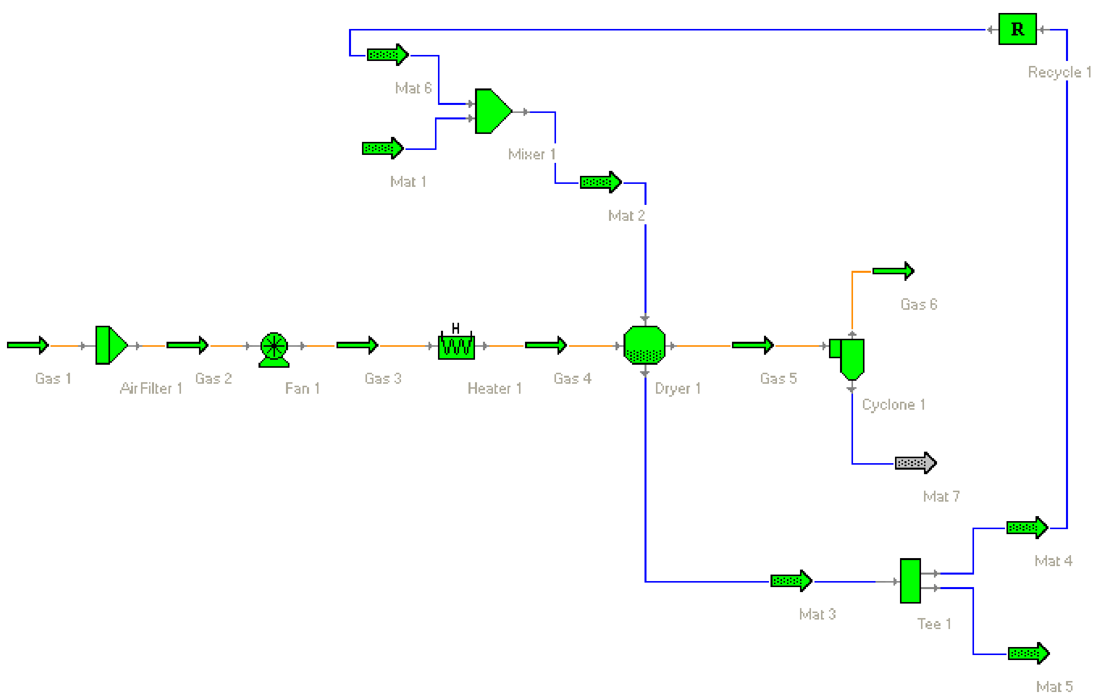


Figure 8a

Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
Mass Flow Rate Wet Basis (kg/h)	10000.000	10000.000	10000.000	10000.000	10248.497	10248.497
Mass Flow Rate Dry Basis (kg/h)	9910.803	9910.803	9910.803	9910.803	9910.803	9910.803
Volume Flow Rate (m3/h)	8348.057	8372.858	8133.363	10710.114	9317.852	9372.526
Pressure (kPa)	101.300	101.000	104.000	103.200	102.000	101.400
Dry-bulb Temperature (°C)	20.000	20.000	20.073	110.000	43.730	43.714
Wet-bulb Temperature (°C)	15.383	15.353	15.669	36.866	35.628	35.536
Dew Point Temperature (°C)	12.458	12.413	12.859	12.741	33.923	33.817
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.009	0.034	0.034
Relative Humidity	0.618	0.616	0.632	0.010	0.590	0.587
Specific Enthalpy (kJ/kg)	42.377	42.377	42.452	133.368	127.287	127.270
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.024	1.066	1.066
Density (kg/m3)	1.198	1.194	1.230	0.934	1.100	1.093

Material Streams:	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Mat 6	Mat 7
Mass Flow Rate Wet Basis (kg/h)	1000.000	1750.000	1500.002	750.001	750.001	750.000	1.426
Mass Flow Rate Dry Basis (kg/h)	750.000	1498.500	1497.002	748.501	748.501	748.500	
Volume Flow Rate (m3/h)							
Pressure (kPa)							
Temperature (°C)	20.000	37.775	75.000	75.000	75.000	75.000	
Vapor Fraction							
Moisture Content Wet Basis (kg/kg)	0.250	0.144	0.002	0.002	0.002	0.002	
Moisture Content Dry Basis (kg/kg)	0.333	0.168	0.002	0.002	0.002	0.002	
Mass Concentration (kg/kg)							
Specific Enthalpy (kJ/kg)	39.889	63.482	94.939	94.939	94.939	94.939	
Specific Heat (kJ/kg.°C)	1.992	1.681	1.266	1.266	1.266	1.266	
Specific Heat Dry Basis (kJ/kg.°C)	2.657	1.963	1.268	1.268	1.268	1.268	
Density (kg/m3)							

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.998
Inlet Particle Loading (g/m3)	1.000
Outlet Particle Loading (g/m3)	0.002
Particle Collection Rate (kg/h)	8.331
Particle Loss to Gas Outlet (kg/h)	0.017
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	5.797
Cyclones:	**Cyclone 1**
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.161
Outlet Particle Loading (g/m3)	0.008
Particle Loss to Gas Outlet (kg/h)	0.075
Dryers:	**Dryer 1**
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	248.497
Specific Heat Consumption (kJ/kg)	3651.640
Thermal Efficiency	0.659
Dust Entrained in Gas/Material Total	0.001
Gas Outlet Dust Loading (g/m3)	0.147
Fans:	**Fan 1**
Static Pressure (kPa)	3.000
Total Discharge Pressure (kPa)	3.000
Efficiency	0.700
Power Input (kW)	9.968
Heaters:	**Heater 1**
Pressure Drop (kPa)	0.800
Heat Loss (kW)	0.000
Heating Duty (kW)	252.543

Figure 8b

Example 9 – Enclosed Drying System (a Nitrogen-Ethanol system)

Problem

The moisture in of the drying material is Ethanol, the drying gas is Nitrogen. A simple enclosed drying system with the following conditions for both the material and the drying gas:

Material:

Feed temperature = 20 ^{o}C
Feed moisture content = 8% wet basis
Mass flow rate wet basis = 2000 kg/hr
Product temperature = 50 ^{o}C
Product moisture content = 0.2% wet basis

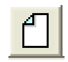
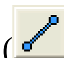
Drying Gas

Pressure at dryer inlet = 102.4 kPa
Temperature at dryer inlet = 120 ^{o}C
Mass flow rate wet basis at dryer Inlet = 3000 kg/hr

Pressure drop of the dryer is 1.2 kPa. Dryer gas outlet stream goes through a fan to gain 1.5 kPa static pressure. Efficiency of the fan is 0.75. Exhaust air coming from the fan goes through a scrubber/condenser to collect the dusts and remove the moisture carried in the exhaust air. Temperature of the exhaust air from the scrubber/condenser is 30 ^{o}C. Air pressure drop in scrubber/condenser is 1.0 kPa. Collection efficiency and liquid gas ratio of the scrubber/ condenser are 99% and 1.0 respectively. Liquid inlet pressure and temperature of the scrubber/condenser are 101.3 kPa and 20 ^{o}C. The air coming out of the scrubber/condenser goes through a fan to gain some static pressure and then go through a heater to be heated to the required dryer inlet temperature (120 ^{o}C). The efficiency of the fan is 0.75. The pressure drop of air in the heater is 0.6 kPa.

Solution Steps

1. Save and close current flowsheet if a flowsheet exists. Otherwise, start Simprosys and close current flowsheet created automatically by Simprosys.
2. Go to ‘Edit | Unit Systems’ to select SI-2 and click **Set Current** button to set SI-2 unit system as the current unit system. Close this dialog.
3. Go to ‘Edit | Numeric Format’ tab to change Decimal Places to 4.
4. Go to ‘Materials | Drying Material Catalog’ to bring up the drying material catalog.
5. Click the “**Add**” button to add a new material to bring up the “New Drying Material” dialog.

6. Change the material name from “New Drying Material” to “Material_Ethanol” and then select *Ethanol* from the Moisture combo box.
7. Go to ‘Materials | Set Default Flowsheet Settings’ to bring up the “Set Default Flowsheet Settings” dialog.
8. Select “Material_Ethanol” and click **Set** button to set this material as the drying material of the to-be-created new flowsheet.
9. Select “Nitrogen” from the Drying Gas combo box
10. Create a new flowsheet by clicking the first icon  in the toolbar or selecting ‘File | New’ menu.
11. Go to ‘Flowsheet | Options’ group box “Unit Operation Creation” and choose radio button “With Input Only”.
12. Select ‘Flowsheet | Add | Unit Operations | Dryer’ and click anywhere on the flowsheet to create a dryer (Dryer 1).
13. Use the same way as in step 7 to create a material stream (Mat 2), a fan (Fan 1), a scrubber/condenser (ScrbCond 1), another fan (Fan 2) and a Heater (Heater 1).
14. Press down the **Connect** () button in the toolbar. Click on the Gas 2 and then click at the middle of the left border (the connection port) of Dryer 1. You will get Dryer 1 and Fan 1 connected.
15. Use the same way as in step 9 to get Fan 1 and ScrbCond 1, ScrbCond 1 and Fan 2, Heater 1 and Dryer 1, Mat 2 and Dryer 1 connected.
16. Go to Edit | Flowsheet Data to bring up the global editor and input all the known values as follows:
    - Gas 1: *Mass Flow Rate Wet Basis* 3000 kg/hr, *Pressure* 102.4 kPa, *Dry-bulb Temperature* 120 ^{o}C.
    - Gas 4: *Dry-bulb Temperature* 30 ^{o}C.
    - Mat 1: *Mass Flow Rate Wet Basis* 2000 kg/hr, *Temperature* 20 ^{o}C, *Moisture Content Wet Basis* 0.08 kg/kg.
    - Mat 2: *Temperature* 50 ^{o}C, *Moisture Content Wet Basis* 0.002 kg/kg.
    - Dryer 1: *Gas Pressure Drop* 1.2 kPa.
    - Fan 1: *Static Pressure* 1.5 kPa, *Efficiency* 0.75.
    - Heater 1: *Pressure Drop* 0.6 kPa.
    - Mat 3: *Pressure* 101.3 kPa, *Temperature* 20 ^{o}C.
    - ScrbCond 1: *Gas Pressure Drop* 1.0 kPa, *Collection Efficiency* 0.99, *Liquid Gas Ratio* 1.0.
    - Fan 2: *Efficiency* 0.75.

The flowsheet is constructed as shown in Figure 9a. The result of the flowsheet is displayed in Figure 9b.

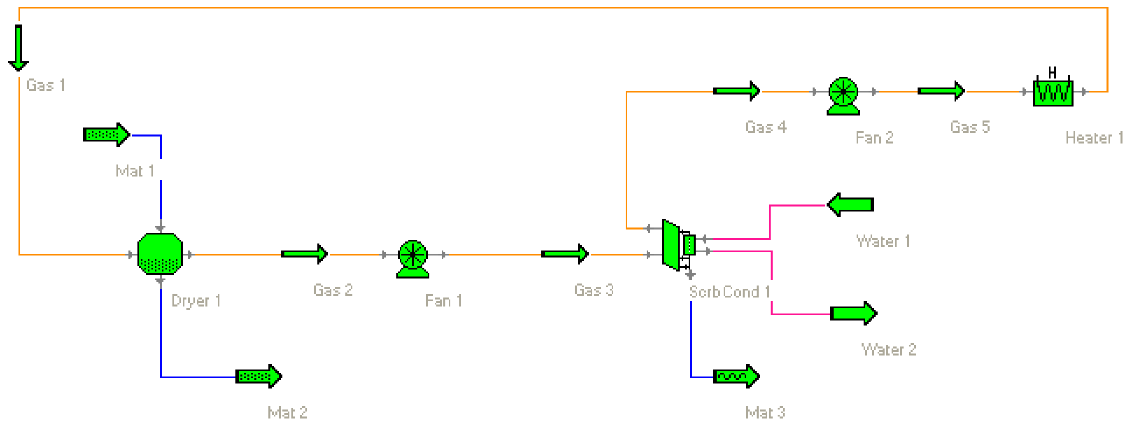
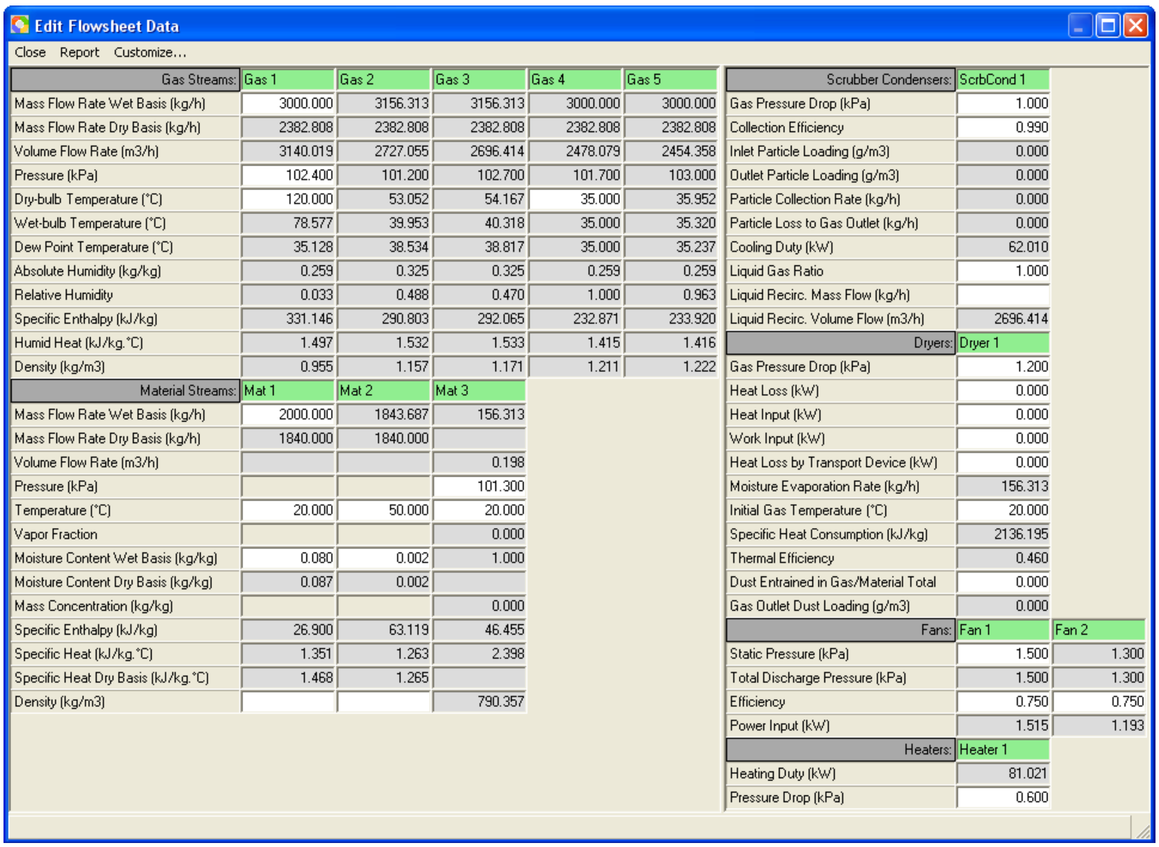


Figure 9a



Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5
Mass Flow Rate Wet Basis (kg/h)	3000.000	3156.313	3156.313	3000.000	3000.000
Mass Flow Rate Dry Basis (kg/h)	2382.808	2382.808	2382.808	2382.808	2382.808
Volume Flow Rate (m3/h)	3140.019	2727.055	2696.414	2478.079	2454.358
Pressure (kPa)	102.400	101.200	102.700	101.700	103.000
Dry-bulb Temperature (°C)	120.000	53.052	54.167	35.000	35.952
Wet-bulb Temperature (°C)	78.577	39.953	40.318	35.000	35.320
Dew Point Temperature (°C)	35.128	38.534	38.817	35.000	35.237
Absolute Humidity (kg/kg)	0.259	0.325	0.325	0.259	0.259
Relative Humidity	0.033	0.488	0.470	1.000	0.963
Specific Enthalpy (kJ/kg)	331.146	290.803	292.065	232.871	233.920
Humid Heat (kJ/kg.°C)	1.497	1.532	1.533	1.415	1.416
Density (kg/m3)	0.955	1.157	1.171	1.211	1.222

Material Streams:	Mat 1	Mat 2	Mat 3
Mass Flow Rate Wet Basis (kg/h)	2000.000	1843.687	156.313
Mass Flow Rate Dry Basis (kg/h)	1840.000	1840.000	
Volume Flow Rate (m3/h)			0.198
Pressure (kPa)			101.300
Temperature (°C)	20.000	50.000	20.000
Vapor Fraction			0.000
Moisture Content Wet Basis (kg/kg)	0.080	0.002	1.000
Moisture Content Dry Basis (kg/kg)	0.087	0.002	
Mass Concentration (kg/kg)			0.000
Specific Enthalpy (kJ/kg)	26.900	63.119	46.455
Specific Heat (kJ/kg.°C)	1.351	1.263	2.398
Specific Heat Dry Basis (kJ/kg.°C)	1.468	1.265	
Density (kg/m3)			790.357

Scrubber Condensers:	ScrbCond 1
Gas Pressure Drop (kPa)	1.000
Collection Efficiency	0.990
Inlet Particle Loading (g/m3)	0.000
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	0.000
Particle Loss to Gas Outlet (kg/h)	0.000
Cooling Duty (kW)	62.010
Liquid Gas Ratio	1.000
Liquid Recirc. Mass Flow (kg/h)	
Liquid Recirc. Volume Flow (m3/h)	2696.414

Dryers:	Dryer 1
Gas Pressure Drop (kPa)	1.200
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	156.313
Initial Gas Temperature (°C)	20.000
Specific Heat Consumption (kJ/kg)	2136.195
Thermal Efficiency	0.460
Dust Entrained in Gas/Material Total	0.000
Gas Outlet Dust Loading (g/m3)	0.000

Fans:	Fan 1	Fan 2
Static Pressure (kPa)	1.500	1.300
Total Discharge Pressure (kPa)	1.500	1.300
Efficiency	0.750	0.750
Power Input (kW)	1.515	1.193

Heaters:	Heater 1
Heating Duty (kW)	81.021
Pressure Drop (kPa)	0.600

Figure 9b

Example 10 – Evaporation

Problem

Liquid material of 50000 kg/hr flow rate is initially at a mass concentration of 0.13 kg/kg and a temperature of 3 ^{o}C. It needs to be concentrated to a mass solid content of 57%. Material density is 720 kg/m^3 at the initial temperature. Concentration process needs to be performed at around atmospheric pressure. Specific heat of the material without moisture is 1.26 kJ/kg·^{o}C. The boiling point rise of the material solution can be described by the following Durhing lines expressed in a Table 1

Table 1. Durhing Lines of Example 10

Mass concentration (kg/kg)	Start Boiling Point (^{o}C)		End Boiling Point (^{o}C)	
	Solvent	Solution	Solvent	Solution
0.0	50	50	200	200
0.2	50	52	200	203
0.4	50	55	200	207
0.6	50	59	200	212

Solution

This can be achieved by a two-effect falling film evaporation process. The initial liquid material is first preheated using part of the secondary vapor from the second effect evaporation to about 81 ^{o}C. Then part of the thermally compressed secondary vapor from the first effect is used to further heat the material to nearly the bubble point of the material. It then goes to the first falling film evaporator operating at a pressure of 106 kPa. Water vapor of 265 kPa is used as the heating medium for this evaporator. Vapor and liquid material mixture coming out of the first evaporator goes to a liquid-vapor separator to separate the concentrated liquid with the vapor. Secondary vapor coming out of the separator is compressed with a fresh vapor at 350 kPa using a steam jet ejector. A very small potion of the compressed vapor is used to preheat the feeding material from 81 ^{o}C as to nearly the bubble point as indicated before. The majority is used as the heating medium of the second effect evaporation. The second evaporator is operating at about 100 kPa. Liquid-vapor mixture coming out of the second evaporator goes to another liquid-vapor separator to separate the concentrated liquid material with the vapor. As is mentioned above part of the secondary vapor coming out of the separator is use to preheat the feeding material.

A falling film evaporator can be modeled by a heat exchange. The to-be-concentrated material is at the cold side of the heat exchanger. The heating steam is at the hot side of the exchanger.

Solution Steps:

1. Save and close current flowsheet if a flowsheet exists. Otherwise, start Simprosys and close current flowsheet created automatically by Simprosys.
2. Go to ‘Edit | Unit Systems’ to select SI-2 and click **Set Current** button to set SI-2 unit system as current unit system. Close this dialog.
3. Go to ‘Edit | Numeric Format’ tab to change Decimal Places to 4.
4. Go to ‘Materials | Drying Material Catalog’ to bring up the “Drying Material Catalog” dialog. Click **Add** button to add a new drying material. In the “Name” field change the name to “Generic Evaporation Material”. Input 1.26 in the *Specific Heat of Absolute Dry Material* field.
5. On the same “Drying Material Catalog” dialog click **Durhing Lines** button to specify the Durhing lines of Generic Evaporation Material according to Table 1. After all the necessary values are input you should have the following “Durhing Lines” dialog as follows,

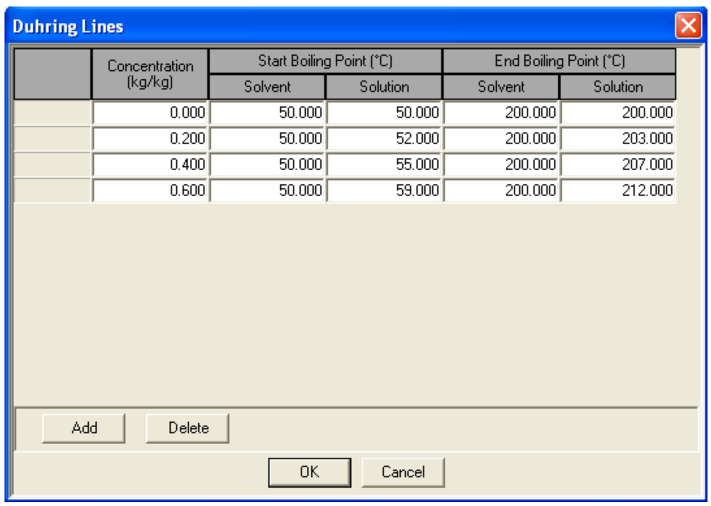


Figure 10a

6. Click **OK** button to close the “Durhing Lines” dialog. Then close the “New Drying Material” dialog and then close “Drying Material Catalog” dialog.
7. Go to ‘Materials | Set Default Flowsheet Settings’ to bring up the Set Default Flowsheet Settings dialog. Select “Generic Evaporation Material” in the Select Drying Material list box. Then click **Set** button to set this material as the drying material of the new flowsheet to be created. Close this dialog.
8. Create a new flowsheet by clicking the first icon  in the toolbar or selecting ‘File | New’.
9. Go to ‘Flowsheet | Options’ group box “Unit Operation Creation” and choose radio button “Without Input and Output”.
10. Select ‘Flowsheet | Add | Unit Operations | Pump’ and click anywhere on the flowsheet to create a pump (Pump 1).
11. Use the same way as in step 10 to create two heat exchangers (Exch 1 and Exch 2), another pump (Pump 2), another heat exchanger (Evap 1), a separator

(Separator 1), an ejector (Ejector 1), a tee (Tee 1), another heat exchanger (Evap 2), another separator (Separator 2) and another tee (Tee 2).

12. Select 'Flowsheet | Add | Streams | Liquid Material' and click anywhere on flowsheet to create a liquid material stream (Mat 1).
13. Use the same way as in Step 12 to add another 21 liquid material streams (Mat 2 to Mat 22
14. Rename Mat 10 through Mat 22 to Steam 1 through Steam 13.
15. Connect the material streams and the unit operations as in Figure 10b.
16. Double click the icon of Pump 1 to bring up the pump editor and input the known values as follows:
    - Mat 1: *Mass Flow Rate Wet Basis* 50000 kg/hr, *Pressure* 101.3 kPa, *Temperature* 3 ^{o}C, *Mass Concentratio*n 0.13 kg/kg, *Density* 720 kg/m^3.
    - Mat 2: *Pressure* 108 kPa.
    - *Static Suction Head* 2.0 m, *Suction Friction Head* 0.5 m, *Static Discharge Head* 2.0 m, *Discharge Friction Head* 3.0 m, *Efficiency* 0.7.
17. Bring up Exch 1's editor and input in
    - Mat 3: *Temperature* 81 ^{o}C.
    - *Cold Side Pressure Drop* 3.0 kPa, *Hot Side Pressure Drop* 3.0 kPa.
18. Bring up Exch 2's editor and input in
    - Mat 4: *Temperature* 100 ^{o}C, *Density* 720 kg/m^3.
    - *Cold Side Pressure Drop* 3.0 kPa, *Hot Side Pressure Drop* 3.0 kPa.
19. Bring up Pump 2's editor and input in
    - Mat 5: *Pressure* 106 kPa.
    - *Static Suction Head* 2.0 m, *Suction Friction Head* 0.5 m, *Static Discharge Head* 3.0 m, *Discharge Friction Head* 0.5 m, *Efficiency* 0.7.
20. Bring up Evap 1's editor and input in
    - Mat 6: *Vapor Fraction* 0.37.
    - Steam 1: *Pressure* 265 kPa, *Vapor Fraction* 1.0, *Mass Concentratio*n 0 kg/kg.
    - Steam 2: Vapor Fraction 0,
    - *Cold Side Pressure Drop* 4.0 kPa, *Hot Side Pressure Drop* 4.0 kPa
21. Bring up Separator 1's editor and input in
    - Steam 4: *Pressure* 100 kPa
22. Bring up Ejector 1's editor and input in
    - Mat 1: *Mass Flow Rate Wet Basis* 4200 kg/hr, *Pressure* 350 kPa, *Vapor Fraction* 1.0, *Mass Concentration* 0 kg/kg.
    - *Compression Ratio* 1.8
23. Bring up Evap 2's editor and input in
    - Mat 8: *Vapor Fraction* 0.64
    - *Cold Side Pressure Drop* 5.0 kPa, *Hot Side Pressure Drop* 5.0 kPa
24. Bring up Separator 2's editor and input in
    - Steam 3: *Pressure* 93 kPa
25. Bring up Tee 1's editor and input in
    - *Steam 6* of Outlet Fractions group box 0.073
26. Bring up Tee 1's editor and input in

- *Steam 12* of Outlet Fractions group box 0.322

27. The known and calculated variable values are displayed in Figure 10c.

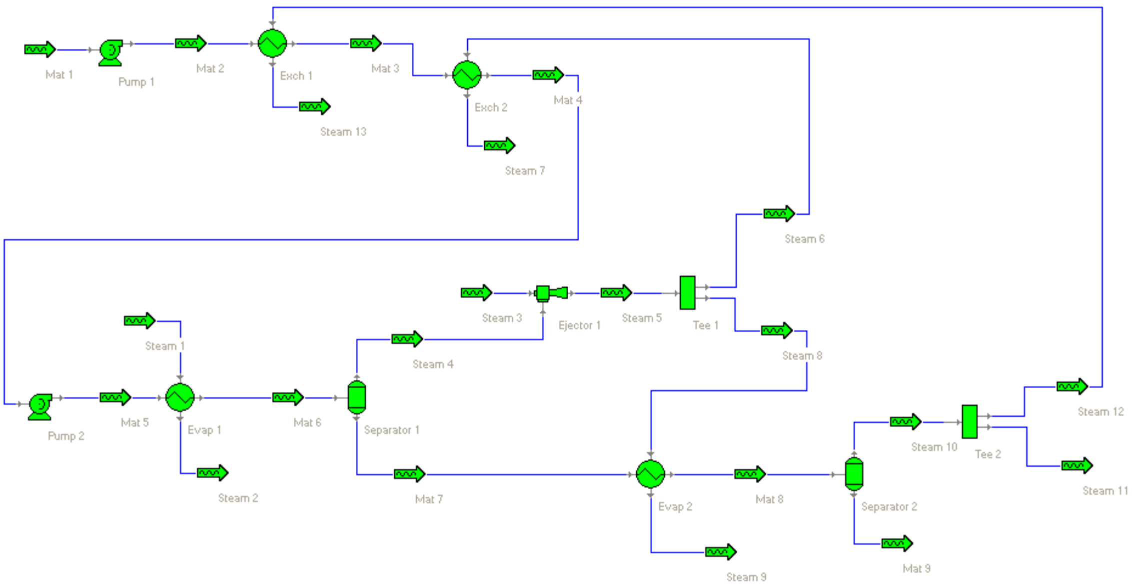


Figure 10b

Edit Flowsheet Data

Close Report Customize...

Material Streams:	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Mat 6	Mat 7	Mat 8	Mat
Mass Flow Rate Wet Basis (kg/h)	50000.000	50000.000	50000.000	50000.000	50000.000	50000.000	31590.009	31590.009	
Mass Flow Rate Dry Basis (kg/h)	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	
Volume Flow Rate (m3/h)	69.444	69.444		69.444	69.444				
Pressure (kPa)	101.300	108.000	105.000	102.000	106.000	102.000	100.000	95.000	
Temperature (°C)	3.000	2.998	81.000	100.000	99.999	101.703	102.058	100.621	
Vapor Fraction	0.000	0.000	0.000	0.000	0.000	0.370	0.000	0.640	
Moisture Content Wet Basis (kg/kg)	0.870	0.870	0.870	0.870	0.870	0.870	0.794	0.794	
Moisture Content Dry Basis (kg/kg)	6.692	6.692	6.692	6.692	6.692	6.692	3.860	3.860	
Mass Concentration (kg/kg)	0.130	0.130	0.130	0.130	0.130	0.130	0.206	0.206	
Specific Enthalpy (kJ/kg)	11.538	11.538	308.336	380.967	380.967	1227.151	366.827	1829.271	
Specific Heat (kJ/kg.°C)	3.835	3.809	3.815	3.835	3.809	3.837	3.613	3.611	
Specific Heat Dry Basis (kJ/kg.°C)	29.499	29.299	29.347	29.498	29.299				
Density (kg/m3)	720.000	720.000		720.000	720.000				

Ejectors:	Ejector 1	
Entrainment Ratio	4.383	
Compression Ratio	1.800	
Suction/Motive Pressure Ratio	0.286	
Heat Exchangers:	**Exch 1**	**Exch 2**
Total Heat Transfer (kW)	4122.191	1008.761
Cold Side Pressure Drop (kPa)	3.000	3.000
Hot Side Pressure Drop (kPa)	3.000	3.000
Pumps:	**Pump 1**	**Pump 2**
Capacity (m3/h)	69.444	69.444
Static Suction Head (m)	2.000	2.000
Suction Friction Head (m)	0.500	0.500
Static Discharge Head (m)	2.000	3.000
Discharge Friction Head (m)	3.000	0.500
Total Dynamic Head (m)	3.500	2.000
Efficiency	0.700	0.700
Power Input (kW)	0.866	0.499

Figure 10c

Please be noted that not all the known values of the variables are presented in the statement of the Problem. However, the missing variable values are assumed and input as in the solution steps.

Example 11 - Evaporation and Drying 1

Problem

This example is an extension of Example 10. The same liquid material needs to be spray dried after being concentrated. The evaporation process has already been described in Example 10. Concentrated liquid material goes to a spray dryer. The drying air of the spray dryer needs to be at 103.2 kPa and 140 ^oC. The exhaust air is at 68 ^oC. Material outlet from the spray dryer is at 55 ^oC and 3% (wet basis). Part of the secondary vapor from the second effect evaporator is used to preheat the drying air.

Solution Steps

Following the solution steps in example 10, the following extra steps are needed:

1. Add an air filter (AirFilter 1), a fan (Fan 1), a heat exchanger (Exch 3), a heater (Heater 1), a liquid dryer (Dryer 1) and a cyclone (Cyclone 1), 7 gas streams (Gas 1 through Gas 7), two liquid material stream (Steam 14 and Stream 15), two solid material streams (Mat 10 and Mat 11).
2. Connect the gas and material streams with the unit operations as in Figure 11a.
3. Bring up AirFilter 1's editor and input in
   - Gas 1: *Pressure* 101.3 kPa, *Dry-buld Temperature* 20 ^oC.
   - *Gas Pressure Drop* 0.3 kPa, *Collection Efficiency* 0.995, *Inlet Particle Loading* 0.1 g/m^3, *Filtration Velocity* 2.5 m/s.
4. Bring up Fan 1's editor and input in
   - *Static Pressure* 4.0 kPa, *Efficiency* 0.73.
5. Bring up Tee 2's editor and input in
   - *Steam 14* of "Outlet Fractions" group box 0.184
6. Bring up Exch 3's editor and input in
   - Steam 15: *Vapor Fraction* 0.
   - *Cold Side Pressure Drop* 1.2, *Hot Side Pressure Drop* 3.0 kPa.
7. Bring up Heater 1's editor and input in
   - Gas 5: *Temperature* 140 ^oC, *Absolute Humidity* 0.009 kg/kg.
   - *Pressure Drop* 0.6 kPa.
8. Bring up Dryer 1's editor and input in
   - Mat 5: *Temperature* 55 ^oC, *Moisture Content Wet Basis* 0.03 kg/kg.
   - Gas 6: *Dry-bulb Temperature* 68 ^oC.
   - *Gas Pressure Drop* 1.0 kPa, *Dust Entrained in Gas/Material Total* 0.001.
9. Bring up Cycone 1's editor and input in
   - *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.95.

The results are displayed in Figure 11b

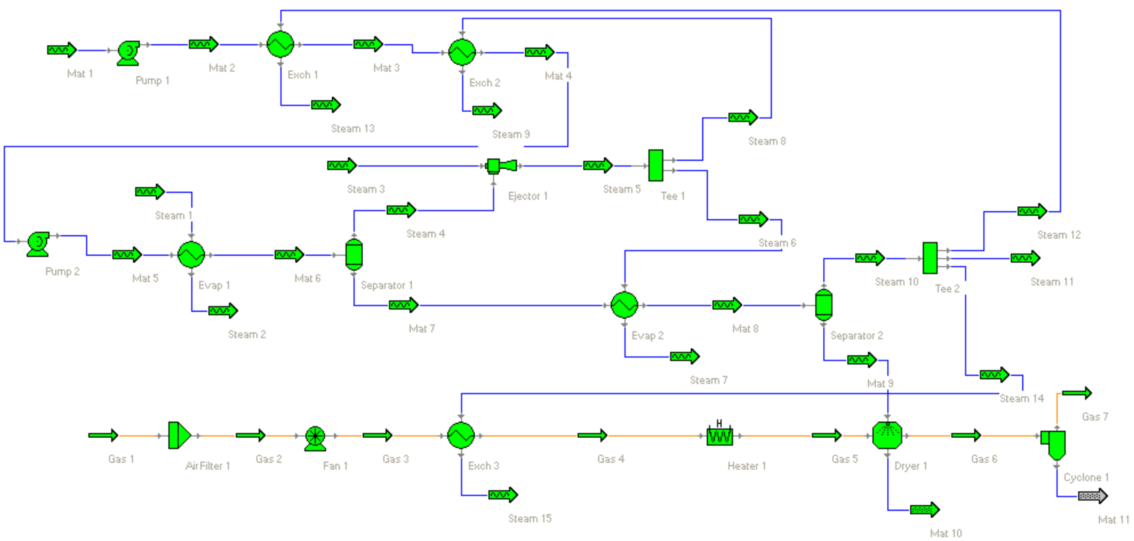
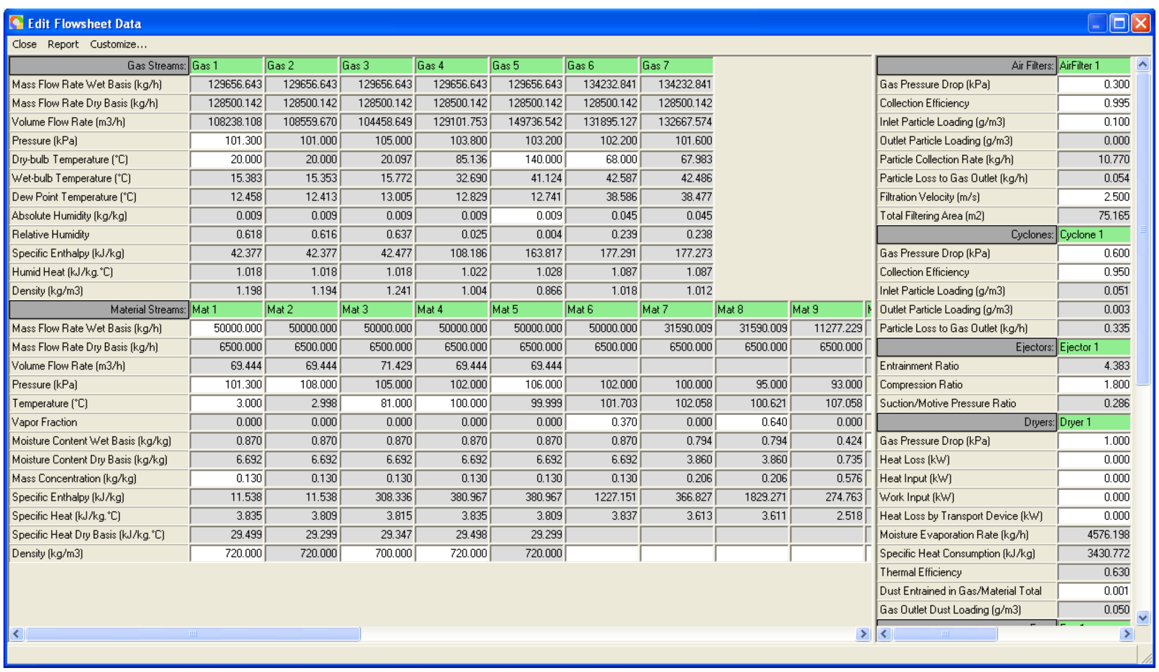


Figure 11a



Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6	Gas 7
Mass Flow Rate Wet Basis (kg/h)	129656.643	129656.643	129656.643	129656.643	129656.643	134232.841	134232.841
Mass Flow Rate Dry Basis (kg/h)	128500.142	128500.142	128500.142	128500.142	128500.142	128500.142	128500.142
Volume Flow Rate (m3/h)	108238.108	108559.670	104458.649	129101.753	149736.542	131895.127	132667.574
Pressure (kPa)	101.300	101.000	105.000	103.800	103.200	102.200	101.600
Dry-bulb Temperature (°C)	20.000	20.000	20.097	85.136	140.000	68.000	67.983
Wet-bulb Temperature (°C)	15.383	15.353	15.772	32.690	41.124	42.587	42.486
Dew Point Temperature (°C)	12.458	12.413	13.005	12.829	12.741	38.586	38.477
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.009	0.009	0.045	0.045
Relative Humidity	0.618	0.616	0.637	0.025	0.004	0.239	0.238
Specific Enthalpy (kJ/kg)	42.377	42.377	42.477	108.186	163.817	177.291	177.273
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.022	1.028	1.087	1.087
Density (kg/m3)	1.198	1.194	1.241	1.004	0.866	1.018	1.012

Material Streams:	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Mat 6	Mat 7	Mat 8	Mat 9
Mass Flow Rate Wet Basis (kg/h)	50000.000	50000.000	50000.000	50000.000	50000.000	50000.000	31590.009	31590.009	11277.229
Mass Flow Rate Dry Basis (kg/h)	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000
Volume Flow Rate (m3/h)	69.444	69.444	71.429	69.444	69.444				
Pressure (kPa)	101.300	108.000	105.000	102.000	106.000	102.000	100.000	95.000	93.000
Temperature (°C)	3.000	2.998	81.000	100.000	99.999	101.703	102.058	100.621	107.058
Vapor Fraction	0.000	0.000	0.000	0.000	0.000	0.370	0.000	0.640	0.000
Moisture Content Wet Basis (kg/kg)	0.870	0.870	0.870	0.870	0.870	0.870	0.794	0.794	0.424
Moisture Content Dry Basis (kg/kg)	6.692	6.692	6.692	6.692	6.692	6.692	3.860	3.860	0.735
Mass Concentration (kg/kg)	0.130	0.130	0.130	0.130	0.130	0.130	0.206	0.206	0.576
Specific Enthalpy (kJ/kg)	11.538	11.538	308.336	380.967	380.967	1227.151	366.827	1829.271	274.763
Specific Heat (kJ/kg.°C)	3.835	3.809	3.815	3.835	3.809	3.837	3.613	3.611	2.518
Specific Heat Dry Basis (kJ/kg.°C)	29.499	29.299	29.347	29.498	29.299				
Density (kg/m3)	720.000	720.000	700.000	720.000	720.000				

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.995
Inlet Particle Loading (g/m3)	0.100
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	10.770
Particle Loss to Gas Outlet (kg/h)	0.054
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	75.165
Cyclones:	**Cyclone 1**
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.051
Outlet Particle Loading (g/m3)	0.003
Particle Loss to Gas Outlet (kg/h)	0.335
Ejectors:	**Ejector 1**
Entrainment Ratio	4.383
Compression Ratio	1.800
Suction/Motive Pressure Ratio	0.286
Dryers:	**Dryer 1**
Gas Pressure Drop (kPa)	1.000
Heat Loss (kW)	0.000
Heat Input (kW)	0.000
Work Input (kW)	0.000
Heat Loss by Transport Device (kW)	0.000
Moisture Evaporation Rate (kg/h)	4576.198
Specific Heat Consumption (kJ/kg)	3430.772
Thermal Efficiency	0.630
Dust Entrained in Gas/Material Total	0.001
Gas Outlet Dust Loading (g/m3)	0.050

Figure 11b

Please be noted that not all the known values of the variables are presented in the statement of the problem. However, the missing variable values are assumed and input as in the solution steps.

Example 12 - Evaporation and Drying 2

Problem

This example is an extension of example 10. After the same liquid material is concentrated it needs to be dried at first in a spray dryer and then in a vibrated fluid bed dryer. The evaporation and first stage drying process has already been described in Example 11 (The drying air of the spray dryer needs to be at 103.2 kPa and 140 ^oC. The exhaust air is at 68 ^oC. Material outlet from the spray dryer is at 55 ^oC and 8% (wet basis) moisture content). The drying air of the vibrated fluid bed dryer needs to be at 103.2 kPa and 85^oC. The exhaust air is at 50 ^oC. Material outlet from the vibrated fluid bed dryer is at 52 ^oC and 0.3% (wet basis) moisture content. Part of the secondary vapor from the second effect evaporator is used to preheat the drying air as is described in Example 11.

Solution Steps:

Following the solution steps in example 10, the following extra steps are needed:

1. Add an air filter (AirFilter 1), a fan (Fan 1), a heat exchanger (Exch 3), a tee (Tee 3), a heater (Heater 1), a liquid dryer (Dryer 1), a solid dryer (Dryer 2), a cyclone (Cyclone 1), a bag filter (BagFilter 1), 8 gas streams (Gas 1 through Gas 8), two liquid material stream (Steam 14 and Stream 15), three solid material streams (Mat 10 through Mat 12).
2. Connect the gas and material streams with the unit operations as in Figure 12a.
3. Bring up AirFilter 1's editor and input in
   - Gas 1: *Pressure* 101.3 kPa, *Dry-buld Temperature* 20 ^oC.
   - *Gas Pressure Drop* 0.3 kPa, *Collection Efficiency* 0.995, *Inlet Particle Loading* 0.1 g/m^3, *Filtration Velocity* 2.5 m/s.
4. Bring up Fan 1's editor and input in
   - *Static Pressure* 4.0 kPa, *Efficiency* 0.73.
5. Bring up Tee 2's editor and input in
   - *Steam 14* of Outlet Fractions group box 0.218
6. Bring up Exch 3's editor and input in
   - Steam 15: *Temperature* 85 ^oC.
   - *Cold Side Pressure Drop* 1.2 kPa, *Hot Side Pressure Drop* 3.0 kPa.
7. Bring up Heater 1's editor and input in
   - Gas 5: *Dry-bulb Temperature* 140 ^oC, *Absolute Humidity* 0.009 kg/kg.
   - *Pressure Drop* 0.6 kPa.
8. Bring up Dryer 1's editor and input in
   - Mat 5: *Temperature* 55 ^oC, *Moisture Content Wet Basis* 0.08 kg/kg.
   - Gas 6: *Dry-bulb temperature* 68 ^oC.
   - *Gas Pressure Drop* 1.0 kPa, *Dust Entrained in Gas/Material Total* 0.001.
9. Bring up Cycone 1's editor and input in
   - *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.95.
10. Bring up Dryer 2's editor and input in

- Mat 5: *Temperature* 52 ^{o}C, *Moisture Content Wet Basis* 0.003 kg/kg
- Gas 10: *Dry-bulb Temperature* 50 ^{o}C.
- *Gas Pressure Drop* 1.0 kPa, *Dust Entrained in Gas/Material Total* 0.001

11. Bring up BagFilter 1's editor and input in
    - *Gas Pressure Drop* 0.6 kPa, *Collection Efficiency* 0.995, *Filtration Velocity* 2.5 m/s, *Bag Diameter* 0.4 m, *Bag Length* 2.0 m.

The results are displayed in Figure 12b

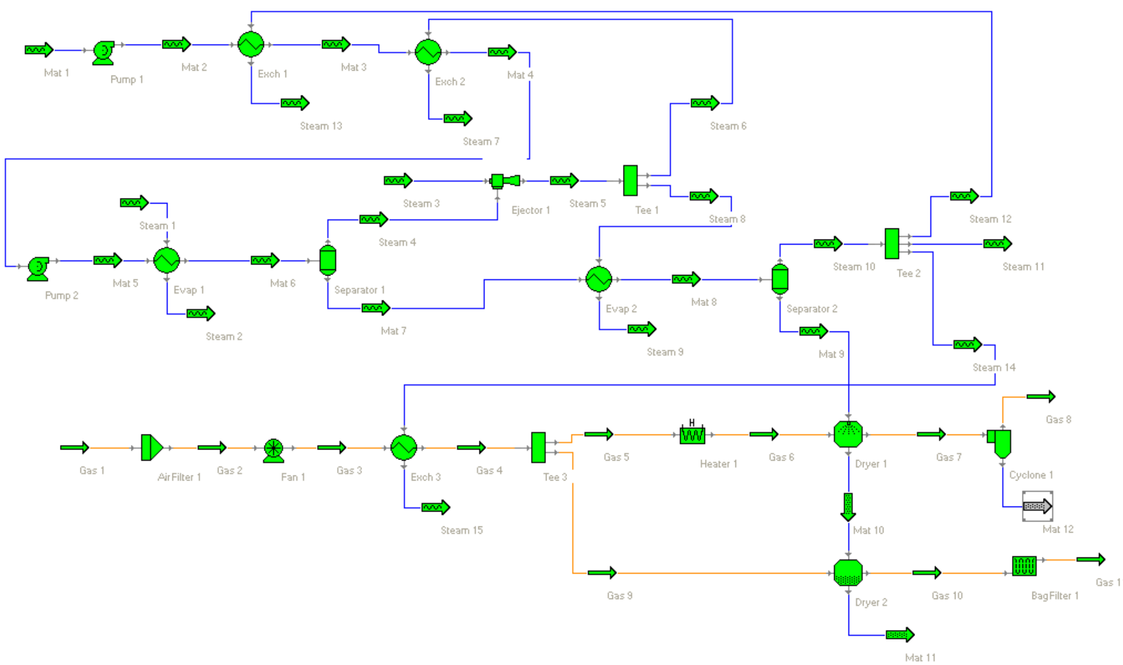
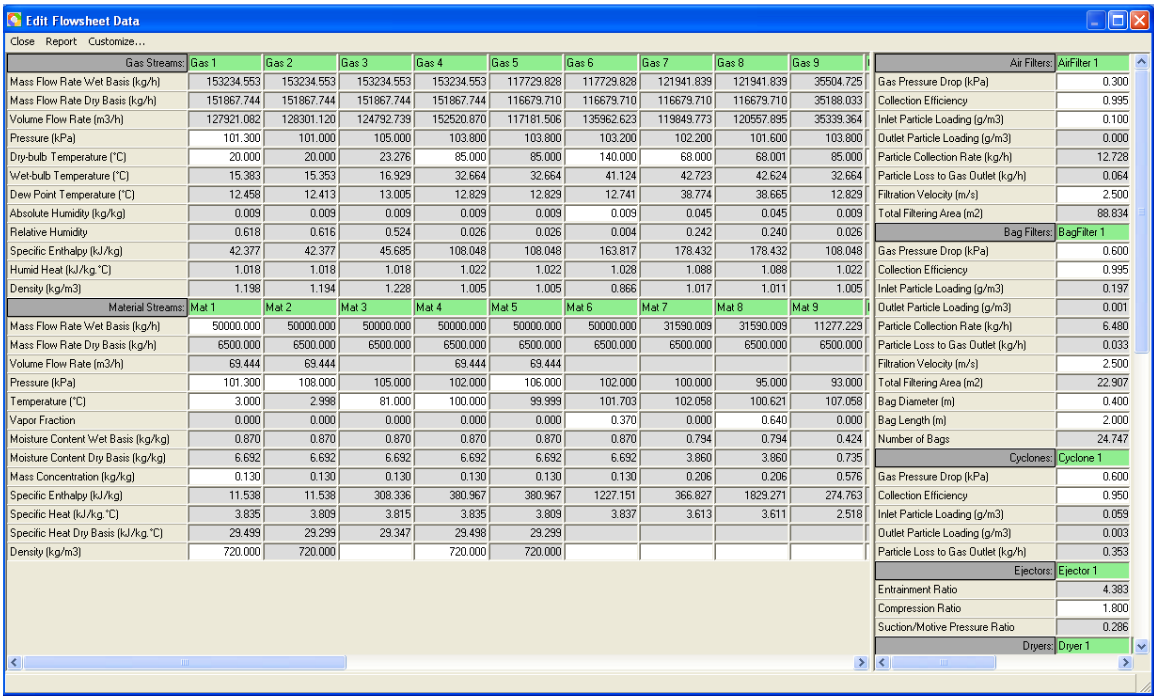


Figure 12a


Edit Flowsheet Data

Close Report Customize...

Gas Streams:	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6	Gas 7	Gas 8	Gas 9
Mass Flow Rate Wet Basis (kg/h)	153234.553	153234.553	153234.553	153234.553	117729.828	117729.828	121941.839	121941.839	35504.725
Mass Flow Rate Dry Basis (kg/h)	151867.744	151867.744	151867.744	151867.744	116679.710	116679.710	116679.710	116679.710	35188.033
Volume Flow Rate (m3/h)	127921.082	128301.120	124792.739	152520.870	117181.506	135962.623	119849.773	120557.895	35339.364
Pressure (kPa)	101.300	101.000	105.000	103.800	103.800	103.200	102.200	101.600	103.800
Dry-bulb Temperature (°C)	20.000	20.000	23.276	85.000	85.000	140.000	68.000	68.001	85.000
Wet-bulb Temperature (°C)	15.383	15.353	16.929	32.664	32.664	41.124	42.723	42.624	32.664
Dew Point Temperature (°C)	12.458	12.413	13.005	12.829	12.829	12.741	38.774	38.665	12.829
Absolute Humidity (kg/kg)	0.009	0.009	0.009	0.009	0.009	0.009	0.045	0.045	0.009
Relative Humidity	0.618	0.616	0.524	0.026	0.026	0.004	0.242	0.240	0.026
Specific Enthalpy (kJ/kg)	42.377	42.377	45.685	108.048	108.048	163.817	178.432	178.432	108.048
Humid Heat (kJ/kg.°C)	1.018	1.018	1.018	1.022	1.022	1.028	1.088	1.088	1.022
Density (kg/m3)	1.198	1.194	1.228	1.005	1.005	0.866	1.017	1.011	1.005
Material Streams:	Mat 1	Mat 2	Mat 3	Mat 4	Mat 5	Mat 6	Mat 7	Mat 8	Mat 9
Mass Flow Rate Wet Basis (kg/h)	50000.000	50000.000	50000.000	50000.000	50000.000	50000.000	31590.009	31590.009	11277.229
Mass Flow Rate Dry Basis (kg/h)	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000	6500.000
Volume Flow Rate (m3/h)	69.444	69.444		69.444	69.444				
Pressure (kPa)	101.300	108.000	105.000	102.000	106.000	102.000	100.000	95.000	93.000
Temperature (°C)	3.000	2.998	81.000	100.000	99.999	101.703	102.058	100.621	107.058
Vapor Fraction	0.000	0.000	0.000	0.000	0.000	0.370	0.000	0.640	0.000
Moisture Content Wet Basis (kg/kg)	0.870	0.870	0.870	0.870	0.870	0.870	0.794	0.794	0.424
Moisture Content Dry Basis (kg/kg)	6.692	6.692	6.692	6.692	6.692	6.692	3.860	3.860	0.735
Mass Concentration (kg/kg)	0.130	0.130	0.130	0.130	0.130	0.130	0.206	0.206	0.576
Specific Enthalpy (kJ/kg)	11.538	11.538	308.336	380.967	380.967	1227.151	366.827	1829.271	274.763
Specific Heat (kJ/kg.°C)	3.835	3.809	3.815	3.835	3.809	3.837	3.613	3.611	2.518
Specific Heat Dry Basis (kJ/kg.°C)	29.499	29.299	29.347	29.498	29.299				
Density (kg/m3)	720.000	720.000		720.000	720.000				

Air Filters:	AirFilter 1
Gas Pressure Drop (kPa)	0.300
Collection Efficiency	0.995
Inlet Particle Loading (g/m3)	0.100
Outlet Particle Loading (g/m3)	0.000
Particle Collection Rate (kg/h)	12.728
Particle Loss to Gas Outlet (kg/h)	0.064
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	88.834
Bag Filters:	BagFilter 1
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.995
Inlet Particle Loading (g/m3)	0.197
Outlet Particle Loading (g/m3)	0.001
Particle Collection Rate (kg/h)	6.480
Particle Loss to Gas Outlet (kg/h)	0.033
Filtration Velocity (m/s)	2.500
Total Filtering Area (m2)	22.907
Bag Diameter (m)	0.400
Bag Length (m)	2.000
Number of Bags	24.747
Cyclones:	Cyclone 1
Gas Pressure Drop (kPa)	0.600
Collection Efficiency	0.950
Inlet Particle Loading (g/m3)	0.059
Outlet Particle Loading (g/m3)	0.003
Particle Loss to Gas Outlet (kg/h)	0.353
Ejectors:	Ejector 1
Entrainment Ratio	4.383
Compression Ratio	1.800
Suction/Motive Pressure Ratio	0.286
Dryers:	Dryer 1

Figure 12b