PEDCO

Process & Equipment Development Corporation

Adsorptive Gas-Dryer Software

PEDCO's Adsorptive Gas-Dryer Simulation software predicts the performance of adsorptive desiccant dryers. The Desiccant Dryer Engineer specifies the dryer type, dryer geometry, desiccant type, operating conditions, and ambient conditions. The program simulates the dryer performance by solving the transient conservation equations of mass, energy, and momentum for the specified system. Output includes dew point, desiccant loading, temperature, etc. as a function of time and bed position. PEDCO's Adsorptive Gas-Dryer Simulation is intended for:

- manufacturers of desiccant and desiccant dryers
- engineering companies specifying and evaluating desiccant dryers
- compressed air system auditors optimizing performance of desiccant dryers
- end users comparing, evaluating, and selecting desiccant dryers
- system engineers using desiccant dryers as an integral part of the system
- service personnel troubleshooting desiccant dryer performance, etc.

DRYER TYPES

The software can be used to simulate performance of:

Thermal Swing (Heated) Dryers

- Atmospheric Pressure Blower Purge
- Closed Loop Blower Purge
- Heated Purge
- Heat of Compression

Pressure Swing (Heatless) Dryers

- Conventional
- Vacuum Assisted
- Single Tower

Once Through Dryers (Non-regenerative)

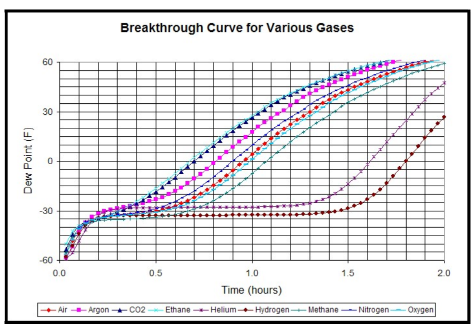
The Dryer Engineer can select from a total of 146 different dryer configurations.

GASES

Drying of:

- Air
- Argon
- Carbon Dioxide
- Ethane
- Helium
- Hydrogen
- Methane
- Nitrogen
- Oxygen
- Mixture of above gases

can be simulated. Based on the dryer type, the gas being dried and gas used to regenerate the desiccant can be different.

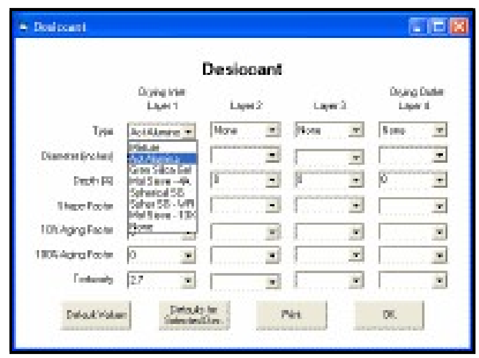


DESICCANTS

The program contains isotherms and property data for all the typical desiccants:

- Activated Alumina
- 3A, 4A, and 13X Molecular Sieves
- Granular and Spherical Silica Gels
- User specified desiccants

Any desiccant diameter can be specified. Aging factors can be specified to study the impact of desiccant aging and contamination on dryer performance.



Up to four layers of desiccant can be specified based on desiccant type, desiccant diameter, or aging factor. Within each layer a mixture of up to four desiccants can be specified.

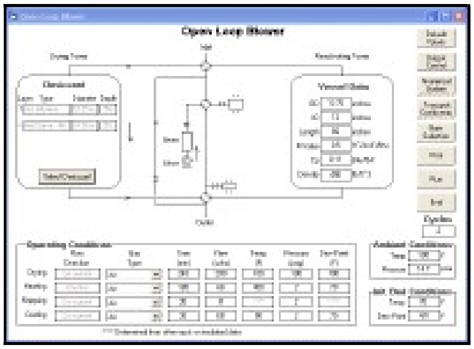
APPLICATIONS

Uses for the program are unlimited for the Desiccant Dryer Engineer. Just a few examples of its use include:

- Predict performance of an existing dryer operating at off-design conditions
- Assist in development of an energy management system
- Enable a better understanding of the inner workings of a desiccant dryer to optimize performance and design
- Evaluate reactivation scheme options to intelligently conduct a cost-benefit analysis
- Conduct a sensitivity analysis to determine purge air requirements for a pressure swing dryer as a function of required dew point, inlet temperature, inlet pressure, inlet relative humidity, desiccant type, desiccant diameter, etc.
- Study the effects of desiccant particle size on dryer performance
- Study the effect of desiccant layering on drying and reactivation performance
- Develop new energy efficient dryers
- Create support documents for proposal presentation

INPUT

The Engineer enters input data describing the dryer and operating conditions in English or SI units into intuitively designed input forms.



Every form includes a *Default Button* that can be clicked to populate all fields with a set of *Default Data*.

Alternatively, a data file generated during a previous simulation run can be specified and data from that run will be read into the input forms. Any desired changes from the previous run can then be made.

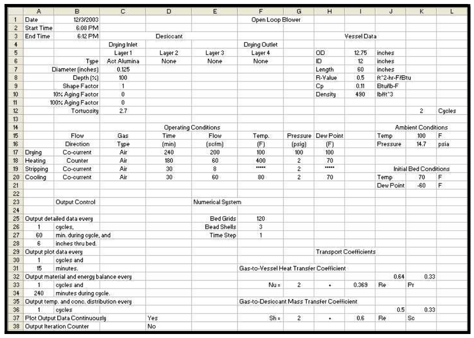
Desiccant properties, transport coefficients, numerical system specifications, output control parameters, etc can be provided by the Engineer - or the programs defaults can be selected.

Four levels of input data checking are included to assure a valid data set is provided. If a data value is deemed unusual, a *warning* is issued that the Engineer can ignore. If a data input *error* is detected, a change must be made before continuing.

1. Individual values are checked as entered and low and high warnings and errors are issued as appropriate.
2. Upon exiting an input data form, all data fields are checked to assure a complete set of data is provided.
3. Prior to running the simulation, all data forms are checked to assure they have been completed. If not, the program prompts the operator to enter data or use the programs default values.
4. When the program begins, relationships between data are checked. For example, the program checks to see if desiccant fluidization is a potential problem.

OUTPUT

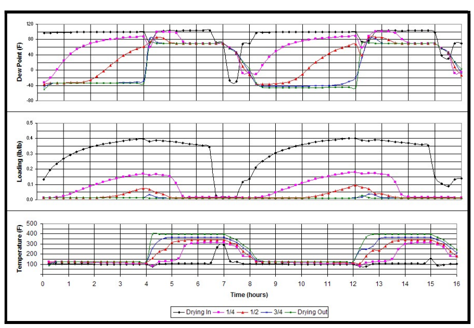
Simulated data is output to an Excel® spreadsheet workbook. All input conditions and simulated output data are saved in one workbook. The program creates a *Model Number* type name for the workbook capturing much of the specific information regarding the dryer and operating conditions.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Date	12/3/2003				Open Loop Blower						
2	Start Time	6:08 PM										
3	End Time	6:12 PM		Desiccant					Vessel Data			
4			Drying Inlet			Drying Outlet						
5			Layer 1	Layer 2	Layer 3	Layer 4		OD	12.75	inches		
6		Type	Act Alumina	None	None	None		ID	12	inches		
7		Diameter (inches)	0.125					Length	60	inches		
8		Depth (%)	100					R-Value	0.5	ft^2-hr-F/Btu		
9		Shape Factor	1					Cp	0.11	Btu/lb-F		
10		10% Aging Factor	0					Density	490	lb/ft^3		
11		100% Aging Factor	0									
12		Tortuosity	2.7								2	Cycles
13												
14				Operating Conditions							Ambient Conditions	
15		Flow	Gas	Time	Flow	Temp.	Pressure	Dew Point		Temp	100	F
16		Direction	Type	(min)	(scfm)	(F)	(psig)	(F)		Pressure	14.7	psia
17	Drying	Co-current	Air	240	200	100	100	100				
18	Heating	Counter	Air	180	60	400	2	70				
19	Stripping	Co-current	Air	30	8	*****	2	*****			Initial Bed Conditions	
20	Cooling	Co-current	Air	30	60	80	2	70		Temp	70	F
21										Dew Point	-60	F
22												
23		Output Control			Numerical System							
24												
25	Output detailed data every				Bed Grids	120						
26	1	cycles,			Bead Shells	3						
27	60	min. during cycle, and			Time Step	1						
28	6	inches thru bed.										
29	Output plot data every							Transport Coefficients				
30	1	cycles and										
31	15	minutes.				Gas-to-Vessel Heat Transfer Coefficient						
32	Output material and energy balance every									0.64	0.33	
33	1	cycles and				Nu =	2	+	0.369	Re	Pr	
34	240	minutes during cycle.										
35	Output temp. and conc. distribution every					Gas-to-Desiccant Mass Transfer Coefficient						
36	1	cycles								0.5	0.33	
37	Plot Output Data Continuously			Yes		Sh =	2	+	0.6	Re	Sc	
38	Output Iteration Counter			No								

Output data includes:

- Dryer outlet Dew Point and Temperature as a function of Time
- Desiccant Bed Temperature, Loading, and Dew Point distributions as a function of Time (output in tabular and plotted formats)
- Water Loading Distribution in a Desiccant Particle as a function of Bed Position and Time
- Desiccant and Gas Properties
- Transport Coefficients - Gas-to-Vessel Heat Transfer Coefficient, Gas-to-Desiccant Mass Transfer Coefficient, Desiccant Bead Effective Diffusivity, etc.



The capabilities of Excel® can be utilized to manipulate and plot data in a format most suitable for the objectives of the immediate project.

SOLUTION ALGORITHM

The program solves the system of non-linear partial-differential equations of mass, momentum, and energy describing the physics of adsorption.

$$\frac{\partial q}{\partial t} + \varepsilon_p \frac{\partial c}{\partial t} = D_{eff} \frac{\partial}{\partial r}\left(\frac{\partial c}{\partial r}\right)$$

Constitutive relations such as the ideal gas law, desiccant isotherms, correlations for molecular diffusivity in a desiccant particle, etc are utilized. The system of differential equations is solved using a finite-difference technique by dividing the bed into a finite number of thin pancake sections and a representative desiccant bead in each pancake into a finite number of shells.

```
'*****************************************************************************************
Public Function ColPresDrop(L As Double, Void As Double, Rp As Double, Den As Double, _
  U As Double, Vis As Double, ShapeFactor As Double) As Double
' Function to calculate pressure drop through a packed bed
' Reference - Principles of Adsorption by Ruthven, page 206
'  ColPresDrop - column pressure drop [lb_f/ft^2]
'  Den - gas density [lb_m/ft^3]
'  L - bed length [ft]
'  Rp - sorbent pellet radius [ft]
'  ShapeFactor - shape factor to account for non spherical geometries [dimensionless]
'  U - superficial gas velocity [ft/min]
'  Vis - gas viscosity [lb/ft-min]
'  Void - voidage of packed bed [dimensionless]
'

' Declare variable types
Dim Re As Double, F As Double
' Reynolds number
   Re = Den * U * 2 * Rp / Vis
' Friction factor
   F = ((1 - Void) / Void ^ 3) * (150 * (1 - Void) / Re + 1.75)
' Pressure drop
   ColPresDrop = F * L / (2 * Rp) * (U / 60) ^ 2 * Den / 32.2 * ShapeFactor
End Function
'*****************************************************************************************
```

The system of non-linear algebraic equations created by discretizing the differential equations is solved using the Newton-Raphson method.

PRICING

Perpetual License

- Complete Program - $13,500 U.S.
- Pressure Swing (Heatless) Only - $7,000 U.S.
- Thermal Swing (Heated) Only - $7,000 U.S.

Training

- $1,500 U.S. / day plus travel expenses

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