Molecular Sieve

Theory, Properties, and Process Optimization

Hi

Did you know that Molecular Sieves are…

- used in dehydration units or beds
- also called zeolite and mole sieve
- tiny, hollow crystals that separate smaller molecules from larger molecules
- able to selectively adsorb molecules due to pore diameter of the crystals

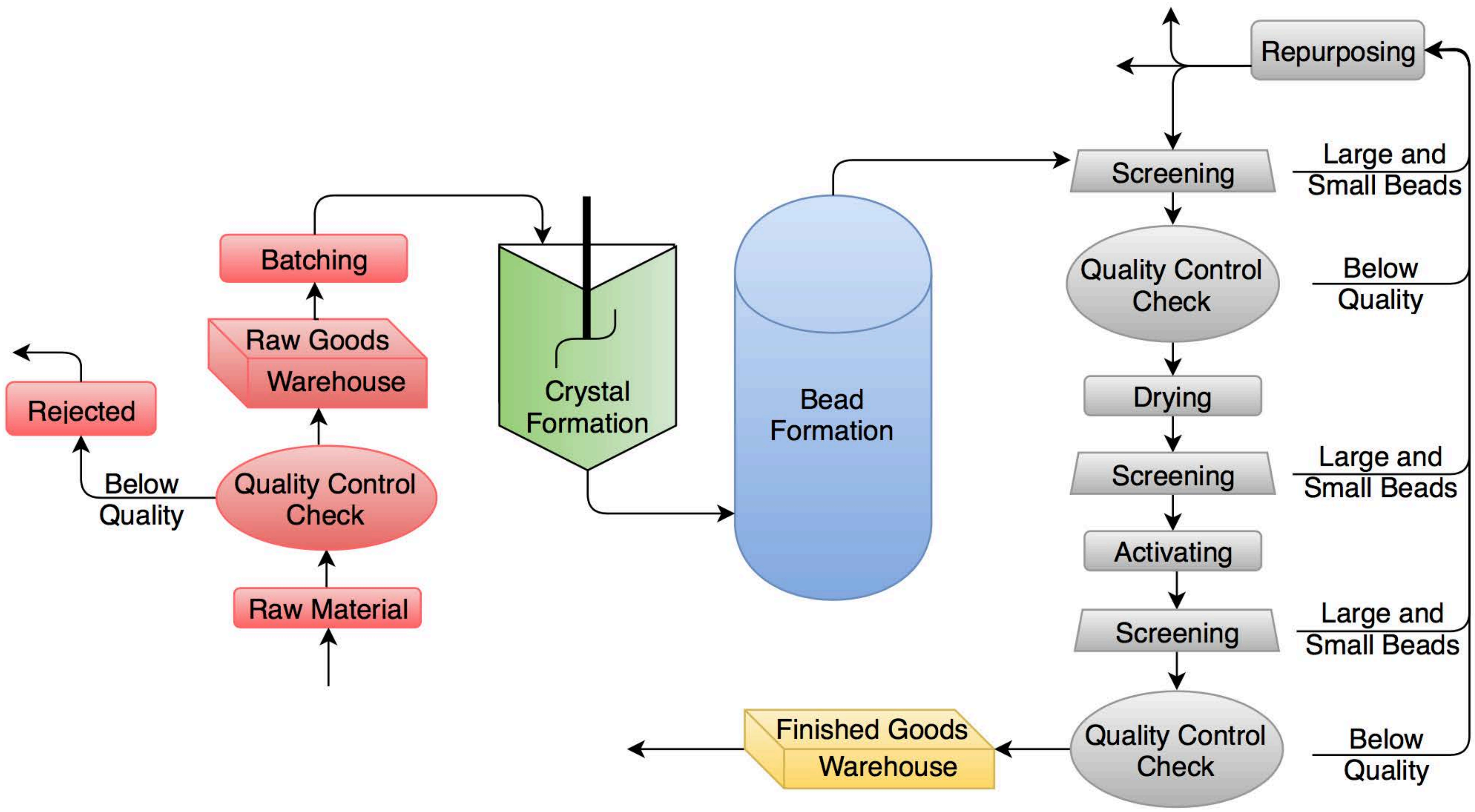
Type A

Water Molecule size = 2.8A
Molecular Sieve Pore size = 3A
Ethanol Molecule size = 3.6A

You've probably seen its beaded or beaded form…

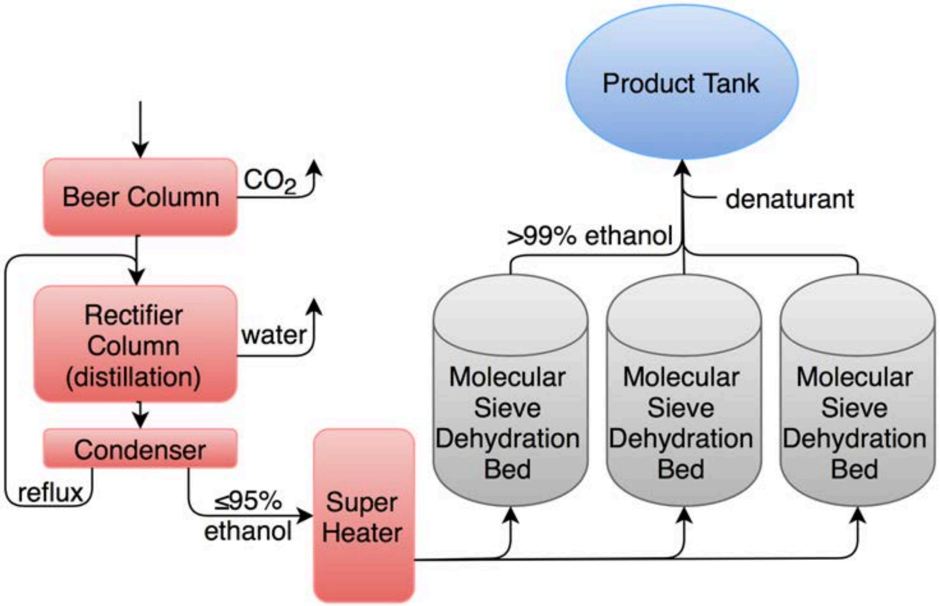
...this is Molecular Sieve in its crystal form

Process of Making



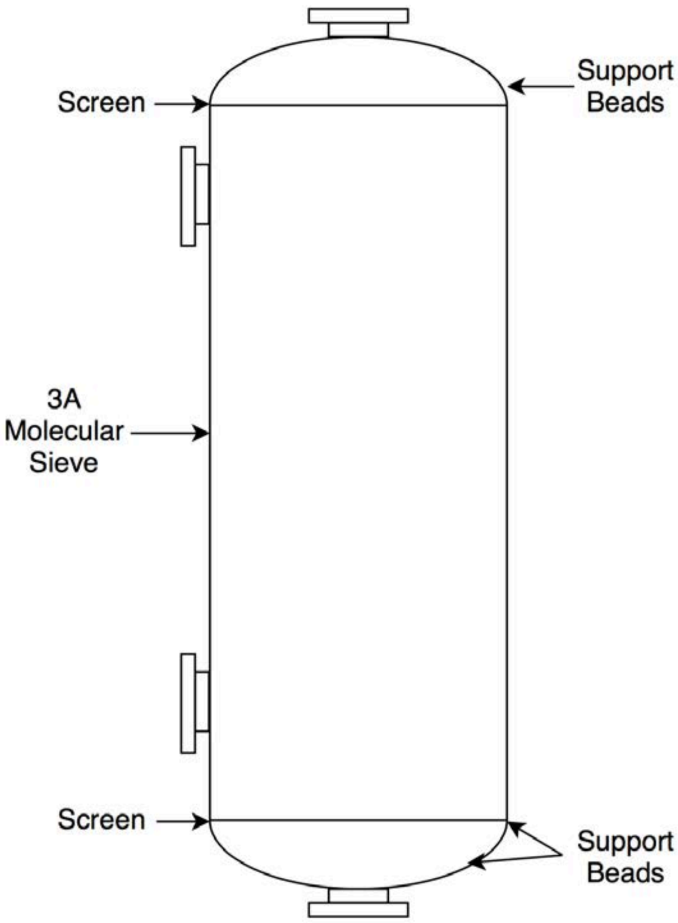
Sieve Purpose

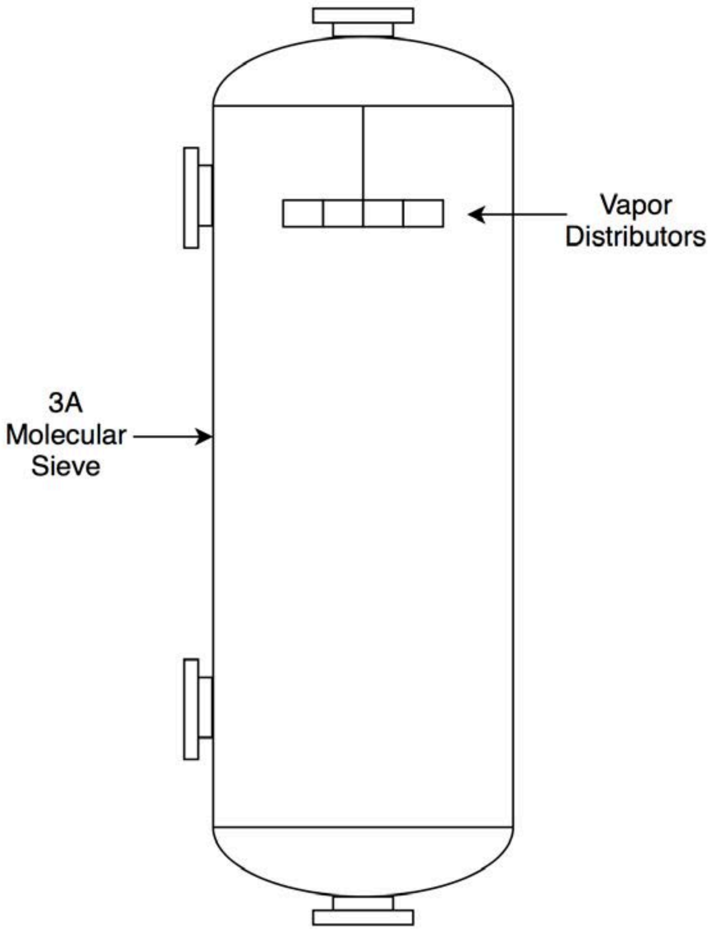
Why use Molecular Sieve



- 3A Molecular Sieve breaks the ethanol/water azeotrope
- Finishes dehydrating ethanol after distillation and removes final 5% of water
- Allows ethanol to be used as a fuel additive

Common Bed Layouts





How to read a Specification Sheet

Hengye Inc. EthaDry HYD03C				Meaning of Property
Property	**Unit**	**Standard**	**Average**	
Bead Diameter	Mesh	4x8	-	important when considering Pressure Drop
Size Distribution	%<2.5mm	0	-	smaller Beads lead to high Pressure Drops and typically have a lower Crush Strength
	%>5mm	0	-	large Bead slows Mass Transfers Rate; inconsistent sizes can cause channeling or uneven wear
Bulk Density	lb/ft^3	43.7-47.4	*45.19*	low Bulk Density offers better movement of fluid through the bed; less weight required to fill the bed
	kg/m^3	696-761	*717.6*	
Crush Strength	lbf	≥20	*25.54*	Durable for extreme △T and △P; Pressure Drop less likely; resistant to cracking and dusting
	kgf	≥9	*11.6*	
Attrition	wt%	≤0.1	*0.07*	high Attrition causes Dust throughout the system, increases Friability
CO_2 Adsorption	%	≤1.0	*0.745*	can be used to infer the amount of Ethanol being adsorbed with the water, caused by residual 4A crystals, lower Ethanol co-adsorption is better
Ethanol Delta T	˚C	1.8	*1.6*	
Methanol Delta T	˚C	≤10	*5*	
Static H_2O Adsorption	%	≥21.0	*21.09*	higher Static Water Adsorption Capacity means potentially greater Working Capacity
Loss on Ignition	wt%	≤1.5	*0.225*	measure of residual organic matter in the sieve beads

How to read a Specification Sheet

Hengye Inc. EthaDry HYD03C				Meaning of Property
Property	**Unit**	**Standard**	**Average**	
Bead Diameter	Mesh	4x8	-	important when considering Pressure Drop
Size Distribution	%<2.5mm	0	-	smaller Beads lead to high Pressure Drops and typically have a lower Crush Strength
	%>5mm	0	-	large Bead slows Mass Transfers Rate; inconsistent sizes can cause channeling or uneven wear
Bulk Density	lb/ft^3	43.7-47.4	*45.19*	low Bulk Density offers better movement of fluid through the bed; less weight required to fill the bed
	kg/m^3	696-761	*717.6*	
Crush Strength	lbf	≥20	*25.54*	Durable for extreme ΔT and ΔP; Pressure Drop less likely; resistant to cracking and dusting
	kgf	≥9	*11.6*	
Attrition	wt%	≤0.1	*0.07*	high Attrition causes Dust throughout the system, increases Friability
CO_2 Adsorption	%	≤1.0	*0.745*	can be used to infer the amount of Ethanol being adsorbed with the water, caused by residual 4A crystals, lower Ethanol co-adsorption is better
Ethanol Delta T	˚C	1.8	*1.6*	
Methanol Delta T	˚C	≤10	*5*	
Static H_2O Adsorption	%	≥21.0	*21.09*	higher Static Water Adsorption Capacity means potentially greater Working Capacity
Loss on Ignition	wt%	≤1.5	*0.225*	measure of residual organic matter in the sieve beads

How to read a Specification Sheet

Hengye Inc. EthaDry HYD03C				Meaning of Property
Property	Unit	Standard	Average	
Bead Diameter	Mesh	4x8	-	important when considering Pressure Drop
Size Distribution	%<2.5mm	0	-	smaller Beads lead to high Pressure Drops and typically have a lower Crush Strength
	%>5mm	0	-	large Bead slows Mass Transfers Rate; inconsistent sizes can cause channeling or uneven wear
Bulk Density	lb/ft^3	43.7-47.4	*45.19*	low Bulk Density offers better movement of fluid through the bed; less weight required to fill the bed
	kg/m^3	696-761	*717.6*	
Crush Strength	lbf	≥20	*25.54*	Durable for extreme △T and △P; Pressure Drop less likely; resistant to cracking and dusting
	kgf	≥9	*11.6*	
Attrition	wt%	≤0.1	*0.07*	high Attrition causes Dust throughout the system, increases Friability
CO_2 Adsorption	%	≤1.0	*0.745*	can be used to infer the amount of Ethanol being adsorbed with the water, caused by residual 4A crystals, lower Ethanol co-adsorption is better
Ethanol Delta T	˚C	1.8	*1.6*	
Methanol Delta T	˚C	≤10	*5*	
Static H_2O Adsorption	%	≥21.0	*21.09*	higher Static Water Adsorption Capacity means potentially greater Working Capacity
Loss on Ignition	wt%	≤1.5	*0.225*	measure of residual organic matter in the sieve beads

How to read a Specification Sheet

Hengye Inc. EthaDry HYD03C				Meaning of Property
Property	Unit	Standard	Average	
Bead Diameter	Mesh	4x8	-	important when considering Pressure Drop
Size Distribution	%<2.5mm	0	-	smaller Beads lead to high Pressure Drops and typically have a lower Crush Strength
	%>5mm	0	-	large Bead slows Mass Transfers Rate; inconsistent sizes can cause channeling or uneven wear
Bulk Density	lb/ft^3	43.7-47.4	45.19	low Bulk Density offers better movement of fluid through the bed; less weight required to fill the bed
	kg/m^3	696-761	717.6	
Crush Strength	lbf	≥20	25.54	Durable for extreme △T and △P; Pressure Drop less likely; resistant to cracking and dusting
	kgf	≥9	11.6	
Attrition	wt%	≤0.1	0.07	high Attrition causes Dust throughout the system, increases Friability
CO_2 Adsorption	%	≤1.0	0.745	can be used to infer the amount of Ethanol being adsorbed with the water, caused by residual 4A crystals, lower Ethanol co-adsorption is better
Ethanol Delta T	˚C	1.8	1.6	
Methanol Delta T	˚C	≤10	5	
Static H_2O Adsorption	%	≥21.0	21.09	higher Static Water Adsorption Capacity means potentially greater Working Capacity
Loss on Ignition	wt%	≤1.5	0.225	measure of residual organic matter in the sieve beads

HENGYE

How to read a Specification Sheet

Hengye Inc. EthaDry HYD03C				Meaning of Property
Property	Unit	Standard	Average	
Bead Diameter	Mesh	4x8	-	important when considering Pressure Drop
Size Distribution	%<2.5mm	0	-	smaller Beads lead to high Pressure Drops and typically have a lower Crush Strength
	%>5mm	0	-	large Bead slows Mass Transfers Rate; inconsistent sizes can cause channeling or uneven wear
Bulk Density	lb/ft^3	43.7-47.4	45.19	low Bulk Density offers better movement of fluid through the bed; less weight required to fill the bed
	kg/m^3	696-761	717.6	
Crush Strength	lbf	≥20	25.54	Durable for extreme △T and △P; Pressure Drop less likely; resistant to cracking and dusting
	kgf	≥9	11.6	
Attrition	wt%	≤0.1	0.07	high Attrition causes Dust throughout the system, increases Friability
CO_2 Adsorption	%	≤1.0	0.745	can be used to infer the amount of Ethanol being adsorbed with the water, caused by residual 4A crystals, lower Ethanol co-adsorption is better
Ethanol Delta T	˚C	1.8	1.6	
Methanol Delta T	˚C	≤10	5	
Static H_2O Adsorption	%	≥21.0	21.09	higher Static Water Adsorption Capacity means potentially greater Working Capacity
Loss on Ignition	wt%	≤1.5	0.225	measure of residual organic matter in the sieve beads

THINGS TO LOOK FOR…

- Frequent filter changes
  - Caused by dust in system
  - Weak beads break and crack over time
- High regeneration proof
  - Caused by loss of adsorption capacity
  - 3A can change back to 4A
- Rapid changes in Pressure Drop
  - Can be caused by wide bead distribution
  - Broken and cracked beads cause irregularities
  - Reductions of Cycle Times

TIME FOR A CHANGE

If you're experiencing these situations and you hope for improvement, you should talk to your ethanol community for a solution.

The opportunities for optimization are endless.

Process Optimization

WORKING CAPACITY

- Capacity increases as pressure increases
- Capacity decreases as temperature increases
- To optimize:
  - Operate at lowest temperature possible without phase change
    - Remain in vapor phase
    - Coolest temperature above boiling point based on ethanol/water composition
    - Liquid phase particles cover and block sieve beads from adsorption
  - Operate at highest pressure the system can allow
    - Check your P&IDs or design constructor
    - Your design determines the maximum pressures able to be used

Process Optimization

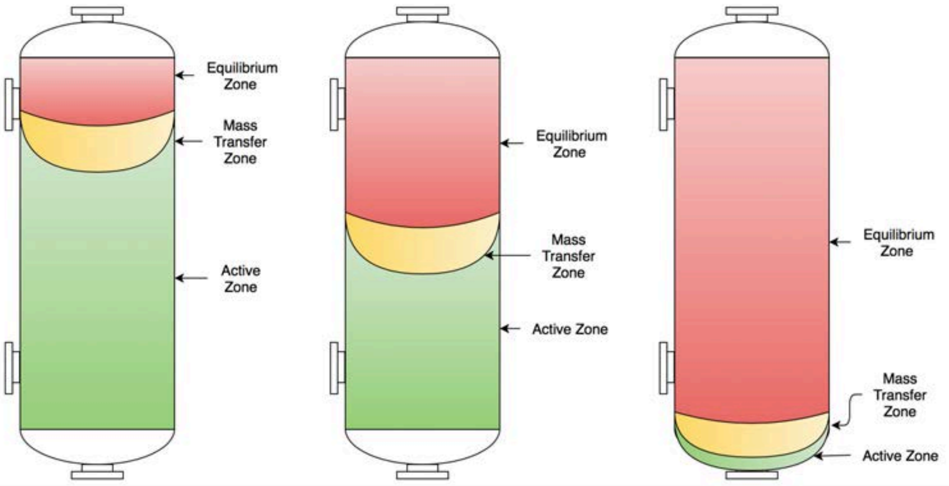
SIEVE QUALITY

- Durable product to withstand conditions
  - A high crush strength can survive high pressure drops and the heat of the system
  - A durable product will offer a high working capacity throughout an increased lifespan
- High working capacity
  - Longer cycle times and fewer regenerations, energy savings
  - Lower regeneration proof, more efficient
  - ΔP at a constant temperature indicates your working capacity, bigger is better
- High selectivity for ethanol
  - Low ethanol co-adsorption, higher return
  - Capacity for water is not wasted

Process Optimization

MASS TRANSFER ZONE

Mass Transfer Zone passing through the Molecular Sieve bed during an ethanol bed dehydration cycle



- Measured by shape and velocity
  - Smaller, tighter zones are better
  - Determines breakthrough point
- Affected by bead quality:
  - Size distribution
    - Channeling
    - Larger beads have slower Mass Transfer Rates
  - Bulk density
    - Denser beads have slower Mass Transfer Rates
- Well maintained MTZs offer longer cycle times and fewer regenerations

Giving you the most

MOLECULAR SIEVE

Theory

- used to dehydrate ethanol
- quality of bead does matter
- ion exchanges
- crystal growth
- clay binders

Properties

- crush strength
- bulk density
- bead distribution
- adsorption

PROCESS

Optimize

- determine boiling point
- find maximum allowed pressures
- increase production capacity

Watch for

- filter changes
- top offs
- high regeneration proof
- extreme pressure drops

Recognizing Value

Remember to

- choose the right Sieve
- take care of the system
- keep records of your day to day

There's always an opportunity to

- optimize your process
- increase your production
- reduce your costs