Theoretic Summary – Provides Sieve Timers, Critical Velocities, avoiding Fluidization and Maximum Outputs for a given system

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153	437142.86	303.57	322.95	99.68	324		
Current Rate, MGY			feed at Proof, GPM				
126	360000	250	313	96.60			

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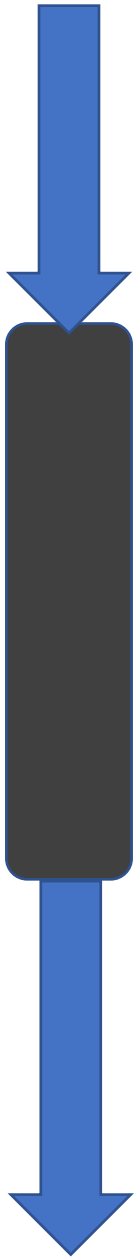
Calculating Cycle Times In A Molecular Sieve Unit

Presented By:

Mark Binns of **Hengye Inc.**

Technical Director

Feed: Defined Flow Rate
Defined Proof
Defined pounds of water per minute, pounds of water per defined feed cycle



Cycle times are based on the amount of water that the sieve can adsorb per cycle, known as Working Capacity

Mass balance can be used to calculate the Working Capacity.

Sieve Bed: Defined volume of sieve
Defined weight of sieve

Feed: Defined Flow rate
Defined Proof
Defined pounds of water per minute, pounds water per defined feed cycle

Defined – limited capacity for water – pounds of water removed / pounds of sieve in use.

Water in - water out divided by the pounds of sieve.

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Molecular sieves are used to remove water from ethanol streams

Molecular Sieves have a limited amount of capacity for water.

Static water capacity is not applicable here, though it can allude working capacity.

Working capacity - the amount of water adsorbed by sieve during the adsorption process. (Pounds of water per pounds of sieve)

This is dependent on the isotherms – the water capacity of the sieve under adsorption conditions minus the the water capacity of the sieve at ender regeneration conditions.

A typical working capacity is around 0.7 pounds of water per pound of sieve.

The working capacity can be determined during operation via mass balance calculations.

Examples here will be with a unit operating at 285 F and 60 psia.

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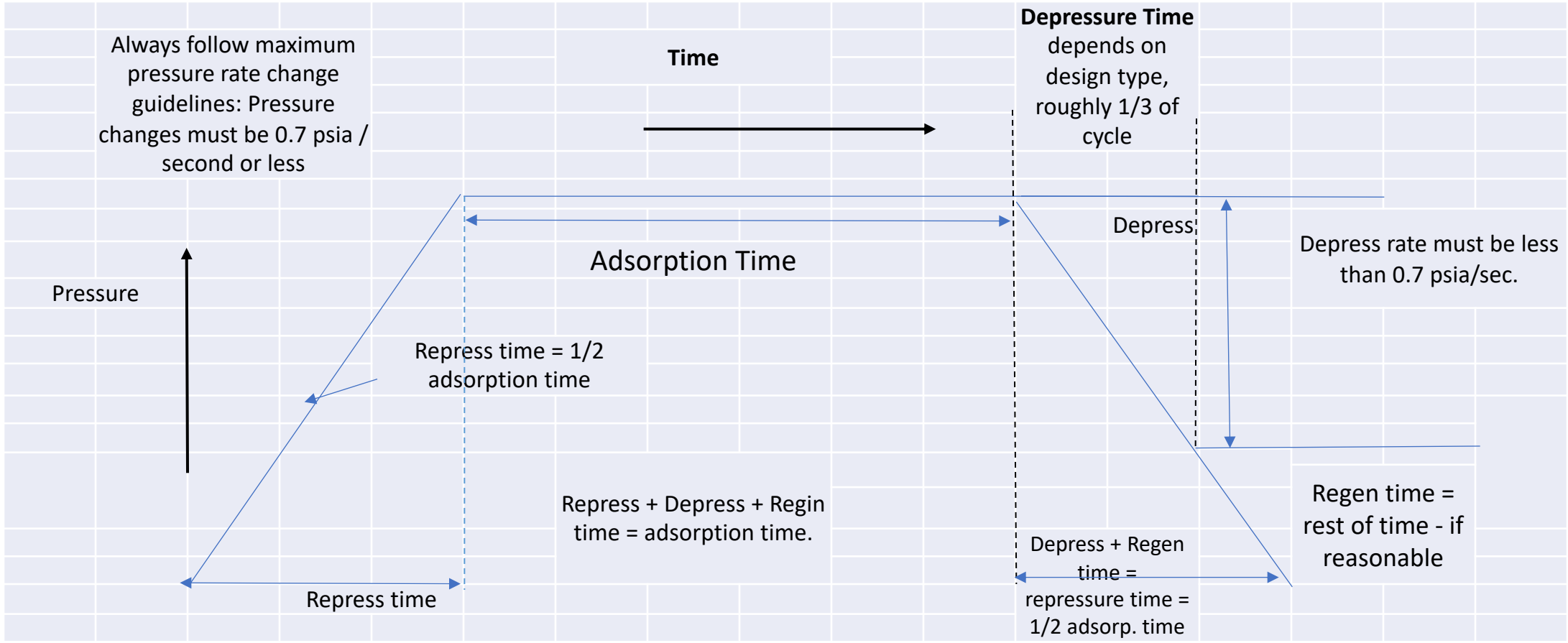
Cycle Times – A Starting Point



Adsorption time = mass feed rate of water/working capacity

Repressure time = ½ of adsorption time (must be less than 0.7 psia/second)

Depressure + regeneration time = ½ of adsorption time

Depressure time is the time required to get down to around 20-25 psia

Regeneration time is all the remaining time

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Mass Balance Actuals

Property	Values	Sieve Efficiency	
Feed Flow, GPM	323	83.57	
Feed Proof	188		
Product Flow, GPM	255		
Product Proof	199		
Regeneration Proof, from regen tank	85	*GPM Ethanol Recycle*	49.895
Adsorption Time	5:10	*Regeneration Flow GPM*	68
Regen proof, KF from sample off regen tank	147	*Gallons Per Year to Recycle (Regen)*	25,147,080
GPM = gallons per minute GPMF = GPM, feed GPMP = GPM, product KF =		*Filter Bag Change, per day*	2
		Calculated Regen Proof	146.75

Mass Balance						
Feed GPM	323	*GPMF Ethanol*	303.62			
Feed Proof	188	*GPMF Water*	19.38	**Working Capacity**		
Product GPM	255	*GPMP Ethanol*	253.725	**W, gal**	**W, Lb**	**Lb Sieve**
Product Proof	199	*GPMP Water*	1.275	79.66	664.38	101,559
Calculated Regen Flow	68	*GPMR Ethanol*	49.895		0.65	
Calculated Regen Proof	146.75	*GPMR Water*	18.105			

Calculations Explained

Colored values are to be input
gray values are automatically calculated from input values
Regen flow and regen proof are calculated from the mass balance based on feed and product.

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Calculating Water Mass Flow Rate

Determine	feed proof
Determine	feed flow, GPM - Feed Rate
Determine	volumetric water concentration (200-feed proof/200)*100 = Cw
Determine	water volumetric flow rate - FRw = (Cw/100)*FR
Determine	water mass flow rate = Wm = FR*8.34 lbs/min.

Calculating Total Cycle Water Adsorbed

- Using the water capacity lb water / lb sieve – Wc (if not determined use 0.7)
- Using the weight of sieve involved in one adsorption cycle. Ws
- Using Water mass flow rate, lbs water/min-Wm
- Adsorption cycle = Wc*Ws/Wm – minutes of adsorption = Ta
- This is the theoretical optimum adsorption segment of the vessel(s).

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The Rest of the Cycle

Repressurization time = ½ Adsorption Time - Tr = 1/2 *Ta

Depressure time,

Td + Regeneration time, Tr

Ta = Tr+Td+Td

Td = time it takes for the vessel to depressure to 20-25 psi

Tr = Time left over,

½ Ta - Td

All pressure changes must be less than 0.7 psia to avoid fluidization. This can become a problem with older sieve requiring shorter cycles.

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Other considerations- Fluid dynamics

- Destructive velocity – Vapor velocity cannot exceed destructive velocity
- Fluidization – Vapor velocity cannot exceed Levi's fluidization and expansion velocities.
- Maximum throughput through a given system is based upon NOT violating these principles.

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Summary

- Although not the final answer – Taking an analytical look using real data to create a baseline give you a point to work from to optimize your system, increase productivity and protect your investment.

- Working capacity is variable based on the quality and condition of the sieve.

- For brand new beads set up initially to these parameters and then adjust to meet production / quality goals.

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Scratch sheet – Vessel Capacity

- Volume of sieve – Volume of sieve = pi* r2 *h = V
- Example – Diameter = 7.5 ft, Sieve Height = 24 ft.
- Volume of sieve = (7.5/2)^2*3.14*24 =1060 ft3
- Weight of Sieve – Weight of sieve = V * Density of sieve = W
- Example – Density of Sieve = 46 lb/ft3, Volume of Sieve = 1060 ft3
- Weight of Sieve = 1060/46 = 48,748 lb = W
- Working Capacity – Calculated from operation or using a typical value at 65 psi and 285 F – 0.7%.
- Vessel Water Capacity during adsorption cycle –Working Cpacity * Weight of sieve,
- Example – 48,748 lbs sieve *(0.7%/100) = 339 lbs of water per adsorption cycle.

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Scratch sheet - 2

How much Water is coming in – Adsorption Cycle Time, Delta P Rate Check

- Water flow rate – Feed Flow, GPM, * ((200 – feed proof)/100)
  - Example – feed proof = 186, feed flow – 150 GPM Feed, 150 *(200-186)/100 = 10.5 GPM water.
- Water mass flow rate – GPM water * density of water 10.5 GPM* 8.34lbs/gallon = 87.57 PPM.
- Maximum adsorption time = vessel water capacity / water mass flow rate.
  - Example – 339 lb / 87.57 PPM = 3.87 minutes adsorption time.
- Repress time = ½ adsorption time = 0.5*3.87 = 1.935 minutes – Check pressure change,
- Example Low pressure = 2 psia, high pressure = 65 psia, Delta P = 65-2 = 63 psia. Delta T = 1.935 minutes = 116 seconds. DP/DT = 63/116 = 0.54. Must be less than 0.7, to avoid fluidization – meets criteria

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Scratch sheet - 3 Delta P rate check, When to switch?

- Depress + Regin = ½ of Adsorption cycle -0.5*3.87 = 1.935 minute.
- Same rate – DP/DT 0.53 but each segment, even instantaneous segments, have to be below 0.7 psia/sec.
- This is the total for both segments. How do you split it – depends. Ideally you would want to check proof on the regen condenser.
- The goal is to minimize the regen flow and proof, don't send anything back to the rectifier that you don't have to – don't send booze to the rectifier – send water with a minimal amount of alcohol.
- An example – for a system with a 190 tank off the rectifier, running at 65 psia adsorption – experience says to switch at around 20-25 psi.

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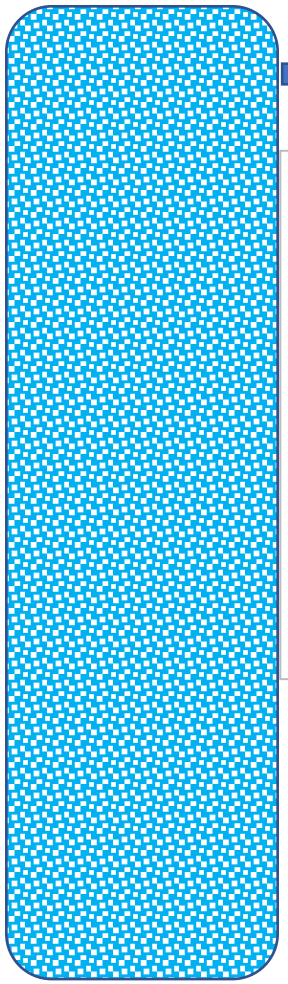

Depress - Time / pressure strategically chosen to send alcohol back to 190 tank, beer well or rectifier. Void volume at the end of feed cycle is roughly the same proof as the feed. End of depress material is surface condensed material, close to feed proof.

Regeneration - Time / pressure strategically chosen to send water back to the rectifier along with whatever alcohol is o-adsorbed. The actual material adsorbed in the molecular sieve. regeneration flow / proof as low as practically possible.

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