Heat of Compression Desiccant Dryer Basic Principles

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Hank van Ormer, *Air Power USA*
Keynote Speaker

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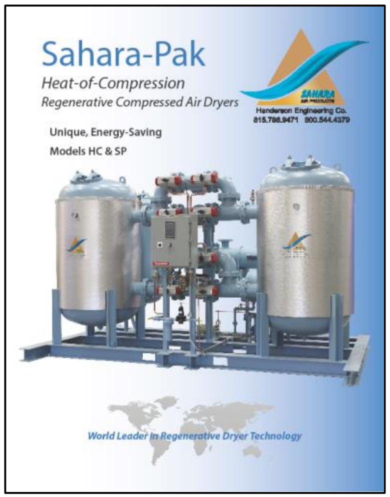

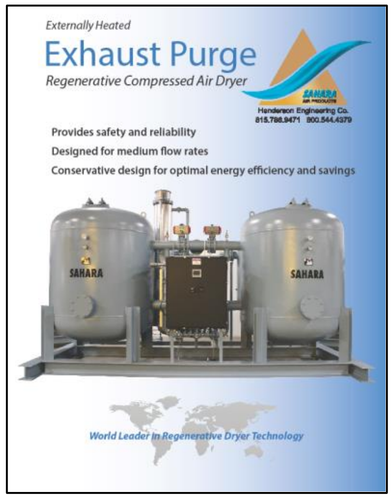

Heat of Compression Desiccant Dryer Basic Principles

Introduction by *Rod Smith*, Publisher

Compressed Air Best Practices® Magazine

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About the Speaker

Hank van Ormer
Air Power USA

- Founded Air Power USA in 1986
- Over 50 years of experience in the compressed air and gas industry

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Utilizing a Heat of Compression Desiccant Dryer to Optimize Effective Drying of a Compressed Air System

November 9, 2017

Air Power USA

Hank van Ormer – Technical Director

AIR POWER USA

Independent and Brand Neutral

Heat of Compression Technology

Heat of compression desiccant compressed air drying is a technology that has been commercially available and utilized for over 40 years… yet today is often misunderstood and subsequently ignored when it is the appropriate technology for the application.

There is no other compressed air drying technology that has lower operating energy and inherent maintenance costs when it can be applied.

Two Basic Types of HOC Dryers – Full Flow and Split Stream

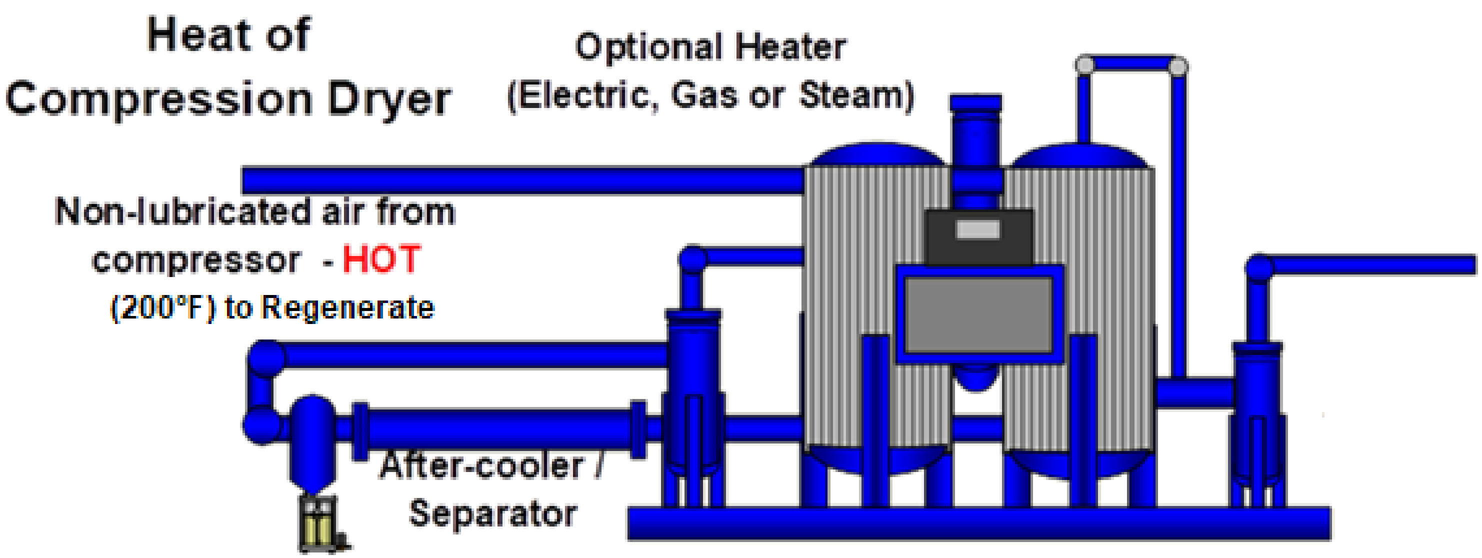
SPLIT STREAM – Uses a fixed percentage of the full flow hot air compressor discharge air during regeneration. This regeneration air is not lost but dried and returned to the system.

FULL FLOW – Has all the hot air compressor discharge air available for regeneration. This regeneration air is not lost but dried and returned to the system.

We will only be discussing full flow type in this presentation.

Heat of Compression Technology

This webinar will address the basic operating parameters of full flow Heat of Compression (HOC) desiccant dryers by identifying basic application considerations as well as limitations.



HOC – Basic Technology

WHAT IS "HEAT OF COMPRESSION" AND WHY IS IT ENERGY FREE?

- Compressed air is a very inefficient transfer of energy – it takes about 8-hp of input electric energy to produce 1-hp of work with 100 psig class compressed air.
- The 7-hp of energy that went into compressing the air and didn't produce any work shows up as heat of compression.
- If we can utilize this heat with little or no additional input energy cost – then the heat of compression is FREE!

8 Horsepower Input Electrical Energy

=

1 Horsepower Work with Compressed Air

Some Basic Dryer Terminology

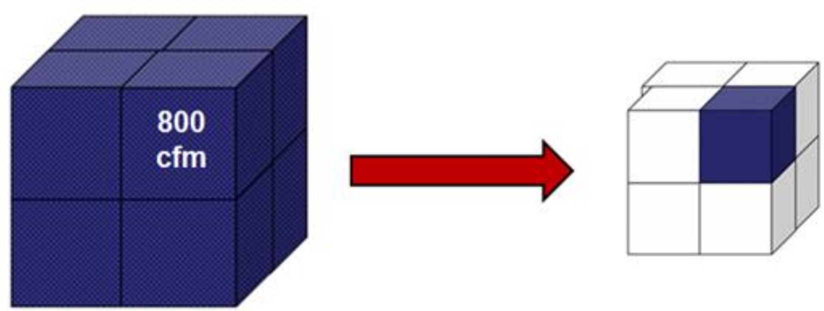
WHAT IS RELATIVE HUMIDITY?

A cubic foot of air can hold a certain amount of water vapor in vapor form (before condensing to liquid water) based on temperature and pressure.

- Higher pressure holds less water vapor in vapor form than lower pressure
- Higher temperature holds more water in vapor form than cold

Relative humidity is the percentage of water vapor in the compressed air volume at the existing pressure and temperature condition compared to what it can hold before condensing from vapor to liquid.

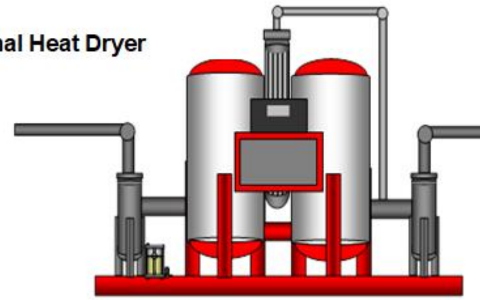
0 psig (14.5 psia)
Atmospheric Dewpoint – 70°F
Temperature – 80°F
Actual Cubic Feet – 800 cfm



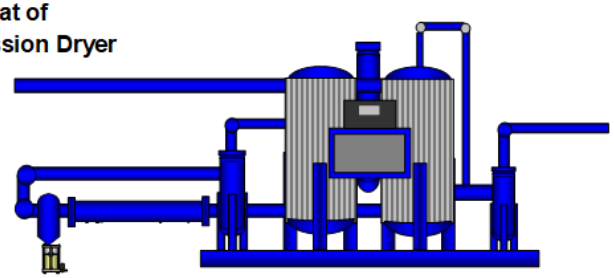
100 psig (114.5 psia)
Pressure Dewpoint – 160°F
Air Temperature – 200-300°F+
Actual Cubic Feet – 100 cfm

Desiccant Drying Process – Common Heated Full Flow Types

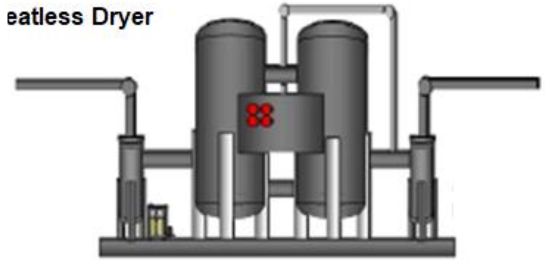
External Heat Dryer



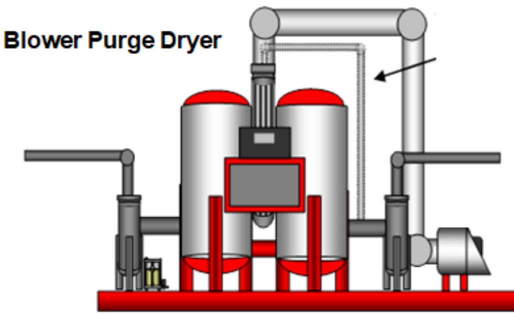
Heat of Compression Dryer



eatless Dryer

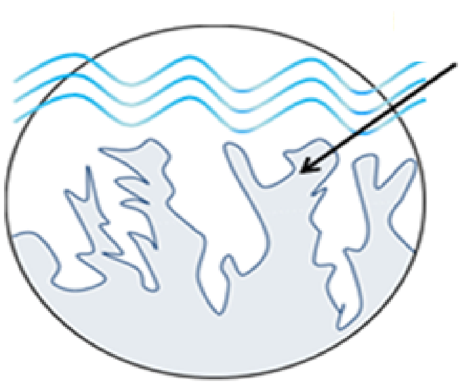


Blower Purge Dryer



Desiccant Dryers (-40°F / °C Class Pressure Dewpoint)

Desiccant ADSORPTION of water vapor



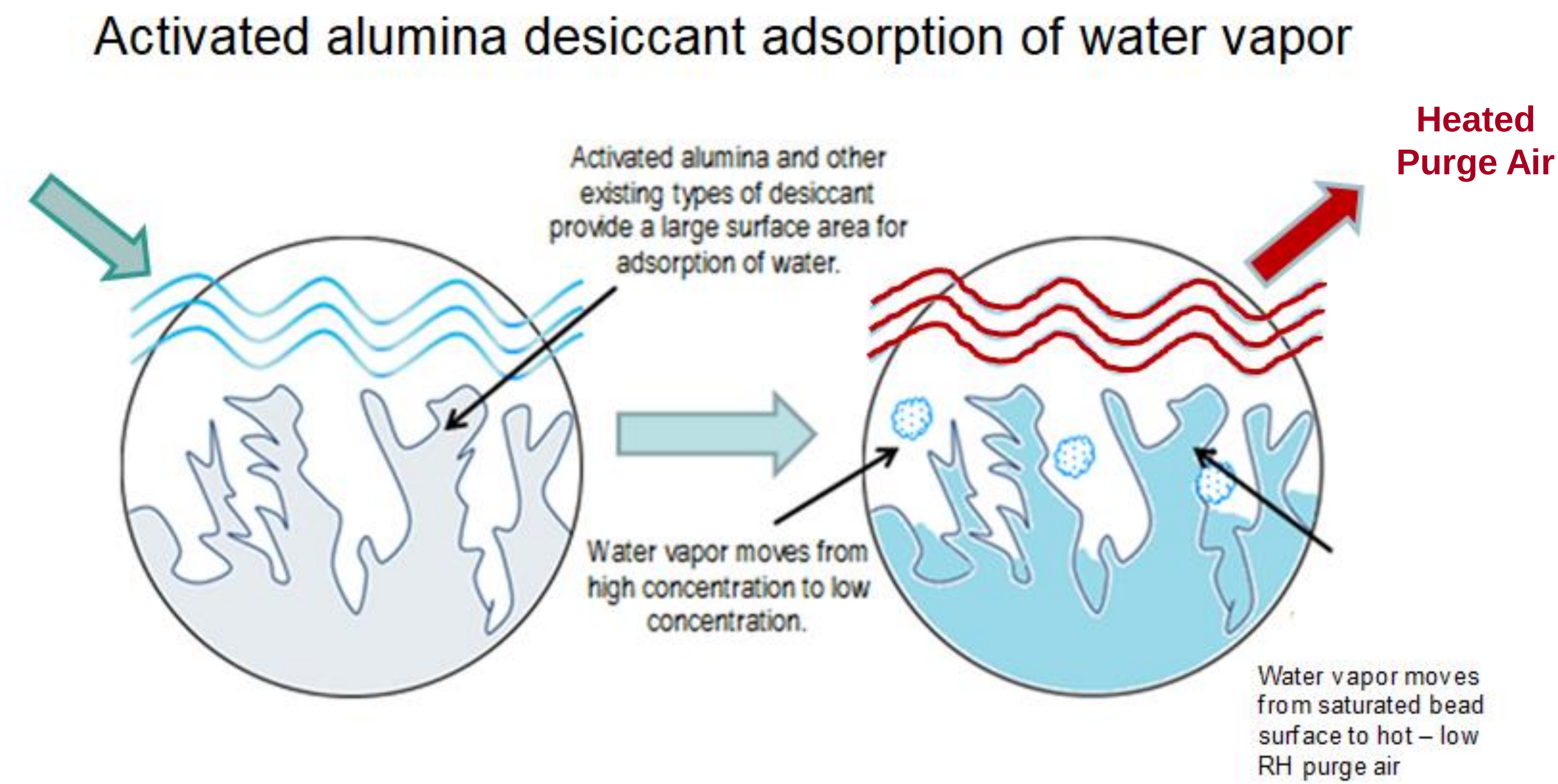
Activated alumina and other existing types of desiccant provide a large surface area for adsorption of water.

Note: Will not dry at all above 130°F

All desiccant dryers utilize the process of adsorption – water vapor moves from the saturated compressed air to the surface of the desiccant bead.

They will NOT remove liquid water!

Desiccant Regeneration Process

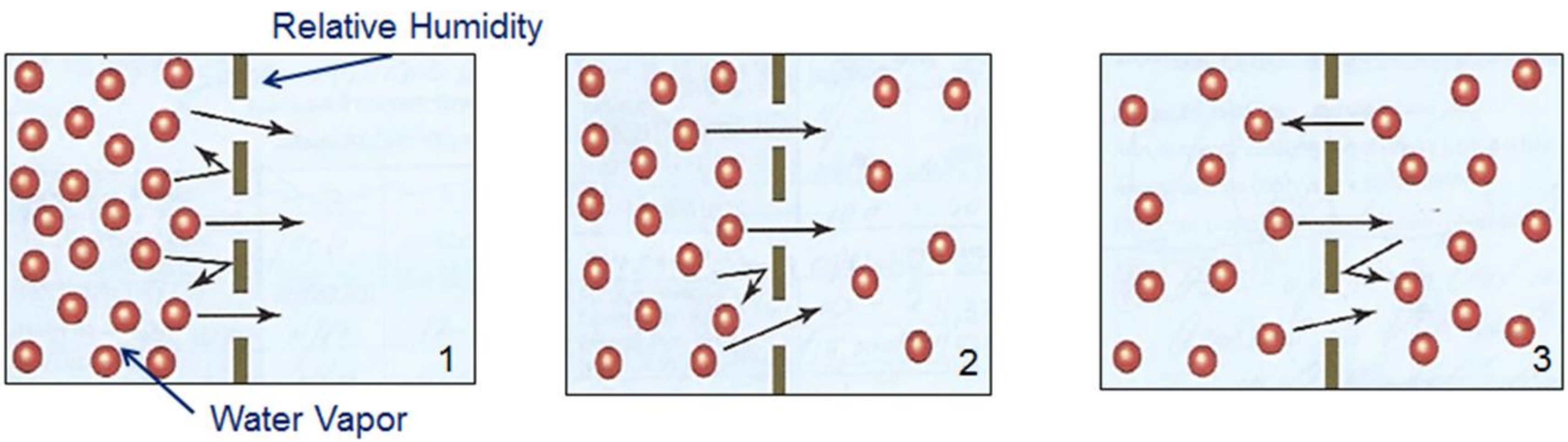


All desiccant dryers regenerate the wet bed by creating low RH purge air to remove the water vapor on the surface of the beads.

A common way of doing this is to add **heat** to increase the RH differential. This is called "heated type" – one heated type of dryer is **HEAT OF COMPRESSION OR HOC.**

Why Does the Water Vapor Move?

<u>Fick's Law of Dispersion</u>: When there is an imbalance in concentration – (water vapor / relative humidity) the vapor will always move from the high concentration level to the low concentration level to try to equalize regardless of flow direction.



The greater the imbalance the FASTER the transfer!

Heat of Compression- Desiccant Dryer Technology

THE HEART OF ANY HEAT OF COMPRESSION DRYER IS KEEPING THE TEMPERATURE OF THE AIR COMPRESSOR DISCHARGE AIR HIGH ENOUGH TO CREATE EFFECTIVE "WET DESICCANT BED" REGENERATION. >200°F

Basic Limitations:

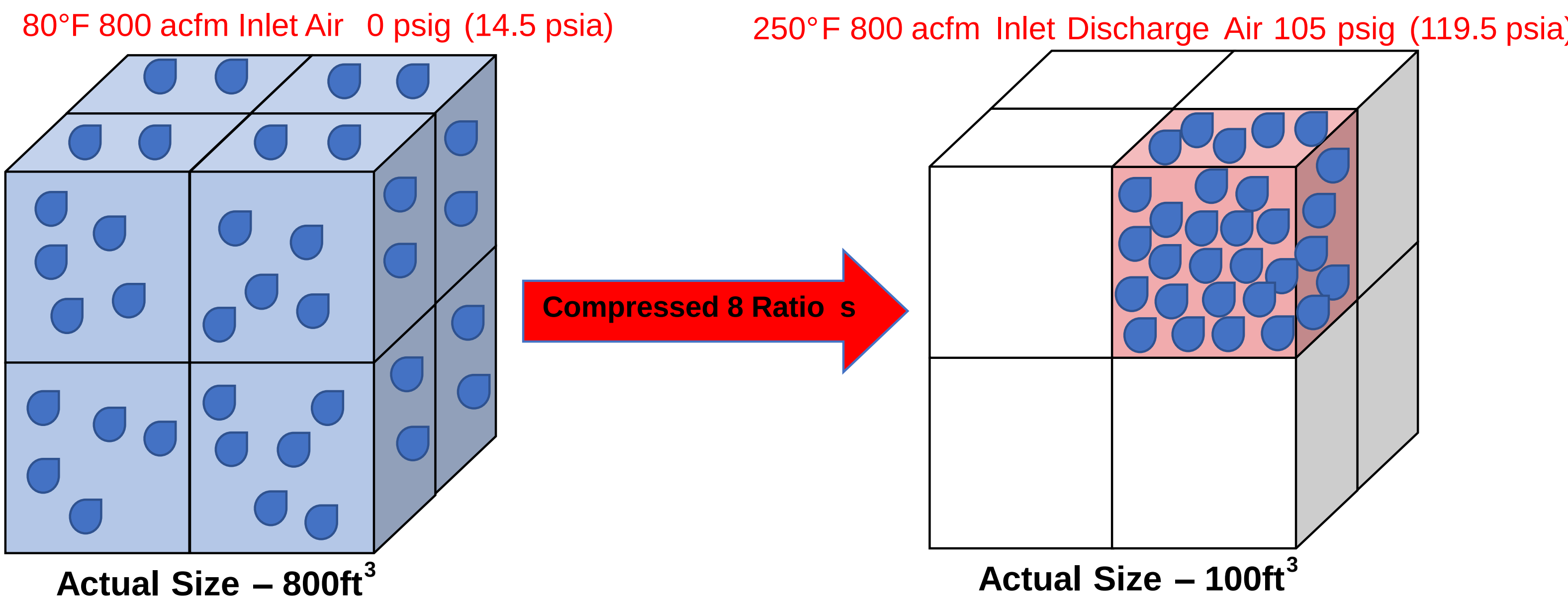
1. Actual volume of air compressor discharge air available in CFM at pressure to hold the water vapor.
2. Temperature of air compressor discharge air being utilized for moisture removal – regeneration.
3. Compressed air from a non-lubricated compressor.

HOT AIR holds **more** air in vapor form (grains/FT^3) than cooler air.

Heat of Compression- Desiccant Dryer Technology

Heat of Compression Technology

Step 1: Compression Process



Total Inlet Moisture grains of water vapor in **800 ft^3 @ 11.04 Gr/ft^3 - 8832 Grains** with no moisture removal during compression process.

Considering the moisture removal of Interstage cooler/separator

Probable exit moisture carry over is 35 gr/ft^3 x 100 ft^3 = 3,500 Total Grains in regeneration discharge air

Regeneration Discharge Air
Pressure 105 psig (CR = 8 ratios)
Actual volume @ 105 psig = 100 ft^3 @ 250°F

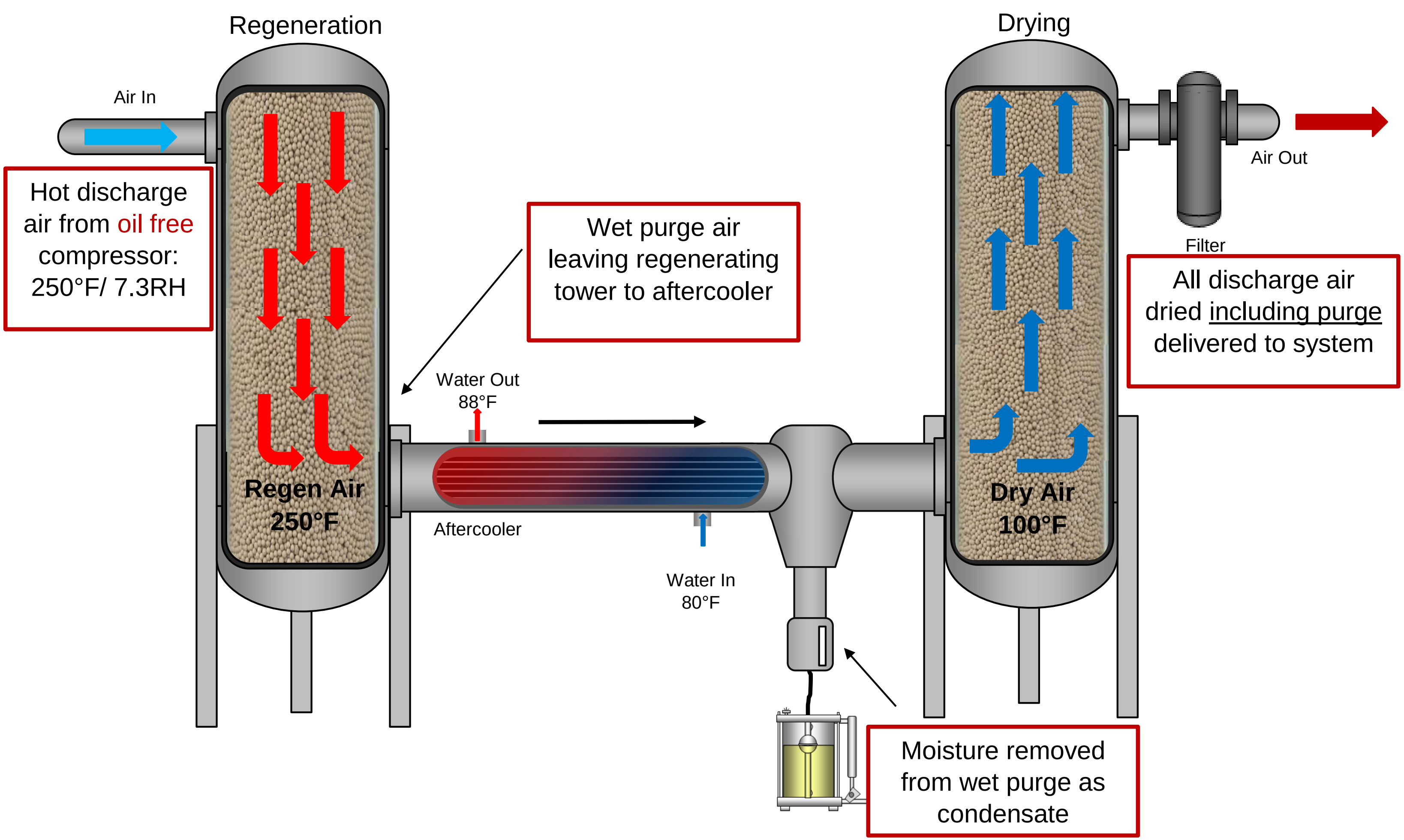
Moisture holding capability
@ 250° F - 482gr/ft^{3}x100 = 48,200 Total gr/100ft^3
Relative Humidity = 7.3%

@ 350°F - 1,083gr/ft^3 = 1,083,000 Total gr/100ft^3
Relative Humidity = 3.2%

Heat of Compression-
Desiccant Dryer Technology

Heat of Compression Technology

Step 2: No Lost Purge Water Vapor Removal by Heat of Compression



HOC DRYER SIZING FACTORS

SEVERAL FACTORS DETERMINE THE POWER, SIZE, AND TYPE OF AN HOC DRYER.

- Minimum discharge temperature of oil-free air
- Maximum inlet flow rate
- Maximum cooling water temperature
- Minimum inlet pressure

Desired continuous pressure dewpoint at site conditions.

Heated Dryers: Drying & Cooling Cycle

OPERATING BED TEMPERATURES AND COOLING CYCLE

The challenge in operating all heated desiccant dryers is to maintain consistent rated performance.

- To dry effectively the drying bed must be heated to about 200°F. When ready to switch the cooling cycle must reduce this temperature to below 130°F.
- Cycle times will vary by brand, type, and conditions.

Optimizing the energy use in twin-tower desiccant dryers and retaining the projected performance is primarily a function of controlling the regeneration cycles.

Basic Regeneration:

- Relative humidity differential bed to purge air – for timely removal.
- Cooling cycle in heated dryer – nominal 1-hour of a total 4-hour cycle with heated air purge.
- Some use compressed air for purge which is lost.
- Blower purge uses heated blower air which usually comes from ambient.
- HOC uses hot discharge air which is returned to the system dry.

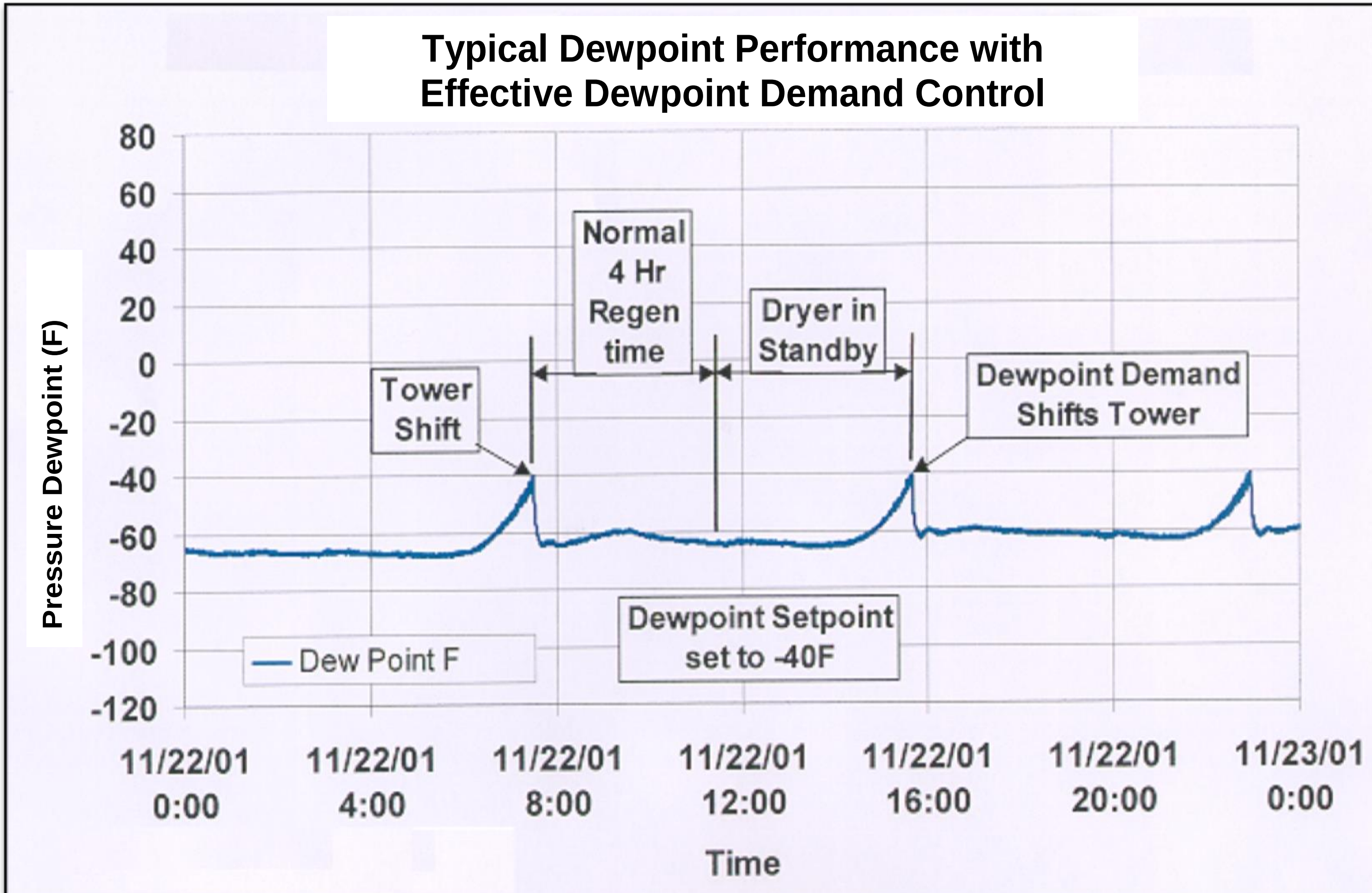
What is the Thermal / Dewpoint Bump or Spike in Heated Type Desiccant Dryers?

Thermal / dewpoint bump or spike occurs at tower switch:

- Magnitude of thermal / dewpoint bump or spike depends on conditions; controls; and valve condition.
- Nominally about 20 minutes in duration “temp spike” / much shorter time PDP bump.
- If on a fixed cycle timer will probably require seasonal adjustments and monitoring.
- A dewpoint demand control will often minimize or eliminate this.
- Pre-cooling the inlet air to the drying tower to 80°F or less will basically lower the moisture load to the drying tower and will often help control the dewpoint/thermal bump, lower the final PDP about 15°F, and extend the drying cycle with pressure dewpoint demand controls.

There are other actions that may be appropriate – work with your OEM and local service provider.

Dewpoint Demand Often Control Dewpoint & Temperature Spike at Tower Switch



Controlling Thermal / PDP Bump with Sweep Air or Dry Air Cooling

Sweep air or “dry gas cooling” is often used in heat of compression and blower purge dryers to cool and dry the bed further before tower switch – reference 4,000 scfm dyer.

Blower Purge – cooling purge air is from the ambient area and UNDRIED - will be prone to leave moisture on the bed. During the cooling cycle a nominal 5% of the rated flow **(200 scfm)** of dry air is used to cool and clear the bed of moisture for (60 min.) which is lost compressed air when required. Average flow rate of about 50 scfm.

Heat of Compression – also uses dry gas cooling when eliminating the thermal PDP bump is critical. In this case a nominal 2% of the rated flow (80 scfm) for 90 minutes out of the 240 minutes of cycle time. Average flow rate of about 30 scfm (4,000 x .02 x 90 / 240)

In practice this is usually required only when conditions require it.

Calculating the Annual Operating Costs of Full Flow Desiccant Drying

ESTIMATED COMPARATIVE ANNUALIZED OPERATING COST INCLUDING LOST PURGE AIR AND AUXILIARY ELECTRIC ENERGY REQUIRED.

All average annualized operating costs in the following table are examples only and the calculations used to generate the tables were **$.05 per kWh at 8,760 hours** annually.

All projected operating costs in the following tables are based on delivering a **-40°F** pressure dewpoint at the above stated inlet conditions with the exception of the HOC without a trim heater and dry air cooling and the refrigerated unit.

Dryer Operating Costs at Specified Conditions

DRYER OPERATING COSTS

DRYER OPERATING CONDITIONS

		AMBIENT
FLOW RATE, SCFM	4,000	PSIA – 14.5
PRESSURE, PSIG	100	TEMPERATURE – 90°F
TEMPERATURE, F	100	Rh – 60%
OPERATING HOURS PER DAY	24	COOLING H_2O – 80°F
OPERATING DAYS PER WEEK	7	
OPERATING HOURS PER YEAR	8,760	

RELEVANT OPERATING COSTS

ELECTRICITY - $.05 KWh	$0.050
COMPRESSED AIR - $.30 / 1,000 scfm	$0.300

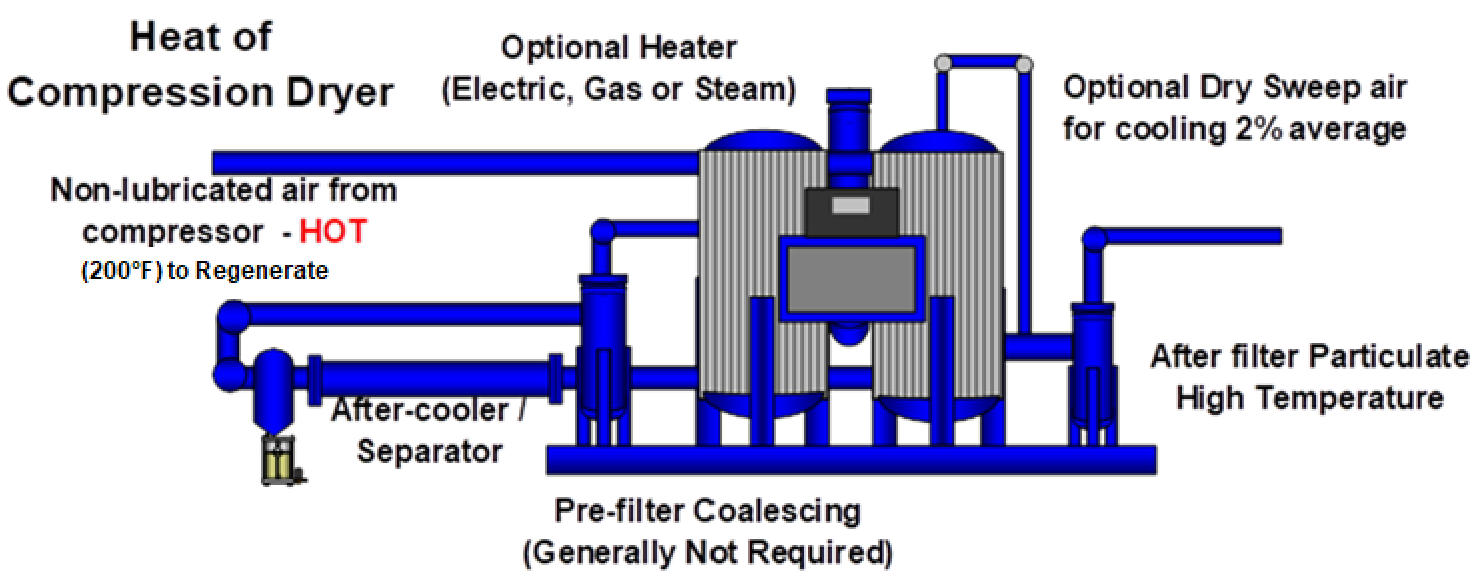
	Heatless	Externally Heated	Blower Purge (With Sweep)	Blower Purge (Without Sweep)	HOC Full Flow With Trim Heater	HOC Full Flow Without Trim Heater	Non Cycling Refrigerated
RATED PRESSURE DEWPOINT (PDP)	-40° to -100°F	-40°F	-40°F	-40°F*	-40°F	0 TO -40°F	+40°F
*DESICCANT REQUIRED (POUNDS)	2,122	2,046	2,046	2,046	2,046	1,044	NA
DRYER RATED FLOW	4,000	4,000	4,000	4,000	4,000	4,000	4,000
PURGE RATE / SCFM – LOST COMPRESSED AIR	15% / 600 SCFM	7% / 280 SCFM	5% / 200 SCFM	** / 0 SCFM	2% / 80 SCFM	0%	NA
HEATER KW / REFRIGERATED COMP. KW	0	22.05	78.74	78.74	11	0	22.16
HRS HEATING PER 24 HOURS	0	18	18	18	4.5	0	24
HEATER ELECTRIC COST / 24 HRS	$0.00	$19.84	$70.87	$70.87	$2.47	$0.00	-
MOTOR ELECTRIC COST / 24 HRS	$0.00	$0.00	$15.92	$21.22	$0.00	$0.00	$26.69
CONTROLS ELECTRIC COST / 24 HRS	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	-
COMPRESSED AIR PURGE COST / 24 HRS	$229.22	$106.97	$26.74	$0.00	$11.46	$0.00	-
TOTAL COST PER DAY	$229.34	$126.93	$113.65	$92.21	$14.05	$0.12	$26.59
TOTAL COST PER WEEK	$1,605.38	$888.51	$795.55	$645.47	$98.35	$0.84	$186.15
TOTAL COST PER YEAR	**$83,479.76**	**$46,202.73**	**$41,368.60**	**$33,564.44**	**$5,114.20**	**$43.68**	**$9,679**

***Heated dryers will experience a PDP and temperature bump at tower switch at certain conditions.

** **“**Sweep air” also called “dry gas cooling” is one way to eliminate this – some amount of dry purge air is used to eliminate this spike when needed.

Summary: Heat of Compression Dryers

- Hot air discharges from the oil-free compressors and enters the dryer at a very low RH, where it picks up the water vapor.
- The hot, wet air then goes to the aftercooler where the temperature is reduced to 100°F or less.
- The cool after-cooled air then enters the drying tower where the remaining moisture is removed from the air.
- After this cycle is completed, the towers switch and the process is repeated.
- **NO LOST PURGE AIR!**



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Energy Efficient Heat of Compression Dryers

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Heat-of-Compression Considerations

Two factors with any mechanical equipment:

1) Basic Design

2) Choice of Components

Basic Design

- Regeneration must be full flow.
- Cooling with wet air preloads desiccant and increases dew point.
- Inlet heaters add to pressure drop and consume significant energy.
- Using 2 aftercoolers doubles GPM.

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Choice of Components

- Valves must be high performance bubble tight; leakage across the valve means high dew points.
- Multi-port valves leak and should never be used in HOC applications.
- Drain traps must work; single traps fail.
  Where does the water go?
- Separators must be efficient at 0-100% flow. Cyclone and centrifugal separators are flow dependent; coalescing separators are not.

The Myth

- You need 350.6°F (177°C) discharge temperature from the compressor.

The Truth

- We developed and patented heat-of-compression dryers back in the 70's and have been improving the design ever since. We have installations operating with compressor discharge temperatures below 199.4°F (93°C).

The Myth

- The compressor must run 100% of the time.

The Truth

- The dryers are designed to operate under varying loads; the key consideration is the compressor must be loaded enough to generate temperature to the dryer. If the system is so lightly loaded that you never see temperature at the dryer, there are a few simple options available to correct the problem.

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The Myth

- If the compressor is down, the dryer is down.

The Truth

- With most HOC designs, the dryer is integrally tied to the compressor; such that if the compressor is down for maintenance, or it failed, the dryer cannot perform and you are forced to bring in rental compressors and dryers. Our HC is designed to be very forgiving and can in fact operate as a heatless dryer by simply hitting a switch and opening a valve. This is a patented feature.

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The Myth

- You have to run one compressor into one dryer.

The Truth

- You can run multiple compressors into one dryer; mixing and matching between centrifugals, screws, and even reciprocating. The only limitation is that the compressors must be oil-free.

The Myth

- Pressure drop is high.

The Truth

- Pressure drop is always a concern and a cost with any drying system. The HOC dryers look worse than other conventional dryers because the aftercooler and separator are an integral part of the dryer, thus it looks like total pressure drop is higher. In reality, the SP is very similar to other designs and the HC is only slightly higher for part of the time.

The Myth

- If the compressor discharge temperature is low, you have to heat all of the inlet air.

The Truth

- If the compressor discharge temperature is low and the customer wants better dew points, a small heater may be added in the stripping line. The size of the heater is comparable to a heated dryer and is only on for 90 minutes of the cycle; making the system very energy efficient. This inexpensive option virtually guarantees performance under any operating condition. This is a patented design feature.

The Myth

- HOC dryers lose a lot of air.

The Truth

- The truth is the SP design loses no air and is the most energy efficient dryer in the world. Some competitive designs use a purge sweep for hours consuming at least 5% of your compressed air volume. These designs are inefficient and do not include a closed loop cooling cycle.

- The HC has a stripping and cooling cycle to optimize performance. Stripping is only 90 minutes and the typical amount of air loss is 2% only during this 90 minutes. This can be reduced in the field, if dew points are acceptable.

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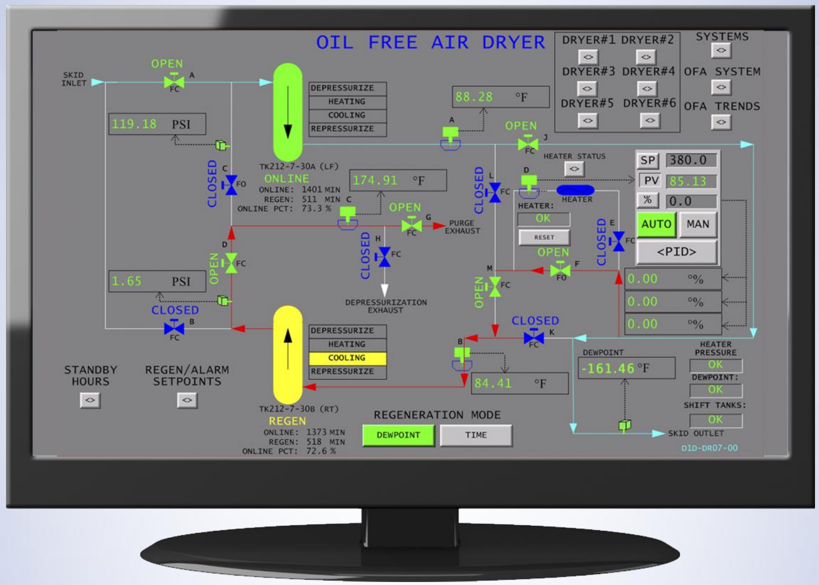
The Myth

- HOC dryers can't deliver low dew points.

The Truth

- The HC design can be optimized to deliver lower than –40°F/C continuously, year round.

Dew Point Integrity to Ensure -40°F/C



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Q&A

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