INDUSTRIAL DEHUMIDIFICATION

Shipyard Dehumidification

<u>Opening:</u>

I’m working as a engineer and making calculations on air systems.

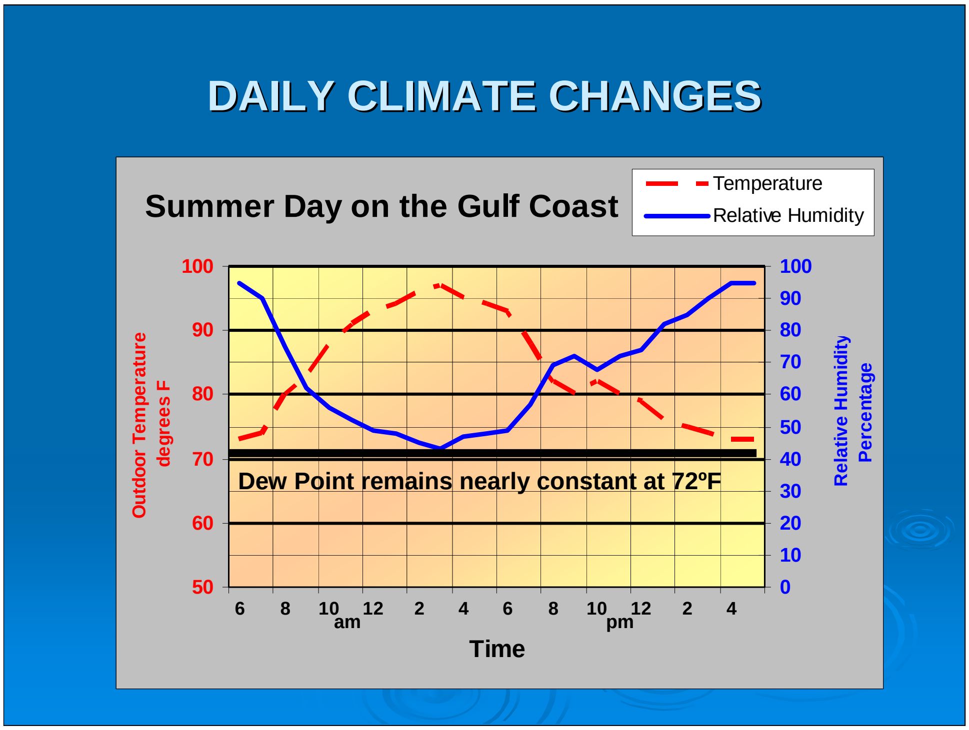
I’d like to thank the SP 3 panel for the privilege of speaking today.

I’d like to talk about selection of dehumidification equipment for industrial shipyard projects in the U.S.A. Please hold any questions until the end of my presentation.

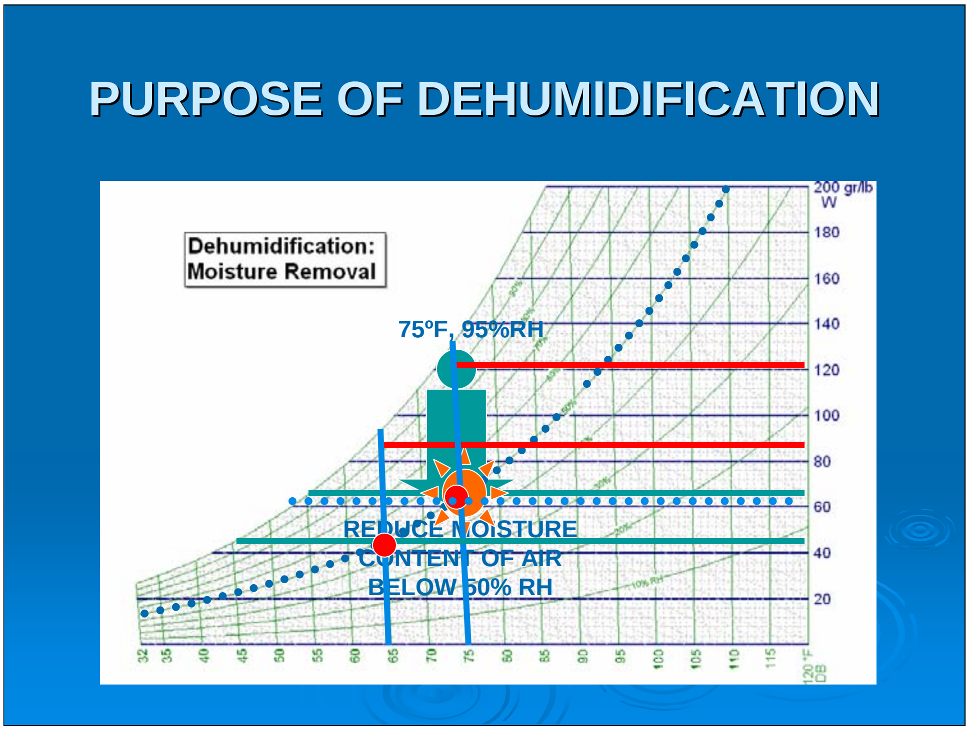
EXTREME CLIMATE CONDITIONS

- Coastal climates present challenging conditions for dehumidification; which by definition is the removal of moisture from air.
- Proper selection of 100% outside air equipment depends upon local ambient conditions and project requirements.

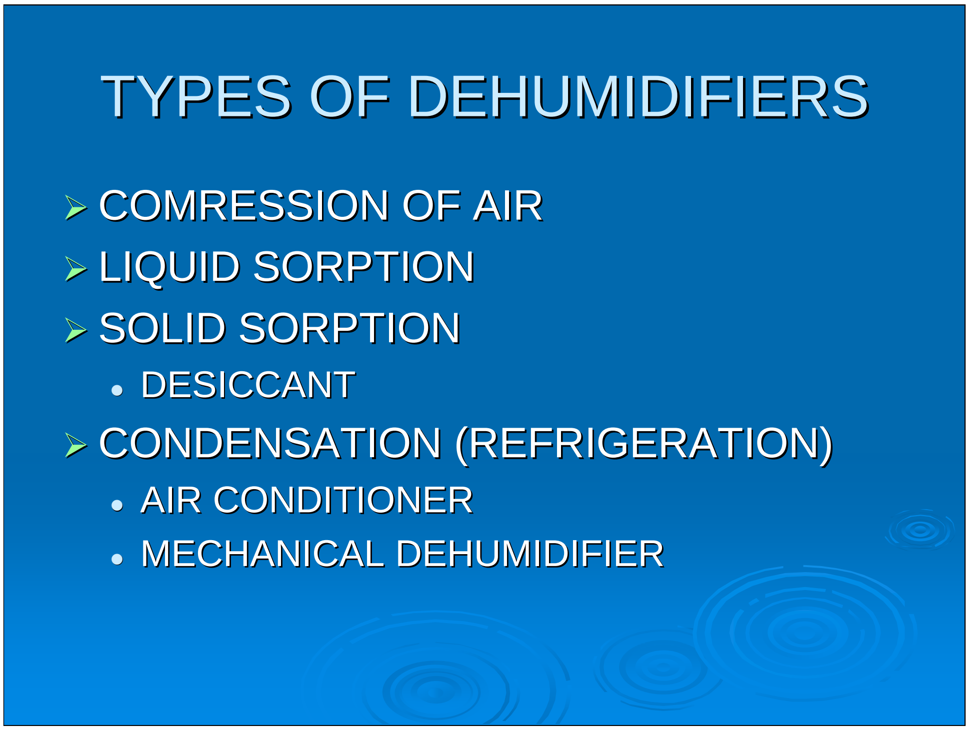
Slide 2: Wet mornings provide good design conditions for many surface preparation or drying projects. *Back in Houston, when I start the car in the morning, the first thing I do is turn on the windshield wipers to remove the morning dew. I'm sure that many of you face this situation. *The main point I want to make is that each type of dehumidifier has a moisture range where it operates more economically than the other types. Performance of dehumidification equipment is dependant on inlet air temperature and humidity conditions.



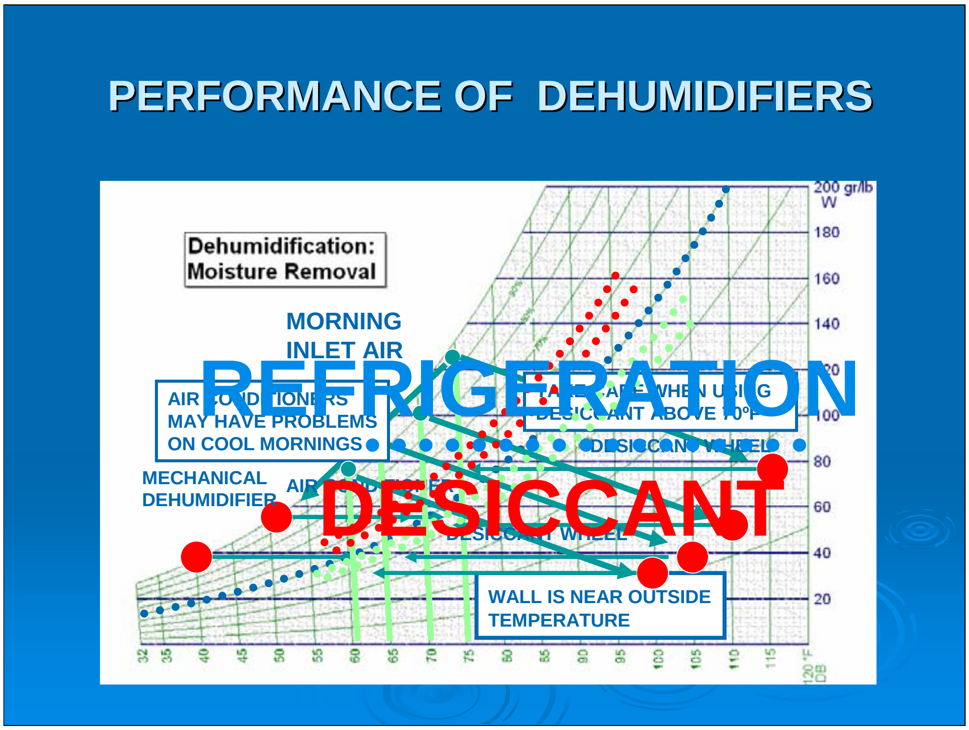
This chart shows how air temperature and relative humidity change on a summer day. Time of day is across the bottom. Outdoor temperature and relative humidity scales are on either side. Air heats up from morning to afternoon, relative humidity decreases, it rises again overnight as the air cools. *The item that stays constant during the day is the amount of moisture or water vapor in the air. Throughout the day, the dew point only varies by a couple of degrees. If weather patterns are changing, warm front, cold front or rain, this chart doesn't hold true.



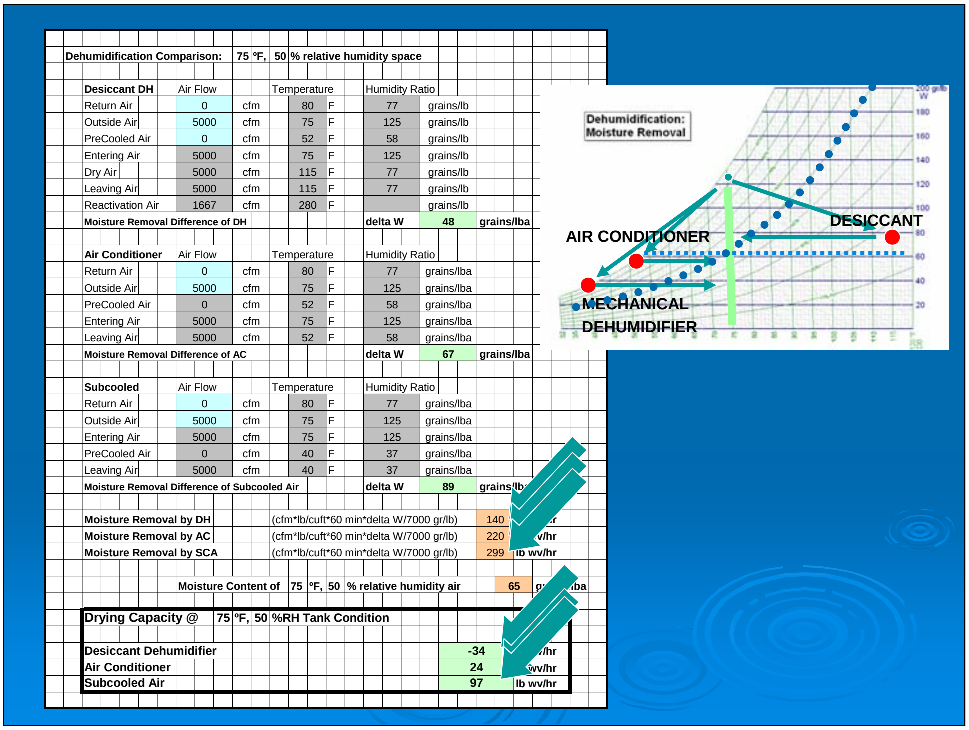
Slide 4: Dehumidification equipment is used to reduce the moisture content in air. Let’s look at a psychrometric chart. Air temperature is listed across the bottom, moisture concentration up the right side. In order to select which type of dehumidifier to use, first look at the project requirements. *A project may call for a specific temperature and relative humidity objective or it may spec an upper relative humidity limit. For a temperature and relative humidity *you need to know the maximum expected moisture content of the inlet air. Dehumidification equipment must dry deeper than the difference between inlet moisture and spec moisture. *If the job requires below 50% relative humidity at wall temperature, dehumidification performance should be reviewed at the highest expected dawn temperature * and dawn moisture content. *Assuming wall temperature is the same as outside air temperature, dehumidification equipment must be able dry beyond this moisture range. *Now determine the minimum expected dawn temperature and associated relative humidity *the wall temperature is cooler and a new moisture range has been established. Dehumidification equipment must be able to protect at both design points to satisfy project requirements. *On a warm, muggy summer morning air can be 75ºF @ 95% relative humidity. *For this discussion, the dehumidifier’s job is to maintain air moisture below



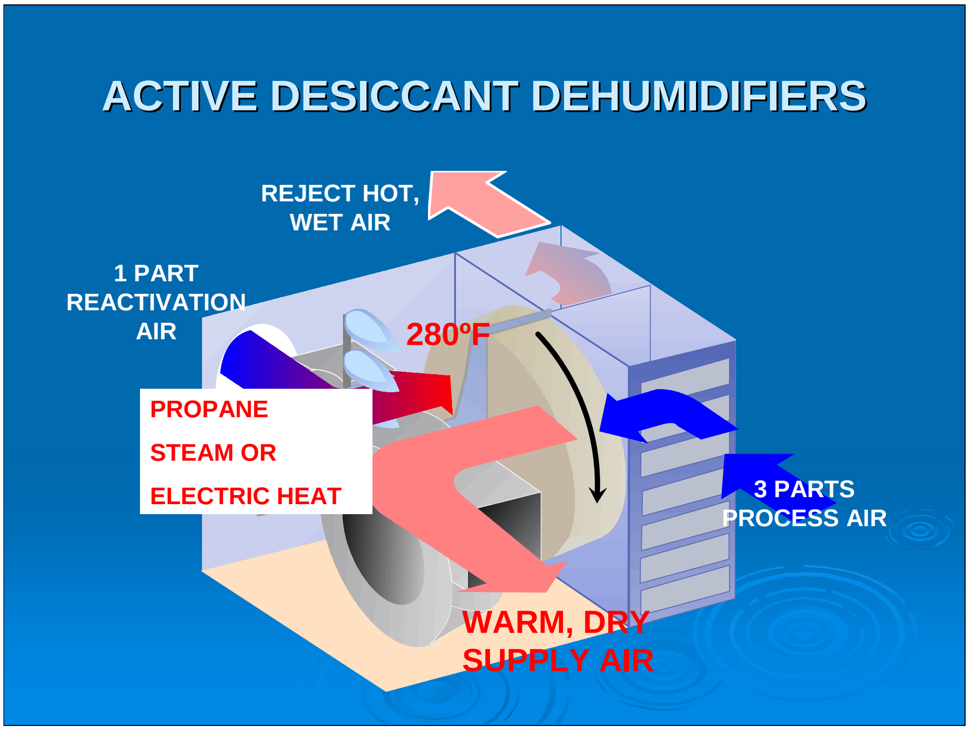
Slide 4: NACE/SSPC recognize four types of air dehumidification equipment. 1) Compression of air – As air is compressed, it's relative humidity increases. When compressed beyond saturation, water vapor in the air begins to condense, leaving air is drier. 2) Liquid sorption systems use glycol or kathene fluids to absorb moisture from an air stream. Water is then boiled out before the sorption liquid is ready to absorb moisture again. Breweries, food processing and natural gas gathering facilities use liquid sorption equipment. Neither of the above systems are generally used for abrasive blasting operations. 3) Solid sorption or desiccant dehumidifiers utilize a difference in vapor pressure to attract moisture from an air stream. The desiccant is a material that readily and repeatedly absorbs and releases moisture. Similar to a sponge and water. The most widely used desiccant is a blend of different types of silica gel. Some solid sorption units use lithium chloride salt as the desiccant. 4) The last type of dehumidifier is condensation or refrigeration. As air is cooled, relative humidity increases., Water begins condensing when the air is cooled below it's dew point or saturation temperature. Air conditioners and mechanical dehumidifiers are both refrigeration dehumidifiers. Mechanical dehumidifiers are designed to remove more moisture than air conditioners. Refrigeration requires less than half of the



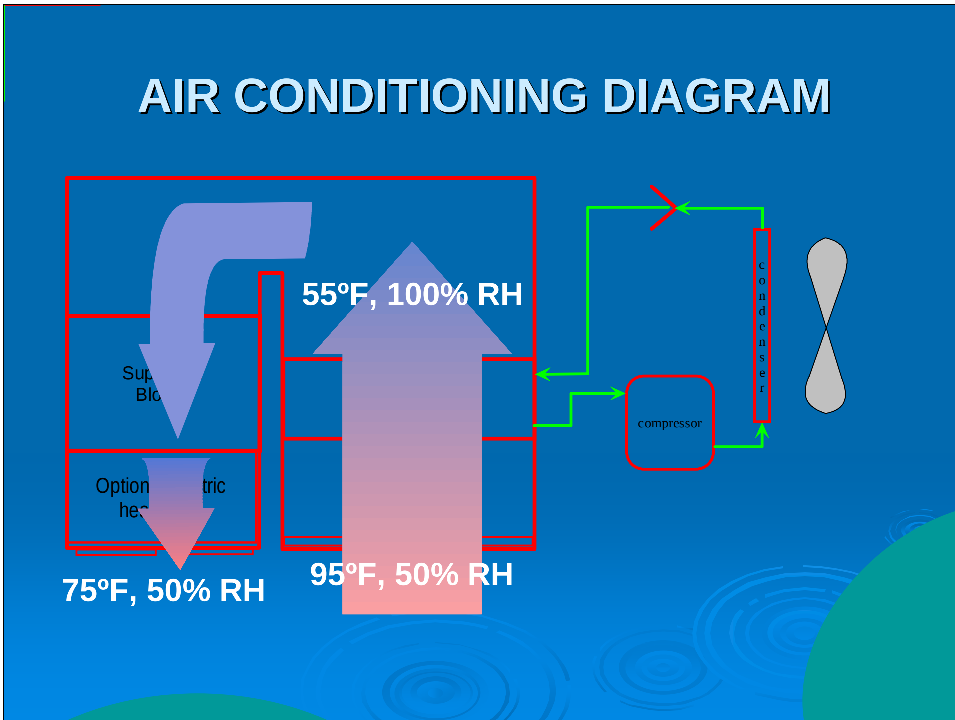
Slide 6: As I mentioned before, t<u>he main point I want to deliver is that each type of dehumidifier has a moisture range where it operates more economically than the other type.</u> Munters and ASHRAE both explain this in great detail in their books on dehumidification. Allow me to demonstrate. *Starting with 75ºF morning air *and a 50% relative humidity maximum, we'll look at the performance of desiccant and refrigeration equipment. *A good industrial air conditioner will cool to about 52ºF. *The desiccant dehumidifier supplies 115ºF air at 17% relative humidity. *A steel surface stays about the same temperature as outside air. As you know, specs are many times written around the inside wall temperature not the air temperature. *The desiccant supply air cools as it reaches the walls. In this case the desiccant doesn't maintain spec. *The air conditioner provides some moisture absorbing capacity and still provides wall humidity below 50%. *Now lower the inlet by 5F to a 70ºF morning. *Both types of equipment provide about the same 50% RH level. *At 65ºF, the desiccant performs below 50% and the air conditioners don't remove enough moisture to maintain humidity levels. *The other type of refrigeration dehumidifier is the mechanical dehumidifier. This unit cools inlet air to 40ºF and provides humidity control to wall temperatures as low as 60ºF. Moisture removal performance is



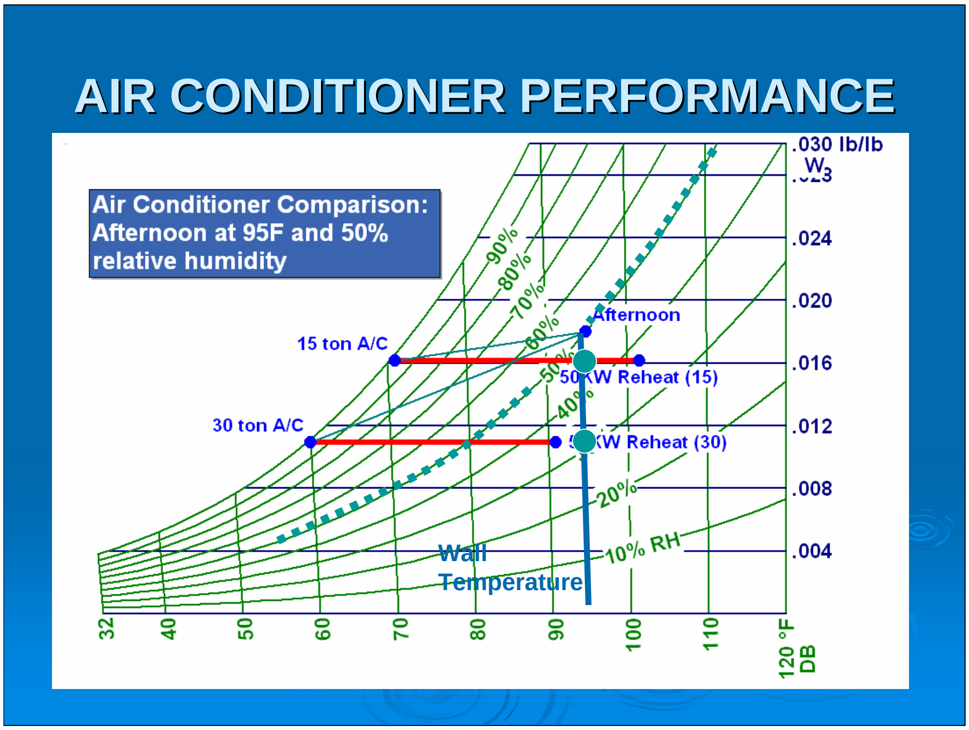
Slide 7: A calculation sheet allows you to compare performance of the different dehumidifiers. *Comparing 5000cfm of 75F inlet air at 95% relative humidity with a *desiccant dehumidifier, *an air conditioner and *a mechanical dehumidifier we find a wide range of moisture removal. *For a wall at 75F, dry air must be supplied *at or below 60 grains per pound to maintain relative humidity below 50%. *Even after removing 140 pounds of water per hour, the desiccant doesn’t remove enough moisture to maintain 50% relative humidity. Air conditioning with 5000cfm of 52F dew point air *delivers 24 pounds of moisture capacity per hour and 5000cfm of 40F dew point mechanical dehumidifier air *delivers a whopping 97 pounds of moisture removal capacity. Under this scenario, 1500cfm of mechanical dehumidifier air delivers more drying capacity than 5000cfm of air conditioned air. Smaller less expensive equipment of one type may control moisture better than larger equipment of another type.



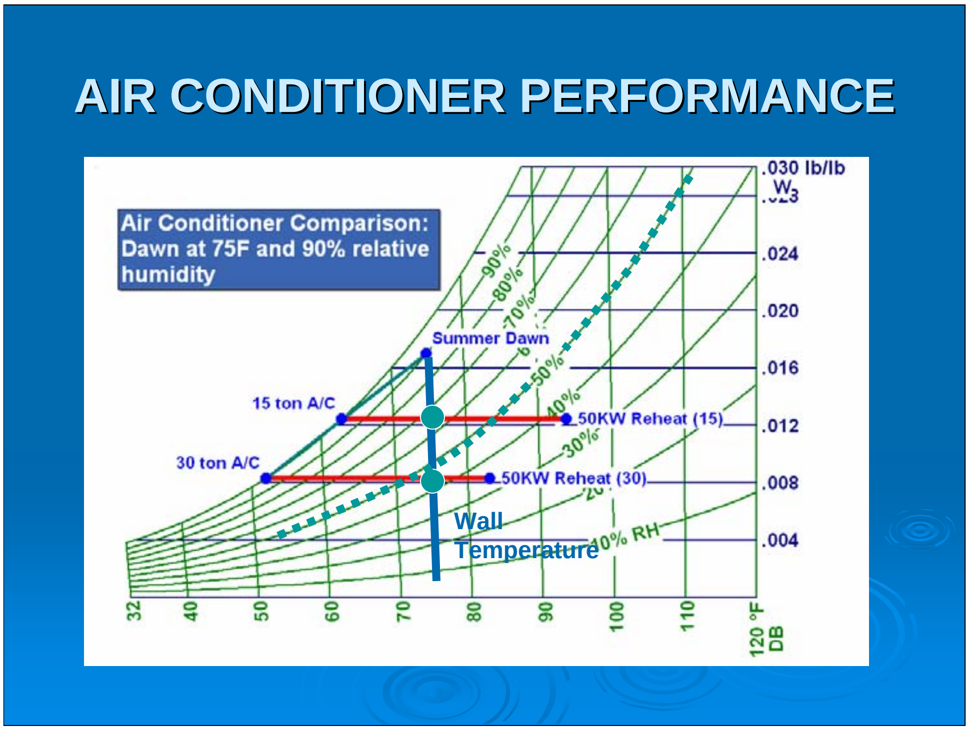
Slide 6: What I've referred to as desiccant dehumidifiers are actually categorized as "active desiccant dehumidifiers. *The unit basically consists of a rotating wheel with honeycombed channels that air passes through. The wheel is impregnated with a desiccant. Two air flow paths occur simultaneously through the wheel. *The reactivation air flow chamber blows hot air through 25% of the wheel area. *Air is heated with gas, steam or electricity. This high heat causes most of the moisture to be liberated from the desiccant. *Hot, humid reactivation air is discarded to the ambient. *The cross flow air path draws outdoor air through the remaining 75% of the wheel. Moisture is removed from the inlet air and is adsorbed onto the desiccant. *With warm, moist inlet air, adsorption capacity of portable dehumidifiers is about 50 grains of water vapor per pound of dry air processed. The thermodynamic heat loss associated with this vaporization of moisture results in a near isenthalpic heat gain imparted to the leaving air stream. Process air leaves at a temperature 40ºF to 50ºF higher than it entered the unit.



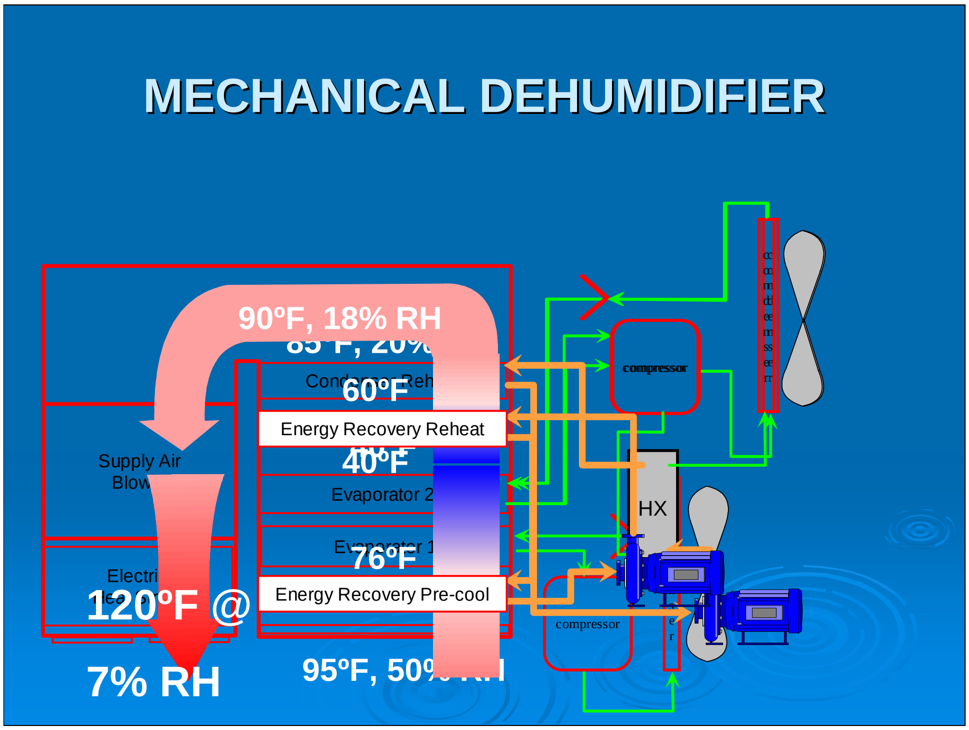
Slide 9: An air conditioner can be thought of as two parts. *The compressor and air-cooled condenser would be the outside unit at your house. *The evaporator, blower and heater would be your attic unit. *I identify industrial air conditioners as pieces of equipment capable of reducing 95ºF, 50% relative humidity air to 55ºF. Your home unit is only designed for a 20ºF temperature drop. One ton of refrigeration cools 400 cfm of air by about 20ºF. Industrial a/c's only process about 200 cfm per ton, to achieve up to a 40ºF temperature difference. *Cool dehumidified air is drawn through a blower. *Many units offer electric heat strips to reduce the relative humidity of leaving air.



Many types of air conditioners are offered in the rental market. I'll compare two air conditioners designed to deliver 5000cfm of leaving air. Outside inlet air is 95F with 50% RH. The first is a mass produced 15 ton air conditioner that has been retrofitted with 50KW of electric heat strips. It cools the inlet air to a 71F dew point then reheats to over 100F. The second is a 30 ton unit designed and built for industrial use. The same 5000cfm of inlet air can be cooled to 60F, removing much more moisture before reheating. *With a 95F wall temperature both units maintain humidity* below 50% at the wall.



The same comparison is now made for dawn inlet air at 75F at 95% RH. The 15 ton air conditioner cools 5000cfm to 63F and can reheat to over 93F. The 30 ton unit can cool to 52F then reheat to 83F. *For a 75F wall the 30 ton unit provides 45% RH while the 15 ton unit only maintains air at 65% RH.



Slide 12: Earlier I spoke about mechanical dehumidifiers. It starts with an air conditioner. *Now add a second cooling coil and refrigeration circuit further cool and dry the air. *Inlet air can be cooled from 95ºF, 50% relative humidity to 40ºF. *Air flow is reduced to about 100 cfm per ton of refrigeration. *The second refrigerant circuit is modified by adding a heat exchanger between the compressor and the condenser. By circulating water (antifreeze) through this exchanger we can control the amount of heat added back to the air stream through another coil. This system provides dehumidification and temperature control. *If cooling is not a major component of the project, *a second pump circulates water (antifreeze) through coils located directly before and after the refrigeration coils. This “recuperative loop” heats leaving air and pre-cools entering air. The benefit is that an additional 25% more air can be dried with the same tonnage of refrigeration. The trade-off is that less cooling is provided. Condenser reheat can now deliver air at 100ºF, 14% relative humidity. For higher temperature applications, electric reheat strips can be employed.

ENERGY REQUIREMENTS

MOISTURE REMOVED PER KW CONSUMED
(BASED UPON 95ºF, 50% RH INLET AIR)

- DESICCANT – 1.5 lb water vapor per KW
- AIR CONDITIONER – 3 lb water vapor per KW
- MECH. DH – 5 lb water vapor per KW

Slide 13: The amount of energy consumed to remove moisture from inlet air varies by machine. Based upon an inlet of 95ºF, 50% relative humidity; desiccant dehumidifiers remove about 1.5 pounds of water vapor per kilowatt of electricity used. Air conditioners remove 3 pounds and mechanical dehumidifiers remove 5 pounds. Desiccant performance is fairly independent of inlet conditions; (1.5 pounds per KW) over a large range of climates. Air conditioner and mechanical dehumidifier deliver varied performance based upon inlet conditions.

EQUIPMENT COMPARISON

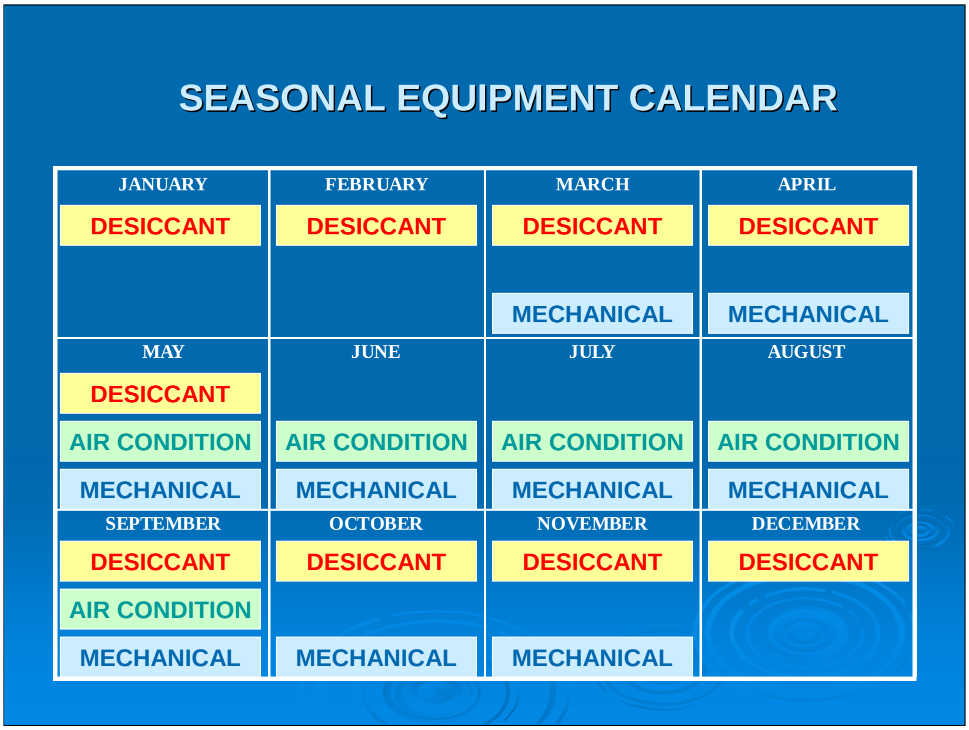
DESICCANT WHEEL

- REMOVES UP TO 50 GRAINS OF MOISTURE PER POUND OF AIR PROCESSED
- CAPABLE OF VERY LOW DEW POINT WITH PROPER INLET AIR
- PERFORMS BETTER THAN REFRIGERATION WHEN MORNINGS ARE BELOW 65ºF
- LEAVING AIR IS 40ºF WARMER THAN INLET AIR
- ENERGY REQUIREMENTS ARE HIGH BECAUSE OF REACTIVATION HEAT

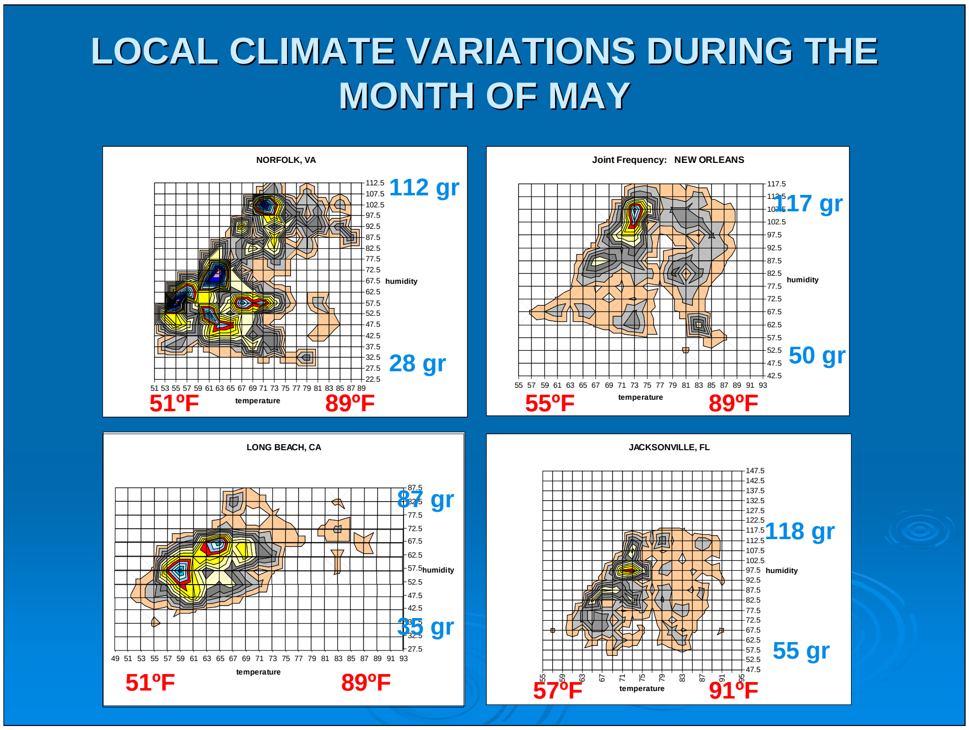
REFRIGERATION

- MOISTURE REMOVAL IS DEPENDENT ON INLET AIR
- STEADY DEW POINT SUPPLY AIR
- PERFORMS BEST WHEN (DEW POINT) MORNING IS ABOVE 55ºF
- REHEAT PROVIDES TEMPERATURE AND RELATIVE HUMIDITY CONTROL
- DELIVERS DEHUMIDIFICATION USING 50% LESS POWER

Here is a brief comparison of desiccant and refrigeration dehumidifiers.



Slide 13: On a seasonal basis, desiccant dehumidifiers can generally be a good choice from January through May and September through December, when morning temperatures are below 65ºF. Air conditioners may be used from May through September when morning lows are above 70ºF. Mechanical dehumidifiers offer value from March through Novenber when morning lows are above 55ºF. This chart is presented as a visual guideline, local climate conditions and specific project requirements ultimately determine actual equipment selections.

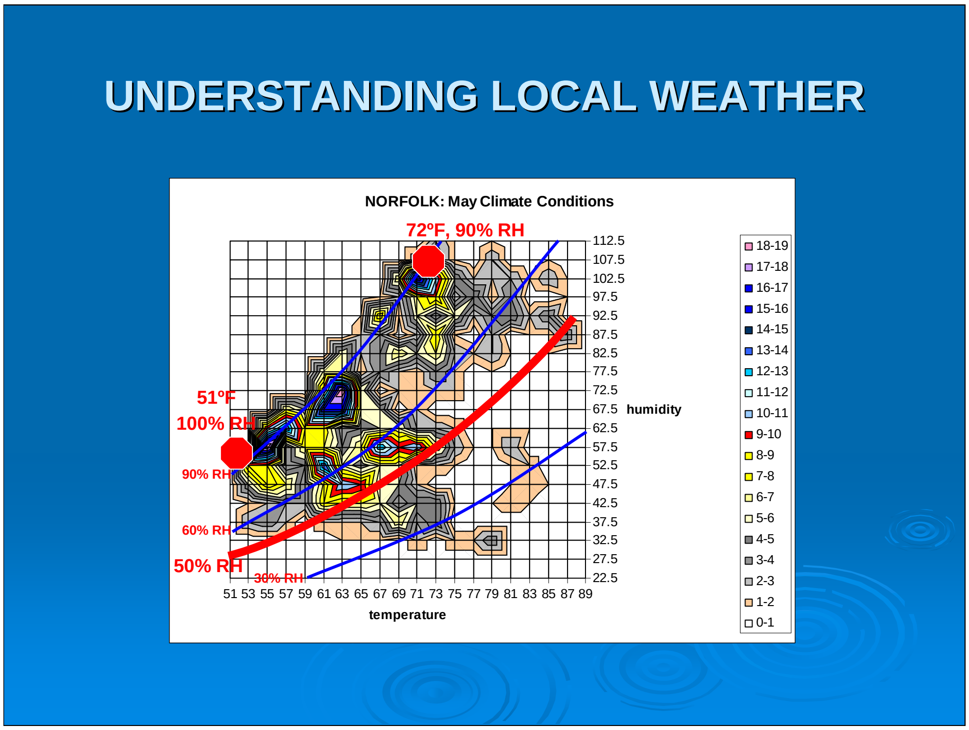


The following charts provide a graphical representation of hourly temperature and humidity readings during the month of May, for four locations. The data represents 15 to 30 years of hourly recording at national weather stations. The charts are statistical models and don't necessarily depict record conditions. In Norfolk temperatures vary from 51ºF to 89ºF during the month with a humidity ratio of 32 grains per pound of dry air to 112 grains. (Grains: 7000 grains of water vapor = 1 pound of water)

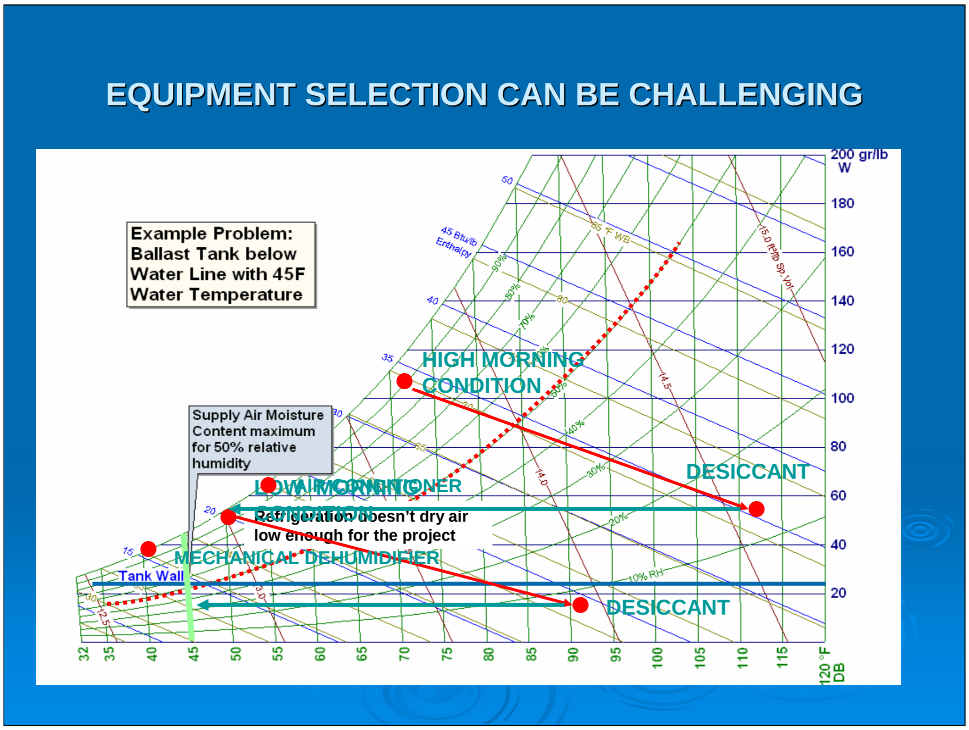
New Orleans: 57ºF to 89ºF with 52 to 118 grains (warmer, more moisture)

Jacksonville: 57ºF to 91ºF with 55 to 118 grains (warmer, more moisture)

Long Beach: 52ºF to 88ºF with 37 to 88 grains (low moisture)

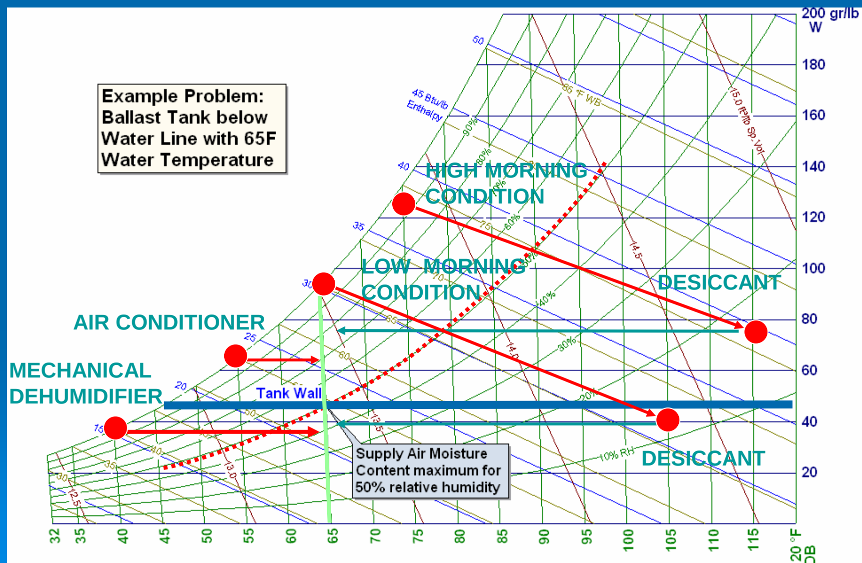


Slide 17: Norfolk, Virginia in the month of May. Temperature varies from 51ºF to 89ºF and humidity ranges from 32 grains of water vapor per pound of dry air to 112 grains. Again, this chart illustrates the number of hours during the month that Norfolk sees a temperature and moisture condition. The pink and blue areas show the greatest concentrations of hourly readings. This pink spot centered at 63ºF and 72.5 grains normally occurs for 18 to 19 hours during the month of May. Outlying conditions occur for only an hour or less, during the month. To gain a clearer picture, *let’s superimpose lines of relative humidity over this chart. As you now see, most of your month is spent with 90% relative humidity. These are generally overnight hours. We’ll pick two extreme points to analyze our equipment selection; *72ºF with 90% RH and *51ºF with 100% RH. The dehumidifiers job is to maintain space air *below 50% RH.

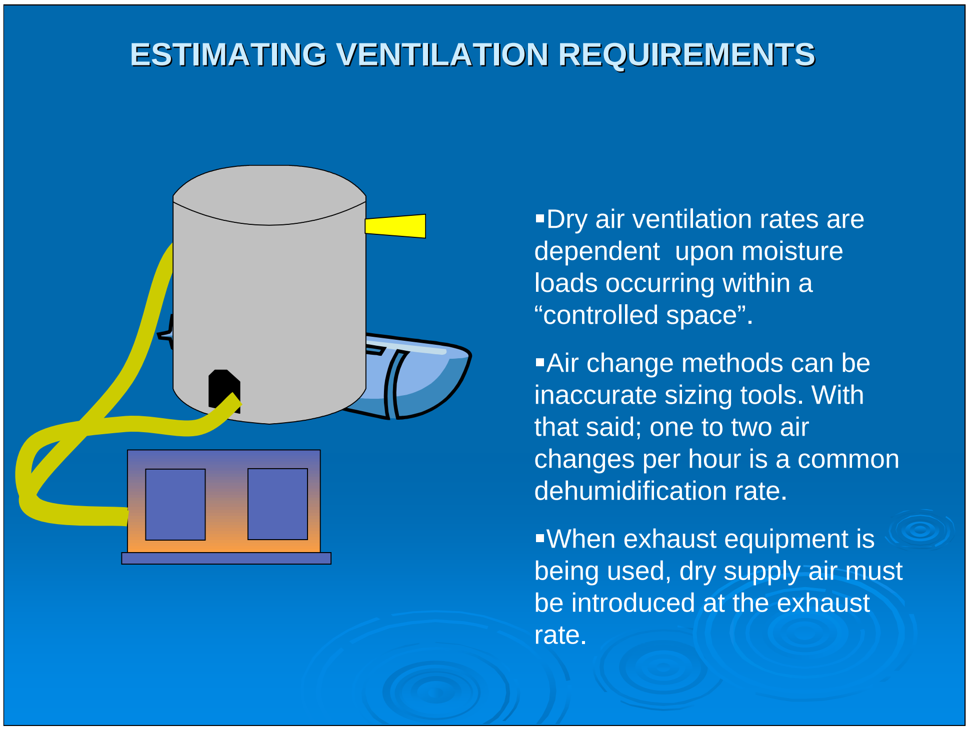


Slide 16: Let's use Norfolk in May for an example problem. A ballast tank below water line is being cleaned and coated. The water temperature is 45ºF and one side of the tank is exposed to water, *resulting in a 45F wall temperature. From the prior slide, our outside design conditions *are air at 72ºF with 90% RH and 51ºF with 100% RH. *Air is to be maintained below 50% RH at the lowest tank wall temperature. *Here is a desiccant's performance for the high inlet condition *and the low inlet condition. *Air leaving the dehumidifier must stay below this moisture content to maintain spec. Equipment supplying moisture levels below the line, such as a desiccant dehumidifier operating on a cool morning meets the necessary level. The same desiccant dehumidifier fails to dry air deeply enough on warm mornings. *Neither air conditioners nor mechanical dehumidifiers *dry air enough to do the job. I would cool the air first, followed by a desiccant unit to insure low enough moisture levels.

THE SAME BALLAST TANK PROJECT IN JUNE



Look at the same project in June. *Water temperature is now 65ºF, outside design conditions are *75ºF with 95% RH *and 65ºF with 95% RH. *For a wall temperature at 65ºF, desiccant dehumidifiers work on cool mornings *but fail on warmer mornings. *Mechanical dehumidifiers will do the job, *air conditioners don't dry well enough. Your main concern when specifying a dehumidifier is that supply air is going to be drier than the spec point all of the time. Moisture loads of the space must also be estimated.



Slide 20: I'd like to briefly touch on ventilation rates used for drying projects. *For moisture control, ventilation rates are dependent upon moisture loads and the moisture level of supply air. *Using ventilation rates to size drying projects can result in inaccurate amounts of equipment for the job. *When exhaust fans are used during a project, always match dehumidifier air flow with exhaust flow.

QUESTIONS?

RoundTank Heat Transfer

input	Diameter	100	ft
input	Height	30	ft
input	Design Temperature	90	°F
input	**(1)**Wall Temperature; **(2)** Air Temp.	2	
input	Ambient Temperature	85	°F
input	"R" Value	0	°F-hr/Btu
input	Ground Temperature	65	°F
input	**(1)** Elevated; **(2)** Ground Level	2	
input	**(1)** Metal; **(2)** Concrete; **(3)** Fiberglass	1	
input	**(1)**White;**(2)**Black;**(3)**Gray	3	
input	**(1)**Afternoon;**(2)**Night	1	

	Area Top (ft2)	7854	ft²
	Area Walls (ft2)	9425	ft²
	Area Floor (ft2)	7854	ft²
	Total Surface Area (ft2)	25133	ft²
	Volume (ft3)	235620	ft³
	Heat Transfer: Top	-49088	Btu/hr
	Heat Transfer: Walls	-58905	Btu/hr
	Heat Transfer: Floor	-245438	Btu/hr
	Heat Transfer: Solar Load	265465	Btu/hr
	Heat Transfer:Total	-87966	Btu/hr
	Total Heat Transfer: cooling	**-7**	**tons**
	heating	**26**	**KW**
input	**Desired Air Changes per Hour**	**3**	
	Required Air Flow	**11781**	**cfm**
	Required Air Temperature	**92**	**°F**

Slide 22: Nothing was mentioned about heating steel walls or inside air. Generally, an uninsulated steel vessel requires many air changes of conditioned air to affect the wall temperature. After years of sizing these types of projects for a large rental company, I developed some software that does a good job of estimating tank heat transfer. Several CD's of this software are available, free of charge at the back of the room. If they run out, leave your business card and I'll email you a copy. Beware, the software doesn't work if it's raining or snowing or when high winds occur.

THANK YOU