Refrigeration Technology Inc.

Presents

REFRIGERATION

How To

Improve Efficiency

And

Lower Operating Costs

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INTRODUCTION

To most people a refrigeration system is a black box that magically makes cold. We know that we spend money on electricity and out comes COLD. Did you know that there is no such thing as COLD? Heat is a form of energy. The less energy something has the COLDER it is. If we have no energy, we have no HEAT, therefore COLD is NOTHING and therefore it does not exist.

Years ago I came across a definition of REFRIGERATION that has stayed with me ever since.
"Refrigeration is the process (work) of removing heat (energy) from a place that it is not wanted and moving it to a place where it is not objectionable." (usually outdoors)
You cool a room by removing heat from the air inside and moving it outdoors. You cool glycol by removing heat from the glycol and moving it also outdoors.

To understand how this is done you must first understand that energy (like other things in life) always flows down hill. This means that heat (or energy) will travel naturally from a high energy source to a low energy source. For example: Take two bricks, one heated in an oven to 300ºF and one cooled in a freezer to 0ºF. The temperature difference is 300ºF. If we take the bricks and put them in an insulated box side by side what will happen? The energy in the hot brick warms the air and the warm air heats the cold brick. This will continue until everything is the same temperature. If both bricks weigh the same, the final temperature will be about 150ºF.

By now you are asking what the H_ _ _ does all of this have to do with reducing your refrigeration costs?! It is important because reducing your refrigeration cost is ALL about energy and how to SAVE it when it is wanted and LOSE it when it is not.

INSULATION

For years I have always said "INSULATE BEFORE YOU REFRIGERATE"

What does this mean? The more insulation you have the less heat transfer will take place. You insulate when you want to reduce the flow of heat. This can be *hot to cold* or *cold to hot.* It just depends on which side of the insulation you are standing. The process is the same for heating or cooling.

Let's look at a typical barrel room. The walls have a U value and insulation has an R value. What does it all mean? To understand this it helps to know the UNITS OF MEASURE.
A 'U VALUE' of a material is the BTUs that will pass through one square foot per hour per degree temperature difference on each side of the material. (U= BTU/HR/SQFT/OTD).
An 'R VALUE' is the reciprocal of a 'U VALUE'. It represents the thermal conductivity of a material. The higher the number, the better the insulation.

U = .05	R = 20
U = .03	R = 33
U = .01	R = 100

Now let's look at three identical barrel rooms with different amounts of insulation. Keep in mind that there are other things to consider when we calculate the total refrigeration required. They are not included in this study as we are only discussing insulation.

BARREL ROOM #1 100ºF out 60ºF in 40ºF TD

Walls = 6,000 sq ft - R-10 = U .1
Roof = 5,000 sq ft - R-20 = U .05

Walls =	6,000 sq ft x .1 x 40 TD =	24,000	BTU / HR
Roof =	5,000 sq ft x .05 x 80 TD =	20,000	BTU / HR
		44,000	**BTU / HR TOTAL**

As you can see, the insulation value for the roof is double the walls but the heat load is almost the same. This is due to the fact that the surface temperature of the roof is usually much higher that the walls.

BARREL ROOM #2

Same as barrel room #1 except more insulation

Walls = 6,000 sq ft - R-30 = U .033
Roof = 5,000 sq ft - R-40 = U .025

Walls =	6,000 sq ft x .033 x 40 TD =	7,920	BTU / HR
Roof =	5,000 sq ft x .025 x 80 TD =	10,000	BTU / HR
		17,920	**BTU / HR TOTAL**

You can see the major reduction in the loss of energy. Now let's look at a super insulated barrel room.

BARREL ROOM #3

Walls = 6,000 sq ft - R-50 = U .02
Roof = 5,000 sq ft - R-60 = U .016

Walls =	6,000 sq ft x .02 x 40 TD =	4,800	BTU / HR
Roof =	5,000 sq ft x .05 x 80 TD =	6,400	BTU / HR
		11,200	**BTU / HR TOTAL**

Now, let's size the refrigeration system for each room.

#1	=	44,000 BTU/HR	=	3.6 Tons of Refrigeration	
#2	=	17,920 BTU/HR	=	1.5 Tons of Refrigeration	59% less than #1
#3	=	11,200 BTU/HR	=	0.93 Tons of Refrigeration	74% less than #1

From this example we see that Room #2 has a 59% less load that #1 and that #3 was 74% less than #1. The more insulation the better but at some point the cost becomes too high to recover over the life of the system. If money is no object then insulate the heck out of the room. If you are looking for a reasonable 3 to 5 year pay back you probably can't go over R-30 or R-40.

TANK INSULATION

Insulation on tanks can be a blessing or a curse. Red fermentation usually runs between 85ºF and 95ºF. White fermentation runs 55ºF to 60ºF.

OUTSIDE TANKS

Outside tanks uncovered see direct sun during the day. Surface temperatures can reach over 100ºF. Insulation would be a help here adding a large heat load to the tank. In Northern California we can see daily temperature swings of 30ºF to 40ºF. So at night we may see temperatures in the 50's and 60's. At night this can actually help cool the tanks and insulation would be less efficient. Then there is the runaway fermentation. If your refrigeration fails the insulated tank will heat up faster and will cause more problems.

So what is the answer?

For outside tanks we recommend covering the tanks from the sun with a roof or shade cloth.
Consider insulation on your white fermenters. Wrap insulation around un-insulated tanks when you cold stabilize indoors or out. This can be temporary and removed when not in use. Do your cold stabilization in the cool months. Do not wait until June or July!

HOT WATER TANKS

This may seem like a drop in the bucket but I wanted to pass this on. We have built several Solar Panels and are testing them for heating glycol to be used to heat tanks and/or to be used to pre-heat water going to a boiler. We have a 120 gal. tank with typical insulation on a metal jacket just like a water heater. The tank was outdoors and we saw it lose 40ºF overnight. We wrapped the heater with R-30 batt insulation and that reduced the loss to 20º. Our goal is to reduce the loss to 5ºF (still testing). More on the solar panels later in the report.

GLYCOL CHILLERS

Glycol chillers use a refrigerant, usually Freon, to remove heat from the glycol and move it outdoors where it is not objectionable. This is done by using heat exchangers. The Freon cannot directly touch the glycol so the heat exchanger is used to separate the two materials. The Freon is colder than the glycol so the glycol heats the surface of the heat exchanger (the chiller) and warms the glycol causing it to boil. The Freon gas carries the heat away eventually to the condenser where it is rejected outside to the ambient air. When it comes to heat exchangers --- “SIZE MATTERS”. The efficiency of a refrigeration system is directly related to the size and condition of the two major heat exchangers, the condenser and the evaporator. The more surface a heat exchanger has the more efficient it is.

EFFICIENCY (SEER RATINGS)

The efficiency of a refrigeration system is directly related to the amount of work the compressor is required to do. The suction pressure is the gas pressure entering the compressor. The discharge pressure is the pressure of the gas leaving the compressor. The difference between the two pressures represents the work of the compressor (PD). The lower the difference the greater the efficiency. As the difference gets lower the system capacity of the compressor and the power required both increase. The efficiency increases because the capacity goes up and the power goes down!

The next question is “How do we lower the P/D”. The Suction pressure is a function of the design suction temperature and the size of the evaporator. The discharge pressure is a function of the discharge pressure and size of the condenser. We can lower the P/D by increasing the size of either or both of the heat exchangers.

A SEER rating is used to measure the efficiency of a refrigeration compressor. SEER stands for the SEASONAL ENERGY EFFICIENCY RATIO, it represents the output of a compressor in BTUs/ HR divided by the input power in Watts /HR. The higher the SEER the higher the efficiency.

Example- Compressor output 5,000 BTU / HR

Power Required 500 Watts / HR

SEER = 10

Once we understand this we can look at the different design conditions for the same compressor and see how it affects the SEER rating.

NOTE: Refrigerant temperature and pressure are directly related, the lower the temperature the lower the pressure and vice versa. The chart below shows suction and condensing temperatures as they are easier to relate to than pressure.

20 HP COMPRESSOR

Suction /Temp	Condensing /Temp	Capacity BTU/HR	KW	AMPS	SEER
40°	110°F	218,000	18.16	25.4	11.99
30°	110°	177,200	16.98	24	10.43
20°	110°	141,600	15.53	22.3	9.12
10°	110°	111,400	13.93	20.5	8.0
Note: 20°F Suction Is Typical for a Glycol Chiller at 30ºF					
20°	100°F	157,400	14.81	21.5	10.62
20°	90°F	173,100	13.94	20.5	12.42
20°	80°F	188,900	12.86	19.29	14.70

From the above table you can see that we can gain efficiency by raising the suction temperature, but we are limited to the design temperature of the glycol. We cannot raise the suction temperature to 40°F for better efficiency when the glycol needs to be at 30°F. The suction is usually designed to be 10°F colder than the desired glycol temperature.

The bottom half of the chart shows the gains in efficiency by lowering the discharge temperature. This has a larger effect on the efficiency than raising the suction temperature (Pressure).

When a chiller is brand new its efficiency is directly related to the design and size of its heat exchangers. A low cost chiller with undersized heat exchangers is no bargain. It will cost you more to operate for the life of the equipment. Chillers lose efficiency when their heat exchangers become less effective. This is the result of poor maintenance where a condenser gets dirty and never cleaned and evaporative condensers get scale buildup. The efficiency of a compressor is directly related to its pressure difference (P/D). A refrigeration compressor pumps gas from the low side of the system and discharges it to the high side where the gas is condensed in the condenser. The more surface area in the condenser the easier the gas will condense, keeping the compressor ratio down. A small and/or dirty condenser causes this P/D to go up (less efficient). On a new system we can oversize the condenser to lower the P/D. On an existing system you can clean the condenser several times a year. Most condensers have pressure controls to operate fans. These should be checked for proper operation on a regular basis. They may turn off too soon keeping the P/D higher than necessary.

FLOATING HEAD PRESSURE CONTROLS

When looking at refrigeration efficiency the terms "Floating Head Pressure Controls" often come up. As discussed, the lower the P/D, the more efficient your refrigeration system. If we run all of the condenser fans and pumps (if water cooled) all at the same time 24/7 you will always have the lowest P/D possible. The problem with this is that in the winter the P/D may get too low to feed Freon to the evaporator (Chiller). A chiller may require special expansion valves in order to feed Freon during extremely low P/D conditions.

This has very limited use in a winery for several reasons. Wineries have a peak load during the warmest part of the year. Their load drops off in the winter. The condensers become way oversized for the load, the P/D is very low and the existing expansion valves work just fine. No additional equipment is required or necessary. They are already operating at maximum efficiency.

HEAT RECLAIM

When Freon is compressed it leaves the compressor at 160°F or higher. It condenses at 100°F or 110°F. The difference in the two temperatures is called SUPER HEAT. If we pass the hot Freon through a heat exchanger on its way to the condenser we can take up to 25% of the heat away from the Freon before it reaches the condenser. We can use this to heat glycol or water to be used to heat tanks and/or preheat wash down water before it goes to the boiler. Adding a heat reclaim heat exchanger actually does two things to improve system efficiency. First it captures wasted heat and uses it to offset heating energy costs. Second it actually increases the size of the condenser lowering the condensing temperature/pressure of the system. This lowers the system P/D and increases the system capacity, lowers the power consumption and increases the compressor SEER rating !!

A small heat reclaim system sized for a 20HP refrigeration system will cost about $7,000. It will reclaim about 60,000 BTU/HR or 600,000 BTU/10HR = 6 Therms/Day.

1 Gal propane = .91 Therms.

6.5 Gal propane saved per day per 20HP =

At $2.60/Gal = $17/Day = $340/Month = 3 to 5 year payback

This is a long pay back for a propane system. If you are on natural gas it may qualify for a rebate with PG&E.

GLYCOL TEMPERATURE

The colder you operate a refrigeration system the less efficient it is. The colder it is the larger the C/R. The recommendation here is

“NEVER RUN YOUR GLYCOL COLDER THAN NECESSARY”.

If 40°F glycol will do the job do not use 30°F. When you are done cold stabilizing at 25°F turn the glycol temperature back up. Do not keep it at 25°F until you notice three feet of ice on your glycol pump.

GLYCOL PUMPS

Nothing costs less to operate than a motor that is not running. Do your glycol pumps run 24/7 ? Do you have to turn them on and off manually? Existing systems can be retrofitted with controls to cycle the pumps off when there is no demand. They can also be retrofitted with variable speed drives. (VFD's). This slows the pumps down at low demand reducing power consumption. VFD's may qualify for Utility Company rebates.

COMPRESSOR CONTROLS

Many refrigeration compressors have capacity controls. This is a system that changes the capacity of a compressor to match changes in the refrigeration load. If a compressor has more capacity than the load it will short cycle as it overpowers the load. If the compressor capacity is too small for the load it will run forever. Some capacity controls will adjust or track the operating temperature of the system. As you change the glycol set point the un-loaders adjust accordingly. If the un-loaders are fixed here is what happens:

The chiller is setup for harvest (30°) and the un-loaders are set. Everything works fine. Later the temperature is lowered to 25°F to cold stabilize. As the glycol temperature goes down the compressor unloads too early. You will have 4 pistons working when the glycol temp is 35°F and only 1 piston works when the glycol reaches 30°F. Your system will continue to operate 24/7 on one piston never being able to reach 25°F. Now compressor #2 turns on and you end up with both compressors running unloaded. Now you call RTI for help! We go out and re-set the un-loaders so all pistons start working and everything is fine. That is until you are finished and raise the glycol back to 30°F. Now the un-loaders are set too low and the compressors will start to cycle. The solution is to reset the un-loaders each time to change the glycol temperature or have external un-loaders that will track the glycol temperature.

SOLAR ELECTRIC SYSTEMS

Today more and more wineries are using Solar Energy to lower costs. The cost is coming down and rebates and tax credits have helped make these systems pencil out. Frog's Leap has had a solar system for several years. Z D Wines has a system that is working well and Schramsberg Winery just installed a 308kw system. These wineries are doing their best to use the solar electric by adding electric heaters for hot water and hot glycol. We installed a 144kw hot water heater and a 72kw glycol heater at Schramsberg. We can install these parallel to existing systems. This way the existing systems provide back up and supplement the electric on high demand days.

SOLAR THERMAL

Solar panels have been around for years. They work great for heating water for domestic and commercial use where you have a high demand for a short period of time. The storage tank is a key to the success of any heat reclaim system. Consider the tank as a battery. The larger the tank, the larger the battery to store our BTUs! Typically the solar panel heats a tank of water until it reaches 150º F or 160º F and then stops working. As the water temperature gets higher and higher the amount of heat collected gets less and less because the temperature difference (TD) across the heat exchanger gets less and less. While heating glycol to heat a wine tank we want the glycol to be 100º F. It goes out at 100º F and returns at 90º F. If we send the 90º F glycol to a solar panel it has a high TD and therefore a high efficiency. The surface temperature of the solar panel will reach over 180º F on a typical summer day. This gives us a TD of 90º and we pick up 75,000 to 100,000 BTU/DAY/PANEL. If you had a 3,000 gallon tank of wine and wanted to heat it from 50º F to 70º F it would take about 500,000 BTU. Five panels could heat the tank in one day! Is it cost effective?

1 panel = 100,000 BTU/Day	=	1 Therm
1 Therm/Day x 365 days x 50%	=	182.5 Therms/Year
182.5 Therms/Year	=	200 gal propane
@ $2.60/Gal	=	$520.00/Year/Panel

Estimated payback to be 3 to 5 years !!!
Panel Life is 15 – 20 years

BARREL ROOM COOLING

Barrel Rooms are usually 58º F and cooled with mechanical refrigeration. If the room is humidified and you are using air conditioning equipment (A/C) for cooling you are wasting a lot of energy. Air conditioning systems by design are de-humidifiers. As you humidify the room the A/C equipment runs and runs removing the humidity. Then your humidity system runs and runs putting humidity back. Years ago we saw a system with (11) roof top A/C units and (7) humidifiers inside the room. Water was pouring out of the drains of all the A/C units. A properly designed system would have oversized heat exchangers that cool the room without removing the moisture.

Another problem with A/C equipment is freeze ups. The equipment is not designed to operate below normal room temperature. When a room gets to 60º F they freeze up and stop operating. This happens all the time to the wine libraries that try to operate below 60º F.

COOLING FANS

Cooling fans should only run on demand unless you are doing barrel fermentation. When the fans are off the air does tend to stratify. It is a good idea to have two temperature sensors, one high and one low in the room. It is also possible to have cooling coils with multiple fans or VFDs. You can slowly circulate air 24/7 and turn all the fans on while cooling.

NIGHT AIR COOLING

Night air cooling has its pluses and minuses.

On the plus side you can use vent fans to pull outdoor air into the room when the outdoor air is about 5º colder than the room. Night air without mechanical cooling requires two things to work well. 1. The room must be insulated extremely well. 2. It must be full of product. The product acts like a fly wheel to keep the room cold during the day. An empty room will not hold temperature.

On the minus side night air is dry air. Well yes and no. As air cools down it reaches the dew point where water drops out in the form of condensation. At this point it is low in temperature and has 100% relative humidity (RH). When this air is pulled into a barrel room it starts out as say 45º F and 100% RH. As it warms up to 58º F the humidity is now 60%. The key word here is *relative*. Humidity is not a quantitative value it is a relative value. As you cool air the humidity goes up until it reaches 100%. If you cool it more the water will condense out. Now take this air and heat it without adding any water and the humidity goes down. To de-humidify a room without changing its temperature you must cool the air to 100% RH to remove the water then heat it back up to room temperature. When night air cools a room without humidification the air takes moisture from the barrels and we all know what that means! You also want to operate CO_2 exhaust fans as little as possible. One last suggestion: Keep The Doors Closed!

CASE STORAGE COOLING

The same things that apply to the Barrel Rooms apply here except for the concerns about humidity. Here night air cooling is great as we want to keep the humidity down. Rainy days can be a problem.

CAVE COOLING

When caves first became popular we thought they were going to put us out of business. What a surprise to find that caves presented a new set of problems that needed to be solved. Most caves seem to run a little too warm. They stay at 63º F or 64º F and we are looking for 58º F. As caves got larger and complete wineries were built inside the cave we needed to add large fans for ventilation. These fans can bring in outdoor air as warm as 100º F on a hot day. Some caves are cooled by taking outside air and cooling it before it enters the cave. To do this 100º F outside air must be cooled to 50º F which is a large cooling load. A better way is to re-circulate the air inside the cave and only cool the outdoor air necessary to vent the cave. With this system you are cooling 60º F return air to 50º F so the load is 80% less.

SUMMARY

1. Insulate before you refrigerate
2. Have regular preventative maintenance
3. Lower the compression ratio of compressors
4. Never set glycol temperature lower than neceessary
5. Check compressor un-loaders
6. Glycol pumps should not operate 24/7
7. Install variable speed drives
8. Lower condenser pressure control settings
9. Consider chiller heat reclaim
10. Consider solar heat reclaim
11. Consider solar electric
12. Do not use A/C equipment to cool barrel rooms
13. Cycle cooling fans in demand
14. Put large cooling fans on VFDs
15. Keep cave vent fans from heating the cave