Evaporative Pre-Cooling of AC Condenser Coil for Improved AC Efficiency

Summary:

This is an attempt to increase the cooling capacity of a standard household split air conditioning system while reducing energy usage. This is accomplished by evaporative cooling of the air entering the condenser (outside part) unit. The lower temperature air allows the condenser to operate at a lower temperature and pressure. The reduced pressure allows the AC compressor to pump additional refrigerant and decrease the energy usage. Some aspects of the project may be of interest to those not using precooling such as the water level control and methodology of adding system hysteresis using mechanical relays.

Purpose:

The purpose of this is to increase cooling capacity when the outside temperature is high.

As the summer of 2012 has been warmer than average, my home a/c unit has performed poorly. Initially, when the house was purchased, the a/c has a difficult time maintaining a reasonable comfort level. The furnace fan speed was increased which decreased temperature but increased humidity. On 95 + degree days the house was not comfortable, 75+ degrees and humid.

2 years ago, the attic had 80 bags of cellulose blown overtop of the blown fiberglass (fiberglass is probably compressed and not insulating much) which has made a significant improvement in heat gain / loss. The a/c unit will now hold 68 degrees on 100+ degree days (running nearly constant) but leave humidity at over 50%. The a/c system runs constantly on the hot days. Several days measured 100-110 on both the normal outside thermometer and a fluke infrared thermometer when pointing at items in the shade.

It is difficult to justify the cost of upgrading to a newer a/c unit. Therefore, something else needs to be done to either reduce heat gain or increase cooling capacity.

Solutions need to be low cost and not take up much time as free time is presently limited.
Some options:

1) Reducing heat gain.
As the attic has about a foot of cellulose, there is little room for improvement in the attic.
Reduce air leakage. The ½ exposed basement probably has the most air leaks of the entire house. This is a time intensive project that is on the todo list.

2) Improve the a/c system output by reducing a/c condenser temperature and therefore the liquid temperature.

This is a known method of increasing cooling capacity and reducing energy consumption. A search of commercial home systems for the most part yield low pressure water spray systems that directly wet the condenser. While this was done at the house for a day when the condenser fan broke and would help in the short term, there is a high risk of plugging the air fins with minerals from the water. One high pressure system than produces a fog is available but it is targeted for large systems and costs accordingly.

Evaporative Cooling

Evaporative cooling is used in dry climates to cool entire homes. This easily reduce temperatures by 30 degrees or more but requires very low humidity (<20%) to be effective and comfortable. These systems utilize a porous pad to hold water while blowing air through the pad and a pump to pump water from the bottom back up to the top. A float refills the reservoir as it empties. These units are commonly called “swamp coolers”. They cool a house for less than ¼ the cost of air conditioning. These systems require maintenance: winterizing and occasionally replacing the evaporative media.

A look at www.weatherspark.com indicates that my climate typically has a relative humidity less than 30% during the peak of days exceeding 90 degrees. The humidity increases quickly as the temperature drops at the end of the day. As this climate also has many days with much higher humidity, a standard “swamp cooler” is not an option for the house. See the swamp cooler chart in Figure 1 f or recommended climates. I am located in northern Illinois, zip code 61084.

Temperatures Delivered by Evaporative Coolers

% Relative Humidity

Air Temperature	2	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
75	54	55	57	58	59	61	62	63	64	65	66	67	68	69	70	71	72
80	57	58	60	62	63	64	66	67	68	69	71	72	73	74	76	76	77
85	61	62	63	65	67	68	70	71	72	73	74	75	76	77	79	81	
90	64	65	67	69	70	72	74	76	77	78	79	81	82	83	84	86	
95	67	68	70	72	74	76	78	79	81	82	84	85	87				
100	69	71	73	76	78	80	82	83	85	87	88						
105	72	74	77	79	81	84	86	88	89								
110	75	77	80	83	85	87	90	92									
115	78	80	83	86	89	91	94										
120	81	83	86	90	93	95											
125	83	86	90	93	96												

Optimum conditions for Evaporative Coolers

Source: Ed Phillips, Arizona Almanac

Figure 1: Swamp Cooler Chart

The evaporative cooler works on the principle that the energy necessary to evaporate a pound of water (heat of vaporization) is 970 btu while the energy needed to increase the temperature of a pound of water by 1 degree is 1 btu. . To simply cool a pound of water takes 1 btu. Therefore, significant amounts of energy can be transferred from air to water by using the energy in the air to evaporate water. Furthermore, the temperature of the water is not terribly important as reasonable amounts of water cooling can occur and only take a few percent of the total evaporative energy gain.

From Figure 1, it can be seen that at a relative humidity of 20-30% that 15-20 degrees can be lost by the evaporative process. If this could be used to reduce the air conditioner liquid temperature by 15 degrees, the pressure would drop from 242.8 to 196 PSI when the liquid (115 degrees to 100 degrees). The corresponding reduction in pressure will reduce energy necessary to compress it and at the same time, increase output. A search of a 30,000 btu piston compressor on Copeland's (cr30k6-pfv) website showed the EER increasing from 10.9 to 17.7 by reducing liquid temperature from 115 degrees to 85 degrees as seen in Table 1. A search for "R22 pressure vs temperature" can be used to find the actual pressure vs temperature curve.

Copeland cr30k6-pfv, R22	Condition 1	condition 2	
evaporator temp	45	45	Change:
condensor temp	130	100	
RG	65	65	
liquid temperature, Deg F	115	85	30
btu output / hr	30000	39200	130.67%
Power Used (W)	2750	2210	80.36%
amps	13	10.7	
refrigerant lbs / hr	439	505	115.03%
EER (btu out / w in)	10.90	17.7	162.59%

Table 1 AC efficiency improvements

It was decided to attempt to fit the air conditioner condenser unit with evaporative cooling.

Planning and Construction:

<u>Evaporation Media</u>

The most critical part of the system is the evaporation media. Swamp coolers use various types of media to evaporate the water. Some options are: wood shavings (Aspen Pads), Polyester "Sponge Pads" such as "DuraCool", and Rigid types: Cellulose and Metal.

Aspen and "sponge" pads require frequent replacement. Sponge pads did not perform as well as Aspen pads. Metallic pads were quite expensive.

Cellulose media made with what is best described as waves of paper bag material. The waves are bonded together to make a brick of paper that air flows through. It also has water channels vertically to allow water to flow down. Cellulose media is for the most part cut to size before shipment though standard sizes ale listed for sale. It is specified by height, length, and thickness. Thicker pads allow for greater evaporation and / or airflow. The cost of the media is basically for the volume purchased (cubic inches).

Airflow through the condenser is small compared to typical evaporative coolers. With 18 sq ft of evaporative pad surface area, the airflow speed will also be well below the normal use of the pads. Accordingly, I chose to use 4” thick material. The air conditioner is 3’ tall and has a useful circumference of 5’.

As my condenser is round and the pads are flat , they do not cover it perfectly. Six pads were required to cover the condenser. They were purchased from http://www.mfmca.com/storefront/c-7-energy-saver.aspx and arrived in about a week. Some good information as to efficiency vs airflow and thickness is found at http://www.piec.com/premier%20cooling%20media%20specs.htm

A search for greenhouse evaporative media should find many sources of cellulose media.

Media Frame:

The media needs to be held in place around the condenser unit. It is also desirable to have a gap between the media and the condenser to keep water from flowing from the frame to the condenser. 1” plastic water tube was used to space the frame from the condenser. Treated 2x4’s were used at either end of the frame and had the plastic tube and other materials stapled or screwed to it.

The media needs to have a water collection device below it to return the excess water to the pump basin. Excess EPDM rubber was used for this purpose. Square A/C units would permit the use of plastic bins.

The media should be shielded from debris, animals, and bugs as best possible. For this, 1/8” wire mesh was chosen. It was to be wrapped around both sides of the media.

The media frame first had the inner plastic tubes screwed to the inside of each 2x4 at the top, middle, and bottom. The frame was then stretched around a couple of tires (same diameter as a/c unit) and tied together at the end.

Next, the wire mesh was fastened to one 2x4 and zip tied to the plastic tubes. It was then fastened to the other 2x4. The media was inserted. The mesh was then wrapped around the media and fastened to the other 2x4. Note, the 8” of extra diameter on the outside x PI and the 8” of mesh used at the 2x4’s when calculating the necessary mesh.

1” water tube was then put around the outside of the assembly to give some support to the mesh. It also provides for a mounting place for the top cover and bottom rubber piece.

The rubber piece was stapled to the bottom plastic tubes so that it retained water. A thick plastic sheet probably would have been easier to work with. 1" plastic spacers made of synthetic deck material scrap were placed under the pads to keep them off the rubber bottom.

Used tank tops were used to distribute the water. They were placed on top of the pads. A vinyl hose was put through the 2x4's run in the middle of the mesh, above the pads. It was held in place by nylon string in a few places. 3/16" Holes were drilled in the bottom of the tube every 1-2 inches. This allows the water to flow to the pads. The end of the vinyl hose was returned to the pump bucket. An air bleed was placed in it to keep air from being sucked into the last several inches of water outlet holes.

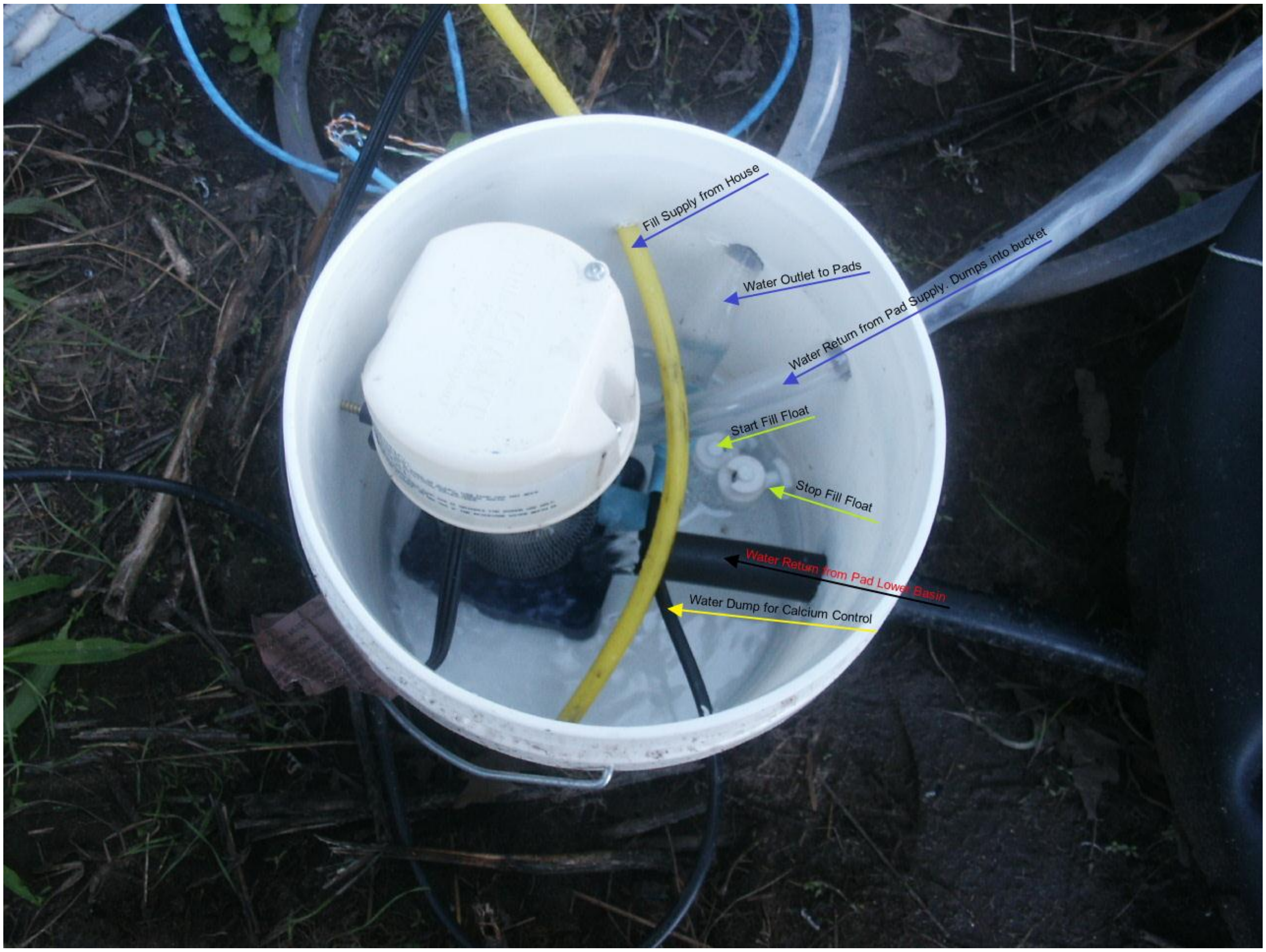
The cooler assembly was made inside and then put around the condenser unit. Note the string used to hold it together. This will be used to hold it around the condenser.

The cooler was placed around the condenser unit.

Water System:

The water delivery system consists of a water supply, water pump, 2 floats switches, water dump tube, water outlet tube, precooler collection return tube, water valve, and excess water return tube. The pump selected was a “Little Giant 540005 CP1-115 1/70 Horsepower Evaporative Cooler Pump”. Note that pumps are available for both 120v and 240v systems.

A small bucket was used to hold excess water, the pump, and floats. Holes were drilled as needed. For the 1” return tube from the rubber basin, a ½” piece of copper pipe was sharpened and used to cleanly cut a hole in the rubber. This allowed the plastic tube to be slid in the hole and it sealed perfectly. In addition to the pump outlet water going to the top of the pads, some is diverted to a ¼” OD tube to bleed to the ground. The purpose of bleeding some water is to limit mineral buildup. As water evaporates, the dissolved mineral content stays behind. If the minerals are never removed, the media will eventually clog and need replacement. This mineral rich water could easily be put to good use if water was scarce. The bucket also had 2 overflow drain holes that will leak water to keep the water level below that of the pump motor.



Once operational and working, plastic was put over the top of the pads and the bucket sealed with a lid:

The water system works as follows:

When the air conditioner turns on (24vac on the Y wire) a solid state relay turns on the water pump socket. The pump pumps water from the bucket to the pads. As the water level in the bucket falls below the BOTTOM float, a relay is activated that turns on an electric solenoid. This solenoid allows water to flow from the water system to the yellow hose. This fills the bucket. A second float (higher up) is used to turn OFF the solenoid relay when the water level is above the float. A manual valve was placed before the solenoid to allow adjustment of the water flow rate and minimizing water “hammer”.

The turn OFF float was positioned so that it turned off when the water was just above the basin drain tube. This increases the water volume between on and off so that it is not turning on and off too quickly.

A mechanical float was considered to regulate the water level. Something similar to a toilet float would work if room existed below for plumbing. A stock tank float was desired but not available at the hardware store visited. After getting the expected “you want what” look at a hardware store, they found an aquarium float that would have worked but cost about $40. This lead to the electric float / solenoid scheme.

While electrical valves and solenoids were used to control the water level, typical swamp coolers use a mechanical float and would simplify the electrical wiring. A search for “pond auto fill valves”, “stock tank valves”, or “swamp cooler float valves” should find many relevant mechanical floats. Many of the valves mount through a side hole in the basin. Some are similar to a brick that is dropped in the basin. One specific example of a side mount valve is “Dial Mfg. 4153 Float Valve” and costs under $10.

Electrical:

Refer to the schematic for the precooler. The schematic contains both electrical and plumbing systems for the house solar system, a/c precooler, and humidification / dehumidification systems. The schematic shows some parts that are intended to be added but are not at this time. See SW3, X10_1, TSW1. These parts are bypassed if not installed. The contacts of bypassed parts can be considered to be shorted together.

A couple of notes: wires labeled AC_NEUT is the 24vac system neutral wire. VACNeutral is the 120vac neutral wire. The ground symbol is a earth ground and is connected to the solar 12 volt power supply negative lead. Positive 12 volts (DC) comes from the solar system power supply. This is an old computer power supply.

Due to the solar thermal system installed in the house, the furnace thermostat is a high end White Rogers 1F95-1291. This thermostat is meant for a 2 stage heat pump with 2 stages of backup heat. The second stage of cooling is labeled Y2. When Y2 is active, Y stays active. Additionally, the thermostat controls winter humidification and summer dehumidification if properly wired.

The furnace thermostat Y wire is the first level of air conditioning request. This is used to enable the precooler system. The a/c system has a utility cutout installed which allows them to turn off the a/c during high demand for 3 hours / day. This is done for a $10 / month credit during the summer. This is listed as SW3 in the precooling schematic. The Precool enable signal is run to both floats and the pump relay. The pump is plugged in to a “in use outdoor outlet” that also has a GFCI to protect against shorts to ground.

The floats used are normally open, and magnetically triggered. They were purchased off eBay. This sensor was installed above the body as this was the open position. They are called “liquid Level Sensors.”

The electric solenoid used was originally a LP (propane) solenoid from an industrial engine, model N-0165. Similar products should be easy to source that are meant for water. As a water flow safety, it may be useful to have 2 solenoids in line: the second would be activated by the Y wire so that water would be turned off when the a/c is not running.

Solid State Relays controlled by 24vac:

Solid state relays are typically used to switch 110vac circuits and are controlled by a DC voltage. They do not control DC voltage unless specifically indicated to do so. To control them with an AC voltage, a bridge rectifier is necessary. Furthermore, to work well at 24vac, a small capacitor is needed across the + and – terminals to keep it turned on completely. See the system schematic for more information.

Mechanical relays:

Most mechanical relays will turn on at one current value (make current) and turn off at a lower value (break current). This was used to add hysteresis to the water solenoid. The lower float was used to apply 24vac to the fill relay when the water was below the float. The upper float turned on when the water level was below it. The upper float was wired apply 24vac to the relay through a resistor. The resistor was sized so that the relay current was ½ way between the make and break current levels. This allowed the lower float to activate the water flow. It then stayed on until the water level was above the top float. The relay used (Packard PR370) turned on at 90mA and turned off at 20mA. The resistor chosen provided for 45mA of “hold” current.

A variable voltage DC power supply with an inline ammeter can be used to determine the make and break currents for both AC and DC relays. If applying the current level to an AC relay, note that the inductive nature of the relay will cause the current flow to be out of phase with the voltage. For this reason, simple V=IxR ohm's law will not yield the proper resistance value to use for a hold resistor. It is probably easiest to simply experiment with resistor values to obtain the necessary value. The necessary resistor will be smaller than ohm's law will dictate. Note, AC or DC relay refers to the coil rating, not the contacts.

It was discovered that other relays consume much more current than needed. A Packard PR340 relay consumed 0.5 amps (24vac). This relay had a make current of 180mA. The newly incorporated dehumidification system used 2 of these relays. As the current output rating of the 24vac system was not known, 55 ohm resistors were inserted in series with each coil. This reduced the current to 200mA.

Dehumidification:
While not directly related to the precooling, the thermostat dehumidifier output was connected to the system at the same time as the installation. This is wired so that the medium blower speed will be used by the furnace for dehumidification and high for full output. Medium is commanded IF Y is ON, and Dehumidification is requested but NOT full coooling (Y2).

Cost

The pads and GFCI outdoor outlet were the majority of the cost. Many of the items were excess from other projects.

	Cost	
pads	91.2	Metal form
fence	30	1/8" mesh, 3' x 16'
electric	65	Menards
pump	20	amazon
plumbing	40	misc parts
floats	10	ebay
relays	10	ebay
solid state relay	5	* had
rubber	20	* had
1/4" 3/8" 1" plastic tube	3	* had
tank tops		* on the shop rag pile
plastic roll	$0.25	* had
2x4's, treated	$2	* had
staples	$0.20	* had
screws	$1	* had
bucket	$2	
electric valve (N3-0165), LP shutoff valve	$20	* had

Terminal Strip	$8 ebay
Total	327.65

Performance:

The system consistently reduces condenser incoming air temperature by 15 degrees. Using a Fluke thermocouple temperature meter, the following measurements were taken late afternoon on a late July day:

outside air temperature of 95.3
pre cooled air was 80.7.
Air exiting the condensing unit was 98.5.
Water in the bucket was 75.7.
The house thermometer read 100 degrees and 23% humidity. This is on the south side of the house while the condenser is on the east.

Other measurements have not been taken. I do not have the means to measure furnace airflow so calculating BTU's of cooling or EER is not feasible. If airflow was available, temperature drop and water output volume would be needed to determine cooling output. Voltage, current, and phase angle would be necessary to measure system power.

Previously, condenser unit current was measured to drop by 2-3 amps from 13-14 (220v) when the condenser was flooded with a hose. It can likely be assumed that less current indicates less power consumed.

This a/c system has a capillary tube metered evaporator which is least able type to adapt to the cooling demands. What a reduction in line pressure does to the refrigerant flow through the condenser is not something I know the answer to. It likely reduces it but to what extent? If a thermostatic expansion valve was used, it likely would be able to better use the additional capacity.

The house feels more comfortable. The thermostat has been bumped up a degree or two. The A/C system seems to reduce humidity better and also cycles on the hotter days.

A psychrometric chart of the precooling process is shown below for the measurements taken on the 100 degree day. As the air humidifies through the pads, it follows the blue line as water evaporates and cools the air. As it goes through the condenser, it follows the red line as it warms up. This could also be plotted on a Mollier chart to show the changes in the refrigeration process. The Mollier chart would have a the upper process line (condensing) moved down to a lower temperature. The lower process line (evaporating) would likely be moved down but that depends on the A/C system.

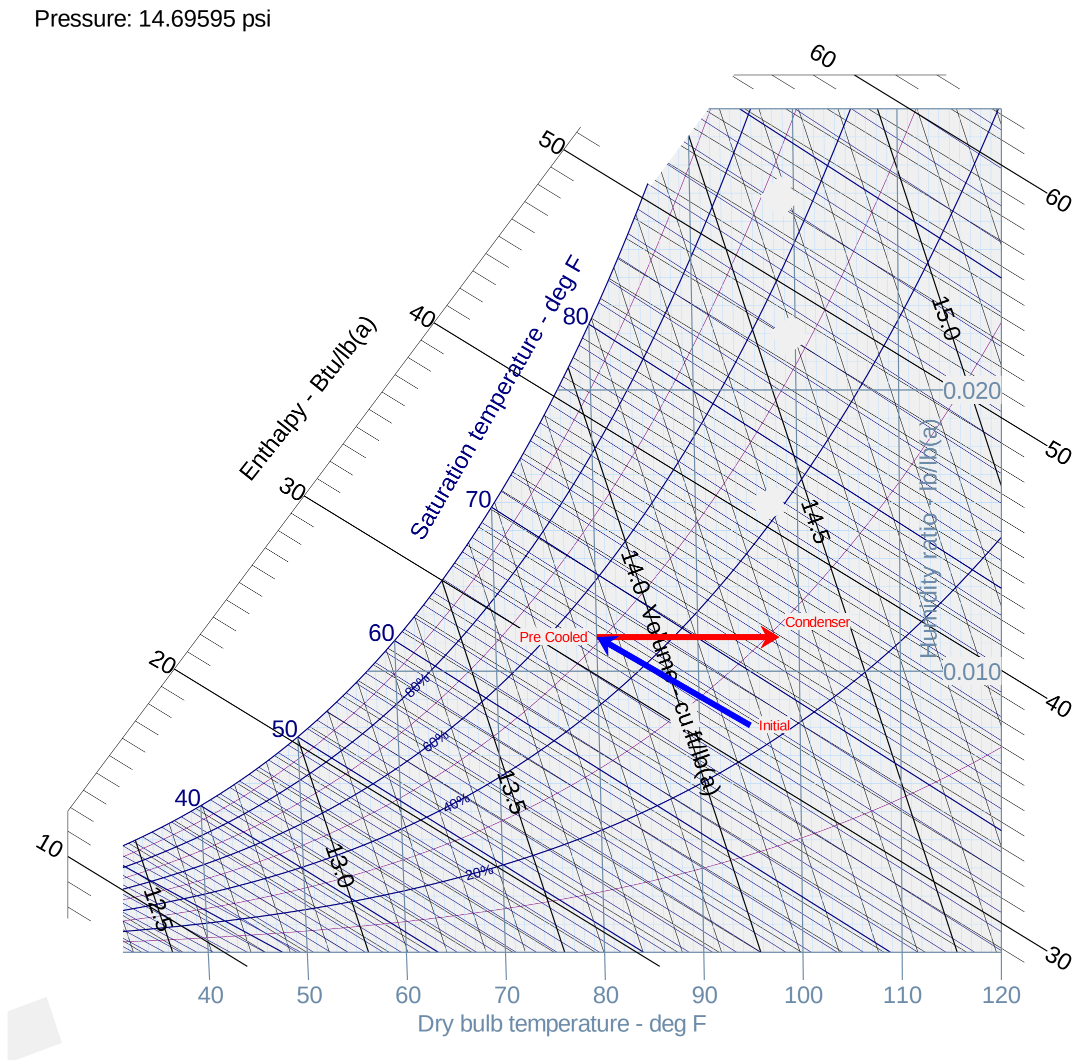


Figure 2 Psychrometric Chart

Winterizing

At minimum, the water should be drained out of the system and the pump removed.
I plan to remove the entire pad / frame assembly and bucket minus the tubes from the house. The floats are wired to an industrial quick disconnect.

Chad Clendening
Clendenc@gmail.com