David Sellers

From: David Sellers
Sent: Wednesday, January 29, 2014 2:20 PM
To: 'Stroupe, Ryan D'
Subject: RE: Fwd: PG&E PEC - Chilled Water System

Hi Ryan,

Pretty sorry state of affairs when the control contractor says they can't read someone else's code, especially when we provided a programming manual.

In my day, we read other peoples cryptic code and we liked it.

I realize that you generally don't have time to deal with a lot of information, which is what I tend to provide because it's how I think and what I do. But in this case, there really are a lot of things that come up that I would be remiss not to somehow offer some advice on. To try to minimize the effort on your end in dealing with this, I am creating a list of the key issues that I think need to be considered here at the beginning having thought things through pretty thoroughly at this point. I will follow that with links that jump you to topics of interest as they relate to the key points.

I also wanted to reiterate that I did this of my own accord and "the meter was off". The development taught me a lot since I have not really had the opportunity to think through the merits and metrics of ice storage in detail for a long time. The topic comes up in classes occasionally - at the PEC, at U of W, and in other venues like the blog, etc. and this puts me in a better position to address questions and bring things to the table, including some interesting interactive type exercise where the class and I think through these things. But I also did it because as I got into it, I realized that there truly were some issues that need to be considered, some of which will come up indirectly if they are not addressed directly (meaning they would be even more of a pain in the butt for you) and others of which might influence how the logic was written in light of future improvements or modifications.

Of course, I would be happy to simply do a call/GoToMeeting with you to go over this; that may be more expedient since we could dialog and maybe focus the discussion based on your questions.

That said, this all got pretty interesting as I started to think my way through stuff; pretty good fodder for some interactive exercises and examples for the control logic class and retrocommissioning workshop and project review, the chilled water class, RCx 101, and stuff I have coming up at U of W and Palo Alto. So I think there is some broader benefit beyond trying to get the controls working at the PEC.

Key Issues

- Depending on exactly how ALC is integrating their system with the chiller, there may be some significant limitations regarding what you can do to manage the chiller and the ice making operation. From what I have been able to tell from past observation and poking around and some research as I wrote this, most of the logic managing the ice making process was handled via network level operations that were happening in the Trane system. Meaning the logic was written and running in their network controllers and/or firmware and was passed to the chiller over the network. Similarly, the controllers with logic in them received operating information from the chiller via the network, not via independent sensors. Certainly, that is what the Trane control drawings would imply; the chiller submittal is less clear in terms of things that might be there that were not directly used by Trane to control the system.

- The economics of making ice vs. making chilled water have likely changed since the original design and sequence was developed and probably since Ross looked at the system. For one thing, there is now partial peak periods and the sequence seems to only be written in the context of the peak period but not the partial peak period.

- The control sequence as written probably intended to favor energy and demand costs over ensuring comfort by allowing fan discharge temperatures and such to drift before making decisions about starting compressors and things like that. But a couple of points:

1. We put in HVAC to deliver comfort, so to some extent, you have to decide what you are willing to give up in that regard in favor of saving $. Ice storage (in my opinion) generally will not save energy at the building level; it's something we do at the building level to benefit the larger picture and for that we receive a financial reward if we don't screw up. The analysis I have done kind of says that the difference between the cost of running conventionally and the cost of using ice may not be that significant a lot of the time, so that might influence what you think about sacrificing comfort. That also may mean that if you screw up at all, you lose your financial reward; that's a bigger deal with a ratcheted demand structure but I also think it could happen in this structure if you were not careful and if there were only minor advantages to be gained that required fairly flawless logic and near design performance from the machinery under all operating conditions.

2. Some of the analysis I did says that the time delays might actually cost energy on other fronts in addition to having significant comfort impacts. So you might get all of the negatives (complaints and cost) and none of the positives (comfort and savings) if you were not careful.

- There are a number of things that are simply not good practice in how the sequence is written; for instance shutting the chiller and pump down together with a single command or via the flow switch. That sort of thing can set up a number of potential problems that show up as nuisance issues like I believe you are already dealing with and/or that ultimately could ruin something.

So, I think what all of this means is that there really are some ways to improve the ice storage sequence based on what the building has told us and what it might tell us if we ask a few more questions. Areas were I think we might want to make changes/questions we might want to ask include:

- What does it cost to making a ton hour of ice off peak with a cold evaporator (bad) but a cool condenser (good) vs. making a ton of chilled water on peak or partial peak with a (relatively) warm condenser but a warm condenser vs. moving more air. I suspect it would not be too hard to get in the ballpark on this by adding some columns to the spreadsheet behind the graphs above (attached) and then playing with the flow and temperature parameters. I took a stab at general costs which I share below.

- Having a spreadsheet or graphic that lets someone plug in current utility rates, demand schedules, and a load profile to figure out what makes sense currently. Having this be a graphic in the system is maybe the next step in terms of operator usability and modeling things for others to learn from.

- How long does an tank full of ice last on standby? Meaning if we made a full tank of ice, how long would it be able to provide meaningful capacity. I think this might be important for mild weather, where you might need a little bit of mechanically generated tonnage to make it through a peak during the peak demand window; not many tons and not for long. So, it could be that making a tank of ice on Sunday and then using it over the course of the week as the first step in mechanical cooling would make sense. But if the ice melted due to standby losses and you have to make it several times before you used it, things could go the opposite way.

- Is a flywheel cycle that leveraged the thermal flywheel of the chilled water piping without consideration for the ice storage better than simply melting ice on days when the load would short cycle the chiller and/or on low cooling demand days as a way to minimize peak demand by limiting the number of compressors allowed to run?

Of course, all of that leaves us with what to do now. One option would be to just have ALC write the code per Ross's sequence with modifications as suggested by your development. For what they are worth, I have inserted notes for your consideration into what you sent to reflect my thoughts, which are mostly in the context of the other information I have included. I color coded them so you could find things a bit more readily as follows;

- comfort - blue highlights,

- operational/demand/energy issues - green highlights, and

- safety issues - red highlights

No matter what, I suspect that even if ALC simply took the narrative you developed from Ross's stuff and turned it into logic, they would realize there were some holes. It would be in everyone's best interest if we encouraged them to get in touch with one of us with those questions vs. making a decision without some input.

Or, we could discuss this a bit and include narrative that started to address some of the issues I think I might have identified in my analysis. I will leave that final call to you; I'm happy to work with you either way on this. I know you are not looking for things to do, but I also know you want the facility to be a model for what to do for the rest of the industry, which is why I bring all of this up.

What follows after my signature is the detail supporting the items above. After that comes your e-mail with my color coded insertions. This links will jump you to key topics; each topic has a link at the end that will bring you back here

- .Chiller Interface Issue
- Ice Making Economics
- Sequence Intent vs. Realities
- Best Practice/Safety Issues
- Comments on the Proposed Sequence

I included a "Back to Contents" link periodically in my comments on your sequence so you could jump back here and then jump to the appropriate discussion topic to understand the reasoning behind my comments.

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A Field Guide for Engineers at http://av8rdas.wordpress.com/

Chiller Interface Issue

What's not totally clear to me from the information I have (basically, the Trane control drawings and the chiller submittal) is which options were provided beyond the basic control package. I will send you a copy of the chiller submittal so you can see what I am seeing via YouSendIt/Hightail (too big to attach plus I will be including a few other things I reference). The chiller submittal implies that all we may have available at a non-network level to run the chiller is:

1. Start Start/stop control

2. Flow interlock

3. External interlock (if triggered would require a manual reset so a safety interlock)

4. kW demand limit

There may also be:

1. An input that would allow a 4-20 ma signal to reset the chilled water temperature.

2. Remote alarm annunciation contacts (2; I think you can program them to close based on a number of different things like compressor failures, compressor operation, etc. but would have to do more research to figure that out).

3. An input (contact closure) that causes the chiller to go into an ice making mode. In that mode, it will run all compressors at full capacity until the return fluid temperature hits the ice making set point, which is an internal set point.

I may be able to tell more if I had a high resolution picture or pictures of the Trane chiller controller boards. I have looked but I do not have any. If you wanted to send me a couple, I can see what I think.

That said, as you can see, there are a number of things that are called out in the sequence that you could not directly control. For instance, there would be no direct control over the number of compressors that were allowed to run. You may be able to accomplish that with the demand limit somehow along with some functional testing.

So the point is that while managing the ice making strategy is not impossible with ALC, it may be limited by the hardware. Some of this comes down to how ALC made the interface. I suspect that might be limited by hardware availability on the Trane side. If they made a network level interface, that may help, but this unit may be of a vintage prior to Trane adopting BACnet as their communications protocol standard. So the objects you can map across the interface may be limited.

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Ice Making Economics

Underlying all of this to some extent is the economics (financial and source energy) associated with running off peak with low evaporator temperatures (bad in terms of efficiency) but low condensing temperatures (good in terms of efficiency) vs. running on peak with the opposite conditions. It gets surprisingly complicated despite being sort of simple in concept. Things I suspect come into play include:

- The cost of making a ton hour of ice off peak with a cold evaporator (bad) but a cool condenser (good) vs. making a ton of chilled water on peak or partial peak with a (relatively) warm condenser but a warm condenser.

- The relatively mild nature of the San Francisco climate, meaning that even during peak demand hours, you often will have relatively cool condensing temperatures and thus relatively good compressor efficiency compared to what happens with similar condensing temperatures but an evaporator at ice making conditions.

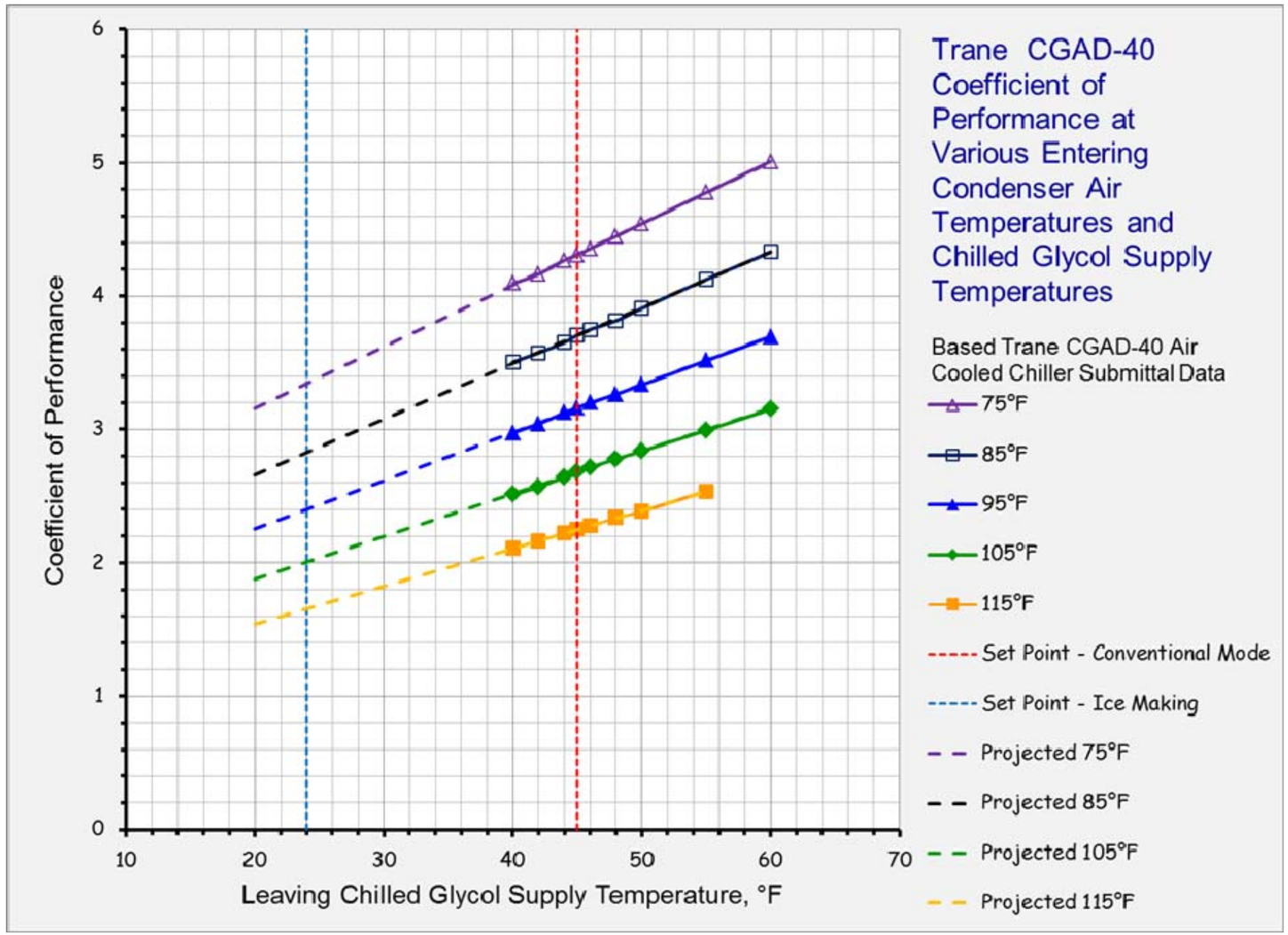
- Actual performance as installed vs. theoretical performance of the chiller and the chilled water coil.

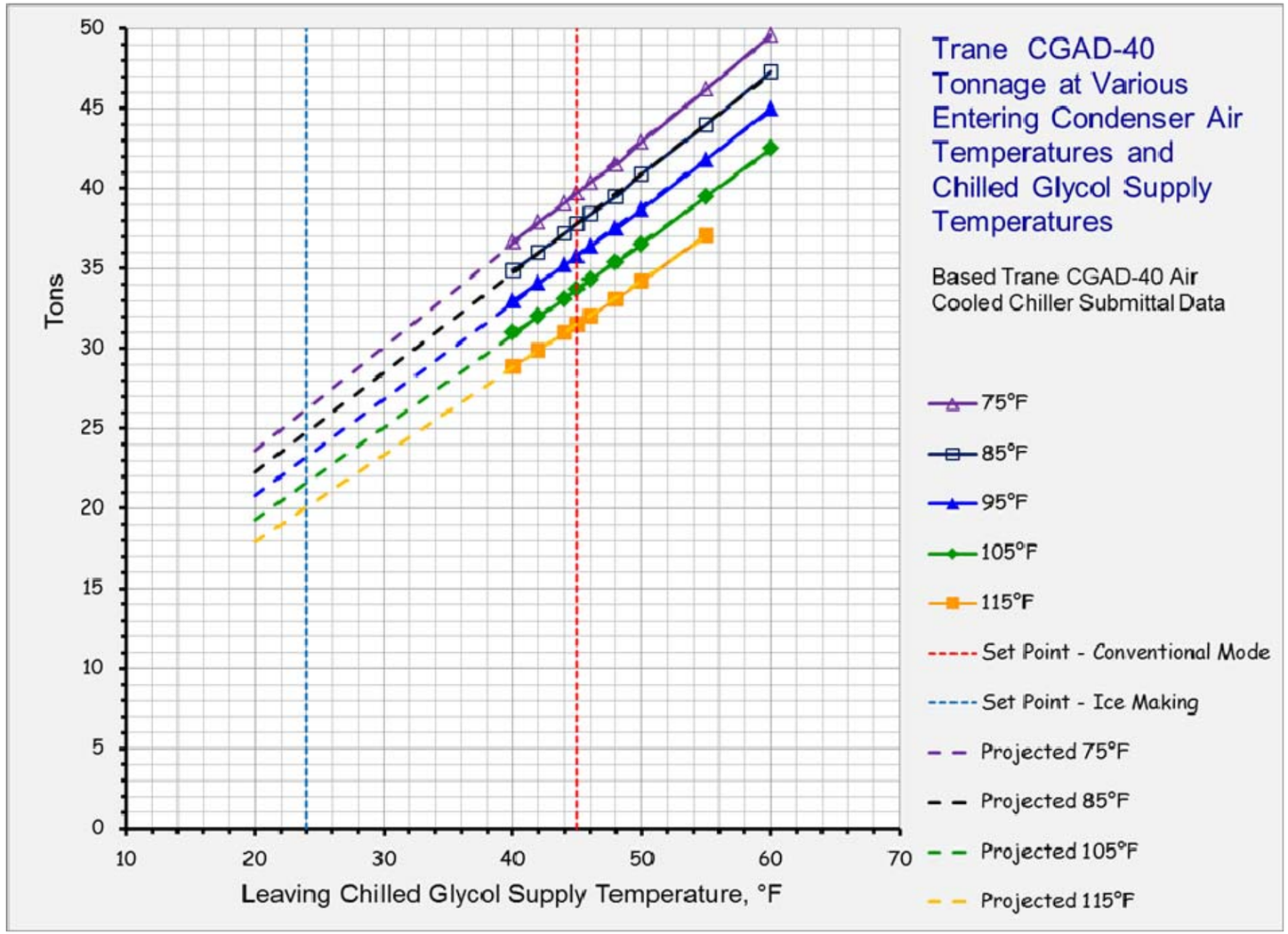
- Actual performance 20 plus years later vs. theoretical performance of the chiller and the chilled water coil.
- The value of fan energy vs. cooling energy to create ice vs. cooling energy to create chilled water, meaning that one way to deal with more load with a given supply temperature is to move more air. Meaning that one way to deal with losing the load because the supply air temperature is getting to warm is to move more air (vs. making the air colder).
- The value of using fan energy to pre-cool the building (store cooling in the thermal mass) vs. moving more air on the economizer cycle vs. running mechanical cooling to peak vs. melting ice to peak.
- The ability of the control system to measure the critical parameters accurately and persistently and make the right decision.

All of that said, I would bet that the economics of the system have changed since the original design analysis and since Ross's analysis.

I would also bet that the performance of the equipment has changed since it was new due to the effects of aging in a somewhat marine like environment for both the condenser coils and the AHU coils. I also would not even be surprised if performance was never per the factory specs, mostly because of the low ambient dampers on two of the condenser fans (which I think we don't need and only work against us but which is harder than you might think to get rid of since I believe it is powered by refrigerant/condenser head pressure, vs. a control signal).

To try to get a feel for how all of this might look with the current rate structure I took the chiller performance data I have and the new rate schedules and did a bit of math to see what it looked like. I will include the spreadsheet but here is the pertinent data information in terms of performance.


Trane CGAD-40 Coefficient of Performance at Various Entering Condenser Air Temperatures and Chilled Glycol Supply Temperatures
Based Trane CGAD-40 Air Cooled Chiller Submittal Data
75°F
85°F
95°F
105°F
115°F
Set Point - Conventional Mode
Set Point - Ice Making
Projected 75°F
Projected 85°F
Projected 105°F
Projected 115°F
Coefficient of Performance
Leaving Chilled Glycol Supply Temperature, °F
0
1
2
3
4
5
6
10
20
30
40
50
60
70



This, of course, has a few assumptions behind it including:

- The projected performance for low LWTs, which is not documented in the literature.
- The data is based on factory specs vs. performance after being in the field for a number of years in a quasi-marine environment.
- The data probably does not reflect the impact of the low ambient dampers on half of the condenser fans.

All of those things probably mean that the following operating cost projections are best case.

Energy Cost to Charge the Ice Tank (Assumes All Compressors Run at Full Load)	Total		Per Ton-Hour	
Condensing Temperature	75	85	75	85
Summer - Off Peak	$15.05	$17.73	$0.15	$0.18
Winter - Off Peak	$11.26	$13.26	$0.11	$0.14
Impact on Monthly Demand Charge if This Set a Peak				
Summer - Off Peak	$392.63	$441.15		
Winter - Off Peak	$183.97	$206.71		

Energy Cost to Deliver 98 Ton-hours as Chilled Water with All Compressors at Full Load	Total			Per Ton-hour		
Condensing Temperature, °F	75	95	105	75	95	105
Summer - Peak	$14.08	$18.72	$22.07	$0.14	$0.19	$0.23
Summer - Partial Peak	$13.47	$17.90	$21.11	$0.14	$0.18	$0.22
Summer - Off Peak	$11.59	$15.41	$18.17	$0.12	$0.16	$0.19
Winter - Partial Peak	$10.28	$13.66	$16.11	$0.10	$0.14	$0.16
Winter - Off Peak	$8.67	$11.53	$13.59	$0.09	$0.12	$0.14
Impact on Monthly Demand Charge if This Set a Peak						
Summer - Peak	$461.74	$553.57	$614.35			
Summer - Partial Peak	$461.74	$553.57	$614.35			
Summer - Off Peak	$461.74	$553.57	$614.35			
Winter - Partial Peak	$216.35	$259.38	$287.86			
Winter - Off Peak	$216.35	$259.38	$287.86			

Energy Cost to Deliver 98 Ton-hours as Chilled Water with One Compressor at Full Load	Total			Per Ton-hour		
Condensing Temperature, °F	75	95	105	75	95	105
Summer - Peak	$16.65	$21.57	$25.10	$0.17	$0.22	$0.26
Summer - Partial Peak	$15.92	$20.63	$24.00	$0.16	$0.21	$0.24
Summer - Off Peak	$13.71	$17.76	$20.66	$0.14	$0.18	$0.21
Winter - Partial Peak	$12.15	$15.74	$18.31	$0.12	$0.16	$0.19
Winter - Off Peak	$10.25	$13.28	$15.45	$0.10	$0.14	$0.16
Impact on Monthly Demand Charge if This Set a Peak						
Summer - Peak	$136.48	$159.43	$174.63			
Summer - Partial Peak	$136.48	$159.43	$174.63			
Summer - Off Peak	$136.48	$159.43	$174.63			
Winter - Partial Peak	$63.95	$74.71	$81.83			
Winter - Off Peak	$63.95	$74.71	$81.83			

If I am thinking about this right and the numbers are anywhere in the ballpark, then I think they mean:

- Right now, in the winter (meaning winter demand rates) you may be better of just not even trying to make ice, especially if the standby losses from the ice tank are significant. Meaning if you make a tank of ice just in case, and it melts without your using it, then the entire cost of that cycle was wasted and the demand peak it set might be higher than just letting one compressor run when you

needed it. Implementing a flywheel cycle like we developed at Le Conte and using it if you needed some mechanical cooling would probably ensure that you never needed more than one compressor. And, since we have brine, you could charge the flywheel all the way down to 33°F, and probably let it spin up into the upper 60's and still manage the building.

- During the summer (demand) months, in cool weather (low condensing temperatures) you may approach breaking even in terms of running the chiller when you need it vs. making ice. But, some projections based on how the building is working now say that you can probably make it all the way through the partial peak and peak conditions most days on ice, without the need for a compressor, so that favors the ice making a bit because of the demand charges I suspect (more on that in a later section).

So, the point is that if costs are close to the same, there may be some things we can do to simplify the sequence. Those things may be helpful in light of the potentially limited functionality we might have as discussed in the preceding bullet.

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Sequence Intent vs. Realities

The more I thought about it, the more I realized that the systems in the PEC probably do not work in the same way that they did before the new control system was in place. The biggest difference is the air handling unit flow profile, as you know. Previously, the system seemed to run in the 12,000 – 19,000 cfm range a lot and on a heavily loaded day, we would come near the design flow rate. Now, unless we are forcing it with a test, the flow profile is fairly flat and runs in the 8,000 – 10,000 cfm range, (I suspect we can improve on it, meaning give it some shape, by optimizing the supply air temperature reset routine a bit; it may be causing more flow than needed by running at too high a supply temperature).

This seems to be the case even on warm days with a significant usage in the facility. The latter is my observation vs. supported by hard data. I had hoped to verify it with trend data but for some reason, the historical trends don't seem to be available back into the warmer weather for a lot of points. The system acts like they are there but never retrieves them. I'm not sure if that means there is something about the remote interface that hangs up that process or if it is a general issue, but it's probably something to have the ALC folks check out.

In any case, I started working with the data I had to try to see how I thought the system might work. I happened to have a couple of years of San Francisco climate data so I used that to see what the patterns tended to look like. My initial interest was because of the way the code was written to trigger a chilled water pump start. Basically I got to wondering how long it would take the OAT to rise above the current supply air temperature set point by 2°F, or if, on a typical day, it would; more on that in the details of my comments below. What I wanted to highlight here are a couple of observations that I think are important in the context of how the system runs currently.

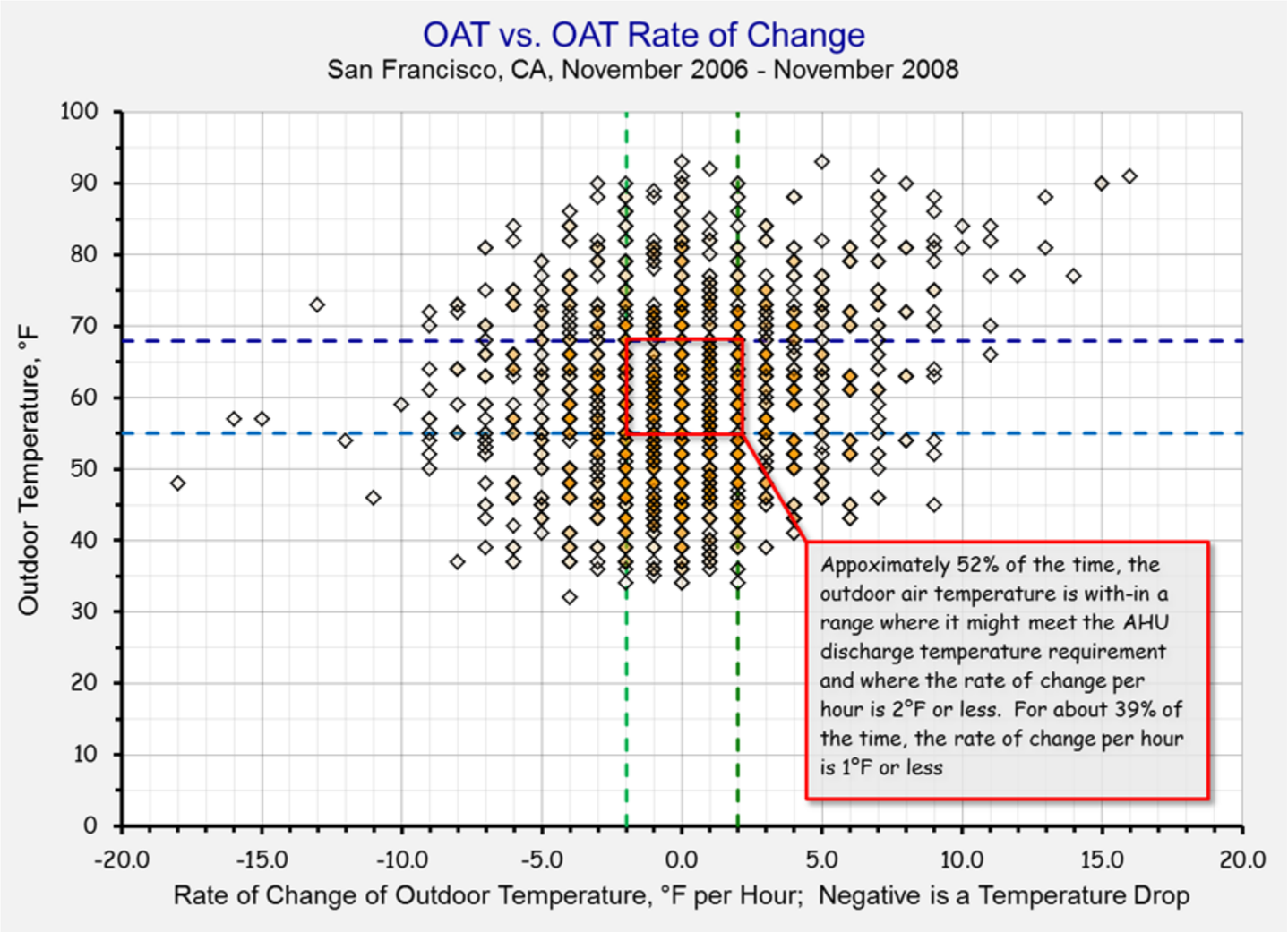
Some of the issues that I think come up if you let the discharge temperature drift from the required set point include:

- When the cooling does start, it will tend to cause a quick change in the discharge temperature, which is basically a step change, which will tend to upset that particular control process and could ripple out to the other control processes. So the non-seamless transition has the potential for introducing some loop tuning/loop instability problems on occasion. How big a deal that is remains to be seen, but I am always wary of the cascading instability thing. And I know from experience that while people may not notice a gradual drift in one direction or another until it reaches the point where they are simply not comfortable, they will definitely notice and react to a temperature change of several degrees that occurs in a matter of minutes or less.

  One example of this is to realize that most people do not notice a zone temperature floating inside the proportional band of a pneumatic thermostat over the course of the day. Basically the load going up and down causes the temperature to float around a degree or so over the course of 8-10 hours. But those same people will call and complain (justifiably in my opinion) if that pneumatic signal trips a pressure electric switch that brings on a single stage electric reheat coil, which then drives the space temperature up 3-5°F in that many minutes. I've personally noticed this effect at the PEC; usually it's what causes me to go get my coat on because it makes me feel cold. I'm not so sure that would be the case if the temperature had not drifted up in the first place.

- Another interesting thing to consider is to ask yourself, if this were to happen, how long might it take to transition through the trigger condition? For instance, let's say the discharge temperature requirement was 59°F. As a result, it would have to get above 61°F for 10 minutes before you would decide to run the mechanical cooling system. There are likely days when you would spend the entire day floating around above 59°F and below 61°F. Meaning that even though there was a technical need for cooling (you could not make set point) you would actually not provide it.

  To try to understand this a bit more, I took a couple years of San Francisco climate data and plotted OAT vs rate of change of OAT and here is what I got.



The shading on the points is set to 95% transparent so that if there are a bunch of points on top of each other, they will look darker. I think what this is telling us is that in the Bay area, there could be a lot of hours where you sat at a temperature above your set point requirement but would not transition through the trigger condition. For instance, there are a lot of hours where the rate of change relative to the previous hour is 0, meaning the temperature just sort of hung there for a while before falling back off.

How critical this is probably depends on what is going on in the PEC. If it is lightly loaded, maybe just the staff, you may never notice it because other stuff might compensate for it (more on that in a minute). But if all of the rooms were in use and it was sunny meaning solar load in the conference center and HVAC class room for instance) then it could become problematic.

- The VAV system will try to compensate by delivering more air because the boxes will drive open in response to the need for more cooling, lacking the cold air they need at the flow setting that were at when the OAT equaled the required supply temperature. So you would spend fan energy when you would not need to if you melted some ice or ran the chiller. The ice was made off peak by a process that delivers multiple Btu's of cooling for each Btu of energy used while the fan energy would probably be used on peak. So you would have to do some analysis to see which actually cost more dollars, (which could be different from which actually cost more source energy). But a lot of time, fan energy costs more. Bear in mind this is just a secondary issue related to my main point about continuity of service and comfort.

- Another possible ripple effect might be that the drift in discharge temperature might drive the AHU discharge temperature reset schedule downward. I would need to look at how this worked currently, but if it was some form of trim and respond, which I would suspect Ken would have used, then if a VAV box reached full flow and could not maintain set point, it might cause the supply temperature to reset downward. Of course, in some trim and respond strategies, it would cause the fan static to go up, which is the next step to the previous bullet (fan speeds up because it can't maintain set point as boxes open, then, if enough boxes are wide open you kick the static set point up to get more air to them).

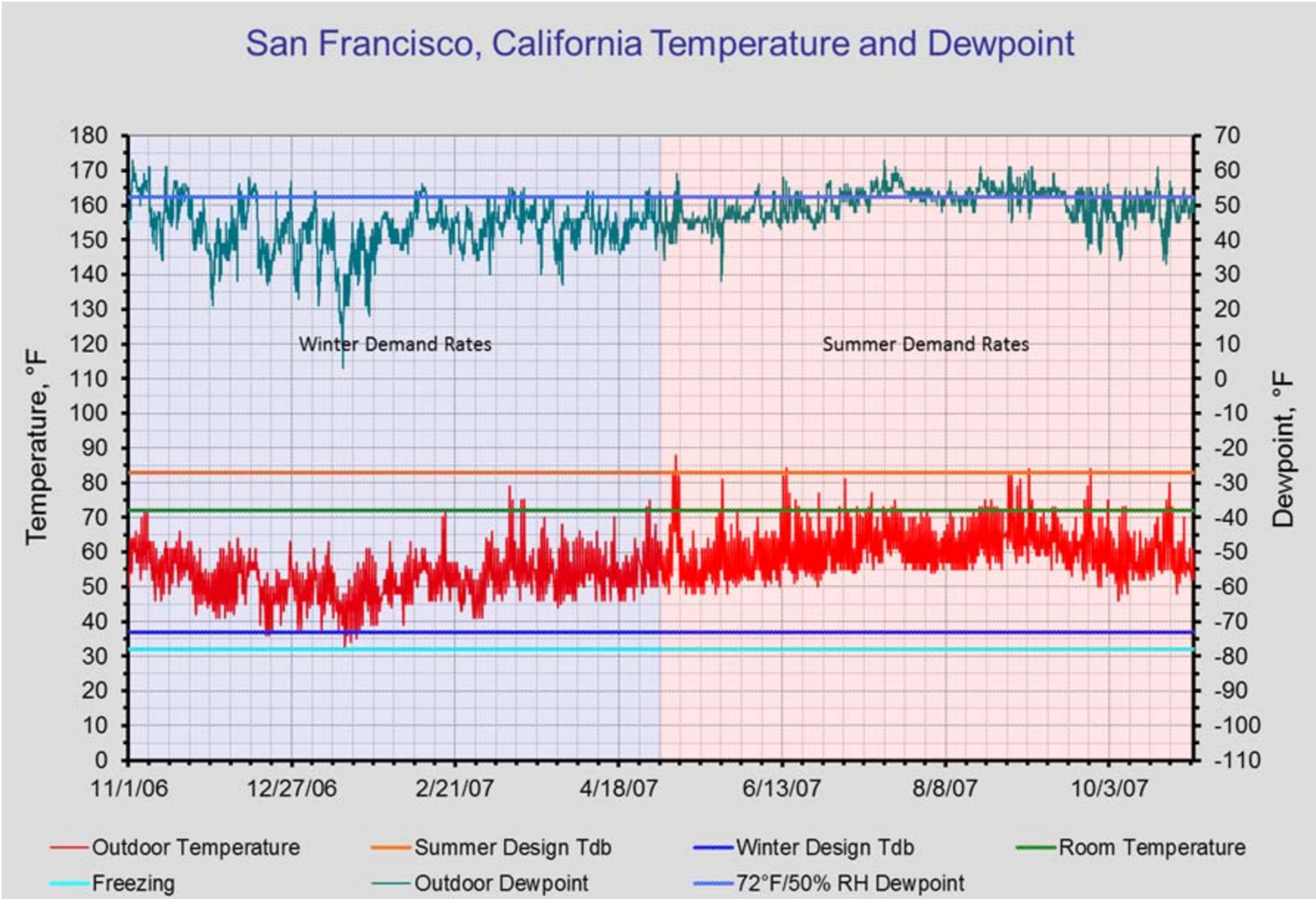
  Either way, it will drive the system towards a higher energy state vs. what may have happened had you simply met the current discharge requirement with mechanical cooling. If you let the space temperatures drift, you are basically storing heat in the mass of the building that you then need to remove later to get back to set point. You may be better off not letting it get out of hand in the first place.

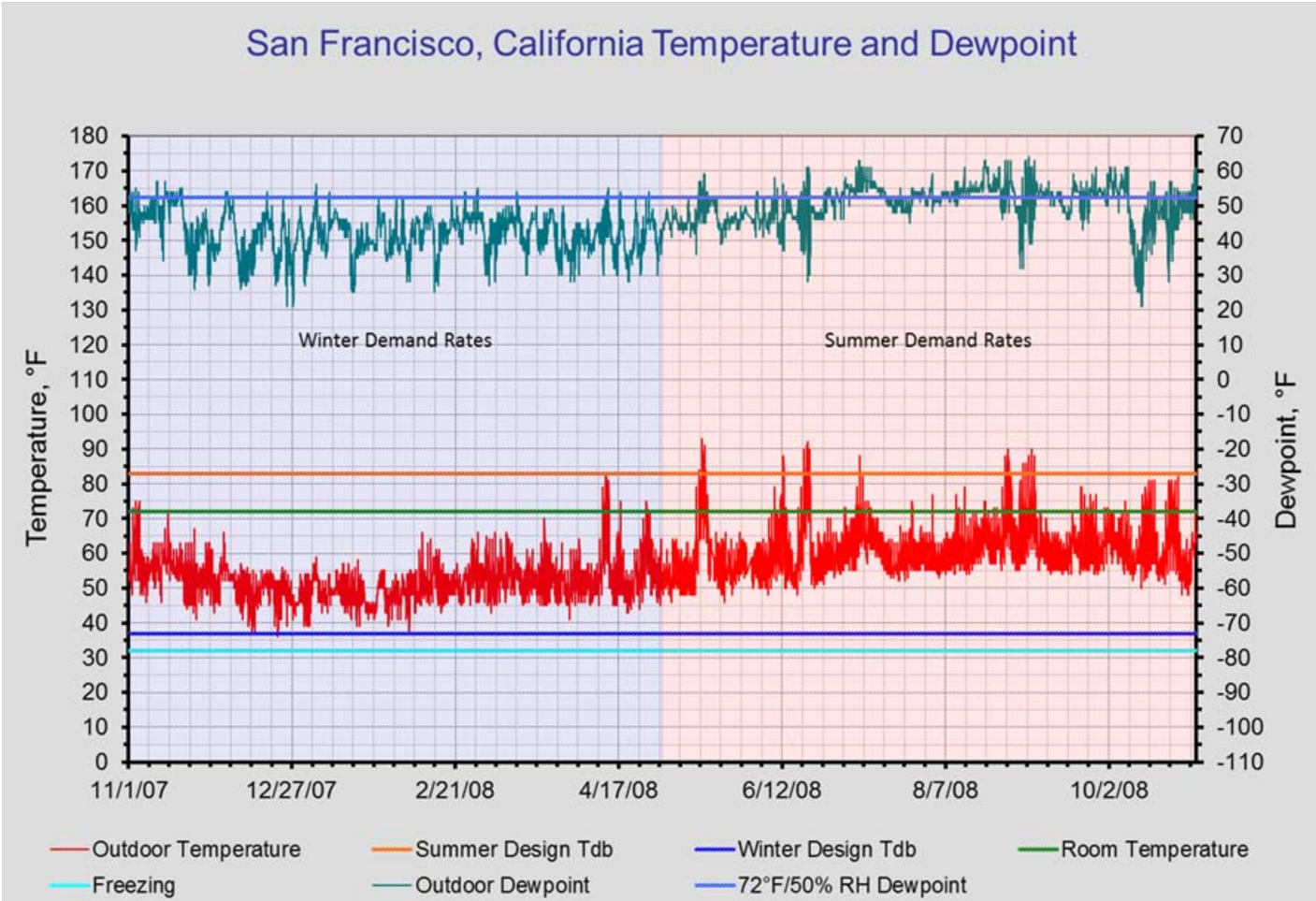
  The interaction of discharge temperature reset and discharge static reset on a VAV system is another can of worms actually that should be addressed, and beyond the immediate focus. My point here is that the decision regarding when and how to enable mechanical cooling plays into the other control processes and the net, interactive, integrated effect probably needs to be considered and addressed. We can do that via ongoing commissioning, but we may want to think this through a bit in the context of controlling the ice system.

One way to think of delaying the chiller start based on the difference between the supply air temperature set point (what you want) and the current outdoor air temperature rise above set point (what you will get) is that it's an energy conservation strategy, meaning that you aren't' going to start the chiller unless you really need it. But "'really need it" is subjective, both in terms of the customer's perception of comfort, the process requirements if you are in production or a more regulated environment like a hospital, and the Owners desire to keep the customer happy.

Plus, depending on the outcome, as described above, it may not really save you dollars, just shift where you spend it. And on a source energy scale, it may or may not save source energy.

I also looked at the data I had as a time series and think there are some insights that should be considered in light of how the building currently works.

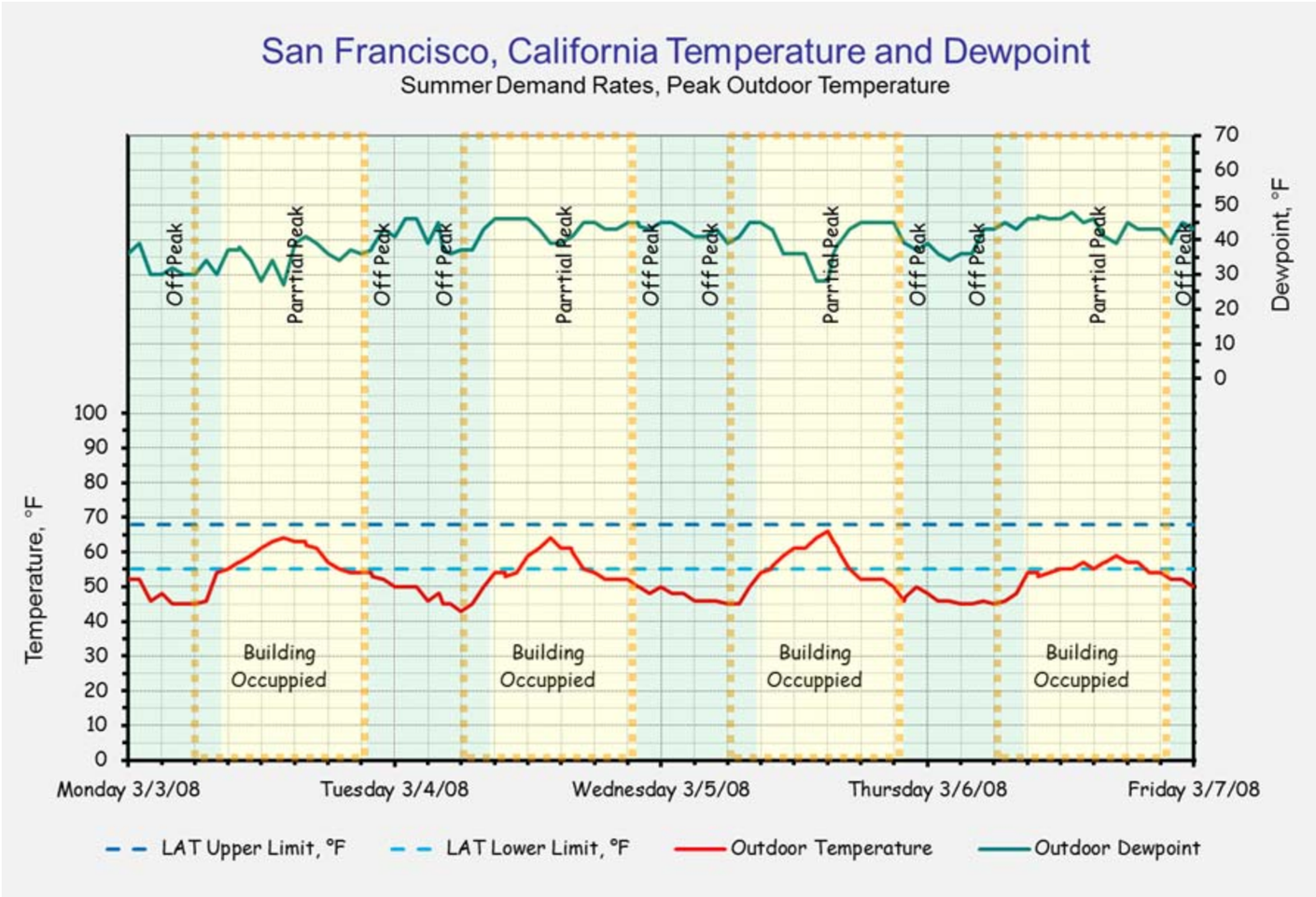

San Francisco, California Temperature and Dewpoint
Temperature, °F
Dewpoint, °F
Winter Demand Rates
Summer Demand Rates
11/1/06
12/27/06
2/21/07
4/18/07
6/13/07
8/8/07
10/3/07
Outdoor Temperature
Summer Design Tdb
Winter Design Tdb
Room Temperature
Freezing
Outdoor Dewpoint
72°F/50% RH Dewpoint

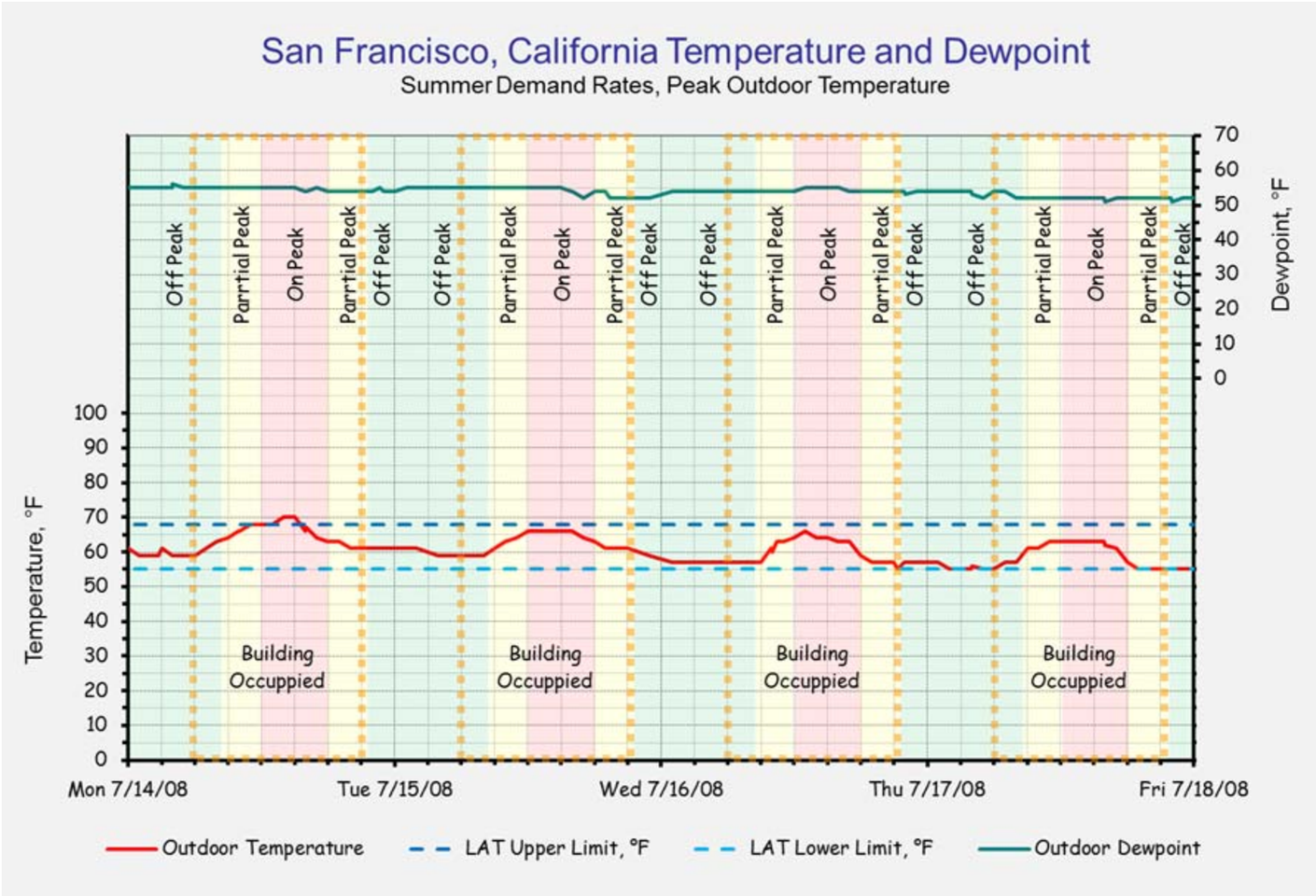


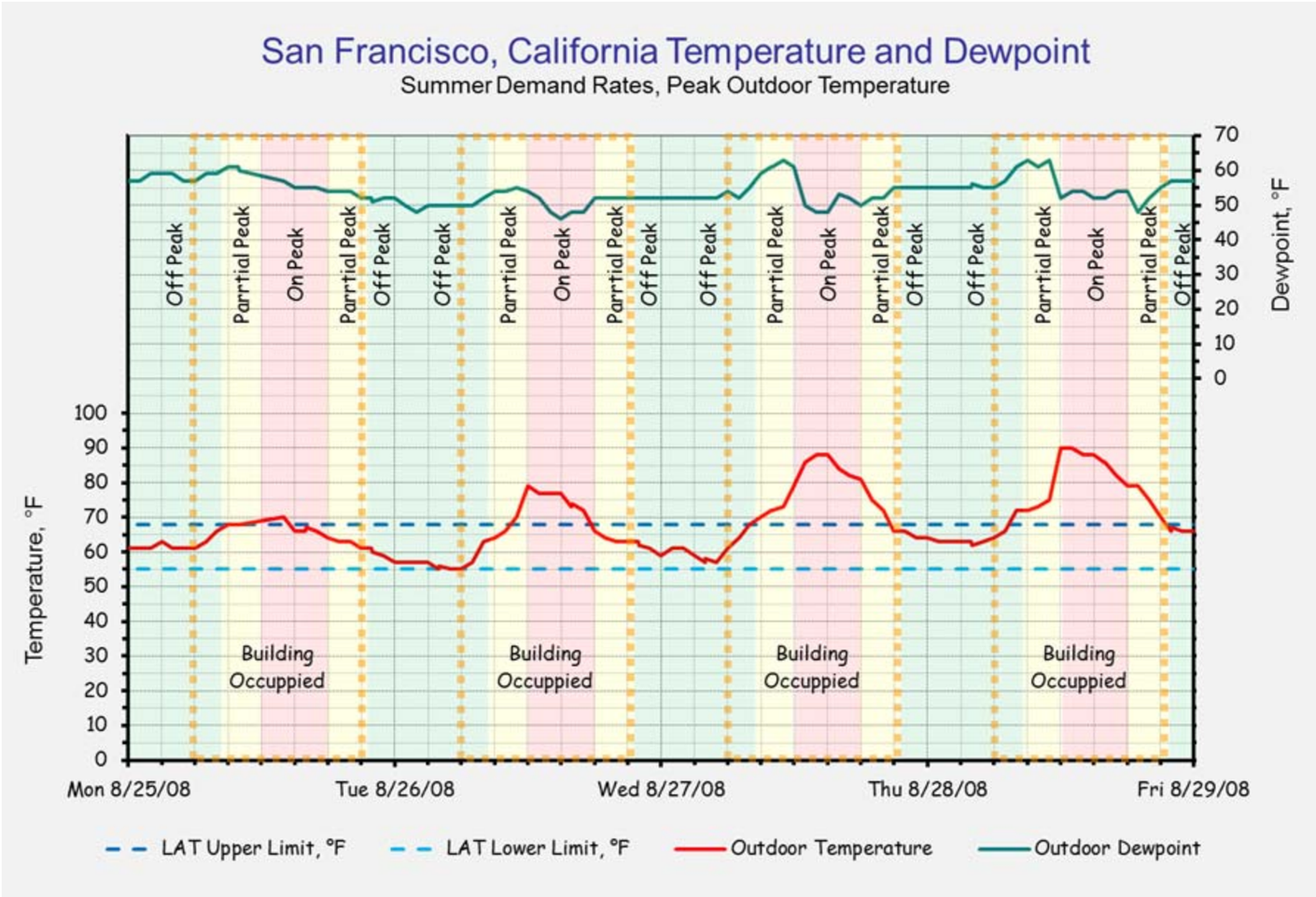
No news there in particular, especially for you I suppose, but it did verify that:

- The average days in during the summer demand months are a bit warmer than the average days during the winter demand months;
- You might see the occasional day that approaches or even exceeds design conditions during summer or winter demand months;
- There is a significant diurnal swing even on the days where you approach or exceed design, even if there are a number of days in a row like that.

So, I focused in a bit on an average week in the winter months, an average week in the summer months, and week that saw some peak conditions, which gave me these charts.

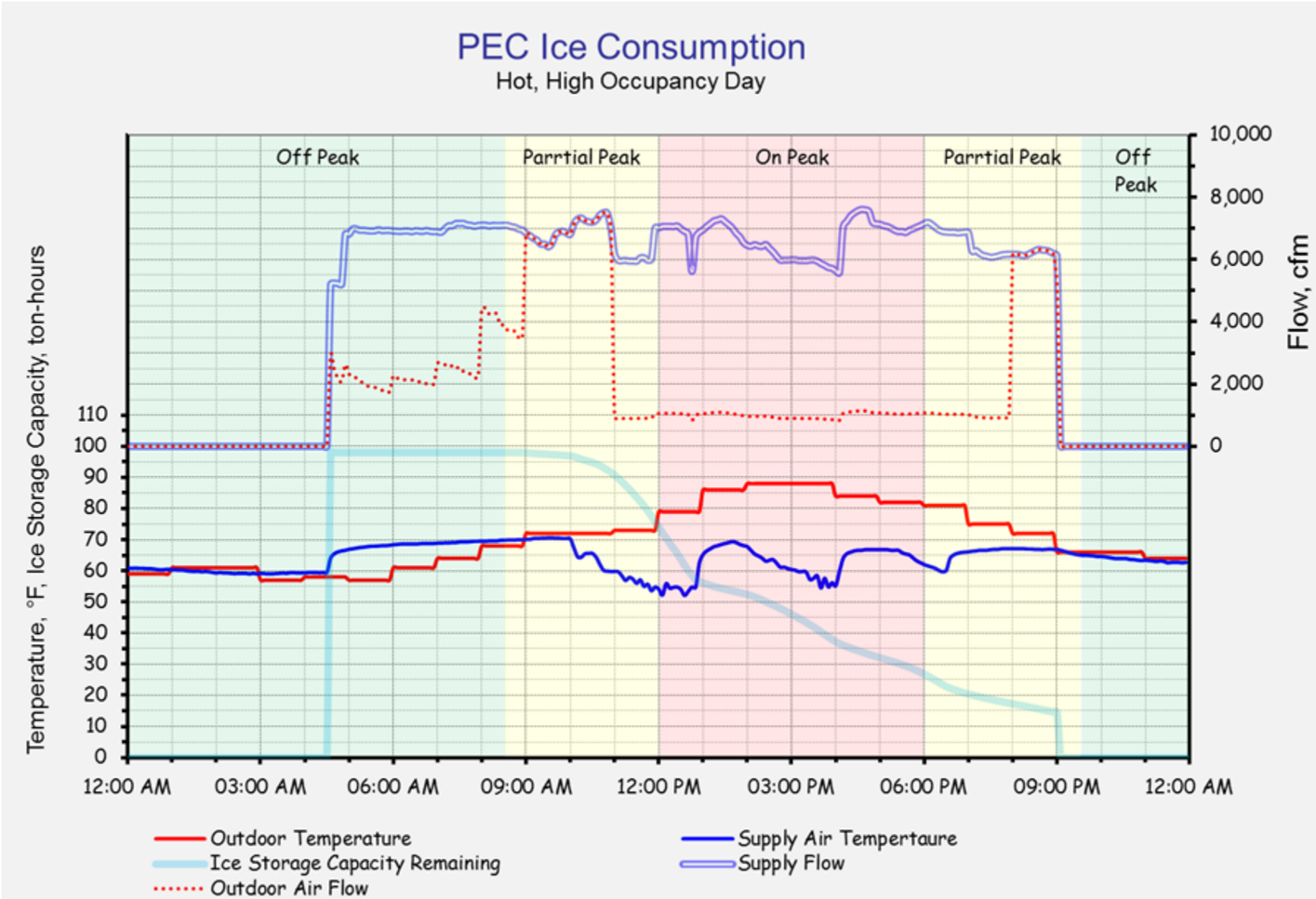

San Francisco, California Temperature and Dewpoint
Summer Demand Rates, Peak Outdoor Temperature
Temperature, °F
Dewpoint, °F
Off Peak
Parrtial Peak
Building Occuppied
Monday 3/3/08
Tuesday 3/4/08
Wednesday 3/5/08
Thursday 3/6/08
Friday 3/7/08
LAT Upper Limit, °F
LAT Lower Limit, °F
Outdoor Temperature
Outdoor Dewpoint


San Francisco, California Temperature and Dewpoint
Summer Demand Rates, Peak Outdoor Temperature
Temperature, °F
Dewpoint, °F
Off Peak
Parrtial Peak
On Peak
Building Occuppied
Mon 7/14/08
Tue 7/15/08
Wed 7/16/08
Thu 7/17/08
Fri 7/18/08
Outdoor Temperature
LAT Upper Limit, °F
LAT Lower Limit, °F
Outdoor Dewpoint



What I got from that was:

- On the average winter demand day, you probably can handle the building with outdoor air; maybe a little chilled water to peak, but not much and not for long.
- In the context of the preceding bullet the cost of delivering more warm air to handle a load (basically fan energy) vs. handling it with cooler air generated by running one compressor on peak vs. handling it with ice would be interesting to assess and probably insightful.
- The "average" week during the summer demand rates months would likely require a bit more tonnage to hold set point and the tons are more expensive on peak. So all of the "talking points" in the previous discussion come up but the metrics change.
- Peak days clearly require mechanical cooling of some sort. What is interesting about that in the context of how the system currently operates is that it looks like you could make it through the peak on ice with some reserve capacity left. This is based on an hour by hour (actually about 5 minute by 5 minute) calculation I did where I used the flow and supply temperature profile from a day that recently had a really high cooling demand along with the outdoor air condition profile from the a peak day in 2008.



What I get from this is that most of the time, the PEC could get by on ice and at the most, you might need one stage of mechanical cooling. There are, I suspect, a bunch of ways to handle the exception (the extreme day) including a pager alarm that lets you or someone enable extra cooling for a onetime event (probably a bit of a cost but since there is not a ratchet, not a long term cost) or simply allowing the control system to make that decision if it gets above a certain outdoor temperature.

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Best Practice/Safety Issues

One thing the current sequence does is shut down the chiller and the pump concurrently, either via command or via the flow interlock. It would be best to have the automation command the chiller off, wait a couple of minutes, and then, if you did not need to run the pump to melt ice, command the pump off.

The reason for this is that there are things settling out in a refrigeration circuit when you command the compressors off. I have not watched your chiller closely enough to know for sure, but I would not be surprised if it had a pump down cycle; the indications on the control drawings are that it does. Meaning that specifically what happens when you turn the chiller off is that a solenoid valve closes off the liquid line (and the hot gas line if the chiller has one) while allowing the compressor to remain in operation. This allows the compressor to continue to try to move refrigerant.

You may be tempted to think that this will very quickly drop the evaporator pressure. But what you have to realize is that initially ,any liquid that is still in the evaporator will boil off, which tends to keep the pressure up due to the volume change associated with going from a gas to a liquid. Once all of the liquid is converted to a gas (which is the goal), then the pressure will start to plummet and a pressure switch will shut down the compressor.

The reason you do this is to make sure there is no liquid refrigerant trapped in the evaporator because if there was, it could make it out of the evaporator as liquid at start up and "slug" the compressor, which can ruin it.

In addition, some control systems interpret a flow switch trip as a safety problem, which dictates that good practice be aborted in the interest of not breaking something. Often, this then means that a manual reset will be required to resume normal operation; not sure if this is true at with the PEC chiller but it is with the general case. So, operationally, one is better to write control logic that triggers a normal operational shut down vs. a safety shutdown. Shutting down the pump and figuring that the flow switch will shut down the chiller is relying on a safety to perform an operational function and is not good practice.

So two underlying points:

1. Since the compressors might run after shut down (moving refrigerant and cooling the water) it is best to keep the pump running for a while to avoid frosting the tubes (or worse).

2. Control code performing an operational shut down should be written to do just that vs. relying on a safety to do the task.

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From: Stroupe, Ryan D [mailto:R2S2@pge.com]
Sent: Friday, January 24, 2014 4:52 PM
To: David Sellers
Subject: FW: Fwd: PG&E PEC - Chilled Water System

David,
Air Systems was not able to work with the Trane line code. So I took Ross Sherrill's sequence from the systems manual and modified it to the best of my ability. Take a look and provide feedback.
Ryan

From: Stroupe, Ryan D
Sent: Friday, January 24, 2014 4:45 PM
To: 'Kevin Li'
Subject: RE: Fwd: PG&E PEC - Chilled Water System

This is disappointing as the line code represents the latest version of the controls. Use this written sequence for now:

SEQUENCE OF OPERATION:

[David Sellers] General comment; It would be desirable to make sure all of the set points were easily adjustable. This is a bit less of an issue with the ALC system since you can get to them in the logic pretty easily. But you may want to think about which set points you would like available in graphics to make it easier for you to make a quick adjustment and/or tune the system over time (like modify a curve fit for the discharge or charging rate of the tank or the relationship between tank level and stored capacity).

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1. HVAC System Cooling Operating Modes: 45°F CHWS (brine) temperature:

A. The building HVAC system cooling demand shall initiate operation during scheduled building occupancy as follows:

1. The "lead" chilled water (brine) pump P-1

[David Sellers] Just verifying that this is the one with the trimmed impeller

shall be programmed "on" when the AHU-1 supply air temperature set point is 2°F below the outside air temperature for a period of 10 minutes.

[David Sellers] Some of this is a philosophical point; so I am not saying what you propose has anything inherently wrong with it, rather just offering a few other things to consider. Where I doing this, I suspect I would write the code to reflect what I am about to discuss. If the goal of HVAC is comfort and safety, then I would think you would want to do something different from this; i.e. get the chilled water system up and running <u>before</u> the outdoor air temperature was above the required discharge set point so that you could transition smoothly from OA cooling to mechanical cooling. With an integrated economizer, that could set you up to use hot gas or to short cycle. But with the thermal inertia represented by the ice, the PEC is actually in a good position to make a seamless transition I think. The supporting data and additional thoughts on this are covered under

Related to all of this, we should look at where the supply temperature sensor is actually installed (before or after the fan) since fan heat, motor efficiency losses and belt losses will come into play. Ideally we should be basing all of this on the cooling coil leaving air condition (before the other stuff, which should be a part of the designer's load calculation anyway and should be accounted for by that). The graphic say it is a single point sensor located in the fan discharge. But it also says the mixed air sensor is a single point sensor ahead of the filters and I am pretty sure it's an averaging sensor after the filters. The latter we can correct by making the graphic match reality. But if the discharge sensor is after the fan, then we may need some conduit and wire to move it. If it's a single point sensor, based on the testing I have done, we will actually get a pretty good number if we put it in the eye of the fan, where the air enters it (vs. needing an averaging sensor).

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2. The "lead" CHW pump shall be programmed "off" when the AHU-1 supply air temperature set point is 2°F above the outside air temperature.

[David Sellers] similar considerations to what I discussed above apply here. But if you kept the preceding concept as an energy conservation strategy (don't run the chiller unless you really need it), this could potentially be an energy waste strategy because you would be using pump energy much longer than you might need it as the outdoor air temperature transitioned through the trigger for a couple of hours, or maybe even hung there (dropped below the set point requirement, but never 2°F below it before you shut down for the day or before the temperature started back up again).

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3. The chiller CH-1 shall be programmed "off" through a software interlock with the "lead" CHW pump as well as automatically stopped by the CHW flow safety switch.

[David Sellers] You should not stop the chiller with the same command as the pump. It is best to command the chiller off and then command the pump off after the chiller has finished its shutdown sequence. In the particular case of the PEC, this becomes a bit more complex because you may want to keep the pump running so you can melt ice if you brought a compressor on to peak and no longer needed it but still needed some cooling and could extract it from the ice and it was not off peak hours yet.

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B. Upon start-up of the lead chilled water pump P-1 for air handler cooling demand, the chilled water (brine) system shall provide the air handlers with 45°F chilled water (brine) as follows:

1. The cool storage tank cooling system 3-way control valve TCV-6 shall be programmed to maintain the chilled water (brine) design 45°F temperature set point.

[David Sellers] It seems to me like you would want to keep the valve forced to full bypass of the tanks until you wanted to melt ice. Otherwise, normal variations in the water temperature could melt some ice when you didn't want to.

2. Chiller and Cool Storage System "Ice-melting" Operating Mode: 45°F CHWS (brine) temperature:

a. On Monday-Friday, the chiller should be the primary source of cooling before 11:55 am.

[David Sellers] I believe these times no longer reflect the current demand schedule. By 11:55, you are on partial peak and my analysis suggests that given the way the AHU runs currently, most days you could get through this and the rest of the day by using OA or melting ice and not running the chiller. Of course, that assumes that you saved money by making the ice off peak vs. running the chiller to make chilled water on peak. My analysis tends to say with the current rates and the mild climate, making and melting ice may not be a clear of a win as you would think on many days.

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b. On Monday-Friday, ice is not utilized until 11:55 am. At this time ice-melting (brine) is primary cooling source and chiller is off unless one of the conditions below occur.

[David Sellers] Ditto above.

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a. A single stage of chiller capacity (one compressor) should run if thermal storage is below 75% capacity before 1:30 pm, or below 50% capacity before 3:00 pm, or below 25% capacity before 4:30 pm. In this mode this stage of cooling runs continuously and ice tank mixing valve is modulated to maintain the chilled water (brine) set-point. If chiller has been running and capacity is above 50% at 3:00 pm or above 25% at 4:30 pm, this stage of chiller cooling can be cycled off.

[David Sellers] Unless this was derived from recent operating data, I doubt if the relationship between time and capacity available to get through the rest of the day is this linear/specific. I also think the times may need to be tweaked based on the rate schedule. You may have already done the math/have trend data that informs this but just flagging it in case since my little one day model says the discharge rate is a curve, not a straight line. I realize that this is looking at capacity available vs. capacity used. But I think you could get fake out if the initial draw-down was light and sort of flat and then got steep all of a sudden. So, if the initial sequence assumes this linear relationship, it may be best if it is set up using a curve fit function as the input so it can be easily adjusted based on experience.

That said, with the limited interface we may have, it could be difficult to measure or manage the chiller capacity precisely. In addition to the problem of measuring tons, the chiller capacity varies fairly significantly as a function of ambient temperature even if we are talking a fairly steady supply temperature. While the sequence does not mention compressor capacity directly (it talks about stored capacity, right), you may need to make some assumptions about available tonnage at some point in the development of the over-all logic. So just flagging the issue here while I am thinking of it.

Managing individual compressors could be tricky with only a kW limit input to do it with. From the control drawings, it looks like a dry contact input, which I suspect means you have two demand control levels available, the normal one and one that you can set based on the contact closing. But, from what I see so far, you may not be able to manage one, two, three, or four compressors available or not at will without using the Trane network interface somehow.

This strategy is also highly dependent on the level control system working, which, I believe, has been problematic at times. So at a minimum, ALC should make sure the system is working and they are calibrated to it.

Assuming it is working, it may take some functional testing or trend analysis to calibrate water level changes in the tank to stored tonnage. That information may exist someplace but I have not seen it (not that I spent a lot of time looking; just saying I wondered about it and have never found an answer) So, ALC should probably include a look up table that lets us do a curve fit based on experience, even if they start out assuming the relationship between level and stored capacity is linear.

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b. A second stage of chiller capacity (two compressors) should run if thermal storage is below 50% capacity before 1:30 pm, or below 25% capacity before 3:00 pm. In this mode this stage of cooling runs continuously and ice tank mixing valve is modulated to maintain the chilled water (brine) set-point. If chiller has been running and capacity is above 25% at 3:00 pm, this stage of chiller cooling can be cycled off.

[David Sellers] Ditto above

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c. A third stage of chiller capacity (three compressors) should run if thermal storage is below 25% capacity before 1:30 pm. In this mode this stage of cooling runs continuously and ice tank mixing valve is modulated to maintain the chilled water (brine) set-point.

[David Sellers] Ditto above; plus, based on the way the AHU runs currently, I suspect that you would not get to this point unless it was extremely hot/humid and/or you had not been able to charge the ice tank the night before.

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d. The fourth compressor should only run when ice is depleted and chilled water set-point cannot be met.

[David Sellers] Ditto above

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e. On Monday-Friday, after 6:05 pm the chiller is the primary cooling source and the 3-way control valve from the ice tanks (TCV-6) should be closed.

[David Sellers] This is now partial peak so the economics may be different from what they were when this was off peak.

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f. The chiller is also the primary source of cooling on weekends.

[David Sellers] I never thought about this exactly, but:

- ***If the demand charge is the demand charge; i.e. it's the peak demand you pay for what you use no matter when it happened, and***
- ***The time of day demand windows (peak, partial peak, and off peak) simply affect the cost of the energy that is used during different times; then***
- ***is it possible that allowing the chiller to be the primary cooling source on the weekend could set a demand peak if you had a weekend event of some sort (intentional or accidental) on a warm day?***

In other words, if the building was up and running on the weekend just like it was for a normal weekday, and the weekend happened to be a hot one and the chiller was allowed to run at full load to deal with that, it would seem that you would set a demand peak in excess of what you might see during a weekday when the ice system was used to manage the number of compressors that ran. The cost of the energy you spent to meet that demand would be less since you would be buying it at the off peak rate, but the connected kW might be higher because you let all four compressors run concurrently along with a peak lighting/equipment/plug load situation.

Not sure about that, but right now, as I write this, I think that could be possible.

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3. The chiller/ice melt-mode shall be programmed to start and to maintain the chilled water (brine) design 45°F temperature set point when any of the following conditions exist:
   a. The chilled water (brine) building return temperature (entering basement) is >52°F (31 tons ±) for a period of ten minutes;
   b. The chilled water (brine) temperature leaving the 3-way control valve TCV-6 (leaving the basement) or entering the chiller is >48°F for a period of ten minutes;
   c. Operator activated when needed.

[David Sellers] Maybe I am just confused or not understanding something, but I thought currently, the idea was to not melt ice until you were about to go into the peak demand window, in which case, you would start to melt ice to limit or eliminate the chiller operation. To me, this says that if there is 31 tons of load (there will be more than that on a warm start) or if the water temperature leaving the ice tank is above 48°F (it will be on a warm start), then you might let the system melt ice. So at a minimum I think the intent of this statement is not clear and it may be in conflict with some of the other stuff.

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2. Cool Storage System "Ice-making" Operating Mode: 24°F CHWS (brine) temperature:
   A. The cool storage charging operating mode shall be automatically activated when the cool storage level indicates <75% full at 10:30 PM on the evenings before scheduled "occupied" days. (Sunday-Thursday evenings)
   B. The "lead" CHW pump shall be programmed "on"
   C. The chiller CH-1 shall be programmed "on" and shall operate as required to maintain the CHW (brine) 24°F design temperature set point.

[David Sellers] Potential interface issue; may require some internal settings of the chiller triggered by a contact closure from ALC.

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   D. The cool storage tank cooling system 3-way control valve (TCV-6) shall be programmed "full open" to the tanks.
   E. The lead chilled water pump shall be programmed "off" when the CHWR (brine) temperature is <26°F for a timed period of 5 minutes.
   F. The chiller CH-1 shall be programmed "off" through a software interlock with the "lead" CHW pump as well as automatically stopped by the CHW flow safety switch.

[David Sellers] Ditto preceding comment regarding shutting the chiller and pump down concurrently.

Also, it would be desirable to command the AHU valves to full closed to the coil positions to make sure you don't pump subfreezing brine through the coils during the ice making cycle, which would waste some capacity and also could frost up the coils, causing an air flow problem the next morning.

Finally, it may be desirable to return the ice tank valve to full bypass after the charging cycle to ensure that you don't melt ice until you really want that to happen. Minor detail though.

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CHILLED WATER (BRINE) PUMPS P-1 & P-2:
The chilled water (brine) pumps are programmed to operate with P-1 as the lead pump and P-2 as a "stand-by". The designated "standby" pump is to be started automatically upon failure of the "lead" pump.

[David Sellers] My recollection is that there is an issue with how the DP switch proving pump operation is piped. Meaning, I think it senses pressure after the check valve so that even if the pump is off, it shows that the pump is on. Not positive other than I think there is an issue and that issue needs to be corrected for the control sequence to work if it is going to use pump status as a trigger.

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CHILLED WATER (BRINE) COOLING COILS (AHU – 1& 2):
1. The AHU-1 cooling coil 3 way control valve (TCV-1) modulates as required to maintain the supply air temperature set-point (TS-3).

[David Sellers] I would suggest specifically stating that the valve be positioned to full bypass any time the AHU is off for a number of reasons related to what happens if you end up flowing water through a coil with no active air flow. They are less of an issue at the PEC, but it would be considered good practice to do this.

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2. The AHU-2 cooling coil 2 way control valve (TCV-2) modulates as required to maintain the cold deck temperature set-point (TS-6). AHU-2 and this associated cooling coil valve should be scheduled off unless over-ridden through the Trane controls.

[David Sellers] Ditto above regarding making a positive command to close the valve an time the AHU is off.

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OPERATING SET POINTS:
CHILLER CONTROL PANEL (UCM):
1. HVAC cooling mode: 45° F Chilled Water (Brine) Supply Temperature;
2. Cool Storage System Charging mode: 24° F Chilled Water (Brine) Supply Temperature;
COOL STORAGE TANK TEMPERATURE CONTROL VALVE TCV-6:
1. Chiller "Off" mode: 45° F Chilled Water (Brine) Return Temperature Entering Chiller;
2. Chiller "On" mode: 50° F Chilled Water (Brine) Return Temperature Entering Chiller;
[David Sellers] This may be a viable way to limit the tonnage if we can't manage the number of compressors with the kW limit input. It may be better to set a differential across the chiller vs. a return temperature since the return temperature assumes a supply temperature in the context of implied tons.

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3. Cool Storage System Charging mode: Full Open to Cool Storage tanks.
ALARM SETPOINTS: NORMAL RANGE TRIP RETURN TYPE
Chiller CH-1 failure (CH-1 controller): digital failure*
[David Sellers] May not be available with a non-network level interface.

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Chiller CH-1 failure (CHWS temp): 45°F 55 50 failure*
[David Sellers] I'm not sure what this means; maybe need to include the note that the asterisk references?

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Chiller CH-1 comp A/D failure (CH-1 controller): digital trouble
[David Sellers] May not be available with a non-network level interface.

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Chilled Water pump P-1,2 failure (DP switch) digital failure
[David Sellers] Not sure how you would figure this out; probably need to provide some guidance for each potential failure mode (pump off but switch says on, pump on but switch says off, etc.).

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High Chilled Water (Brine) Return Temperature: 57°F 65 60 trouble

[David Sellers] I'm not sure what this means; maybe need to include the note that the asterisk references?

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Low Chilled Water (Brine) Return Temperature: 26°F 25 26 trouble

[David Sellers] I'm not sure what this means; maybe need to include the note that the asterisk references?

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Ice tanks 1&2 full/empty (ice level sensors) 0-100% 98/2 90/10 trouble

[David Sellers] I'm not sure what this means; maybe need to include the note that the asterisk references?

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From: Kevin Li [mailto:Kevin.Li@airsystemsinc.com]
Sent: Friday, January 24, 2014 11:08 AM
To: Stroupe, Ryan D
Cc: Jim O'Rourke; Joseph Lofft; Roel Mallari
Subject: RE: Fwd: PG&E PEC - Chilled Water System

Thanks for the Trane code, but was there ever a written sequence of operations that this code was based off of? It will be difficult for us to write our program based off of this line code doc as our method of programming is completely different.

Kevin Li
Project Manager, BAS Division
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From: "Stroupe, Ryan D" <R2S2@pge.com>
To: Kevin Li <Kevin.Li@airsystemsinc.com>
Cc: "Jim O'Rourke" <Jim.ORourke@airsystemsinc.com>, Roel Mallari <Roel.Mallari@airsystemsinc.com>, Joseph Lofft <Joseph.Lofft@airsystemsinc.com>
Date: 01/22/2014 09:45 AM
Subject: RE: Fwd: PG&E PEC - Chilled Water System

Kevin,

I found the code for the thermal storage system from the Trane controls. See attached. Take a look and we can discuss if you have any questions. Sorry for the delay.

BTW, it seems the desktop computer with the HVAC controls does not have a copy of the Trane control program (Trane Summit). I will need to get this re-installed before your team can demonstrate the ability to toggle between Trane and ALC for AHU2.
Ryan

From: Kevin Li [mailto:Kevin.Li@airsystemsinc.com]
Sent: Wednesday, January 22, 2014 8:14 AM
To: Stroupe, Ryan D
Cc: Jim O'Rourke; Roel Mallari; Joseph Lofft
Subject: Re: Fwd: PG&E PEC - Chilled Water System

Good Morning Ryan,

We are at a point where we are ready to begin the chilled water system controls cutover, but we still need to know the sequence of operations for the ice making plant. We still need to prepare the program and graphics prior to the cutover. We of course cannot complete our closeout docs and conduct training without completing this scope of work. If you like, I can meet you onsite to discuss and go over the existing system with you.

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From: "Kevin Li" <Kevin.Li@airsystemsinc.com>
Date: January 14, 2014 at 12:58:47 PM PST
To: R2S2@pge.com
Cc: "Chris Jenkins" <Chris.Jenkins@airsystemsinc.com>,"Horacio Cornejo" <Horacio.Cornejo@airsystemsinc.com>, "Hussain Mandviwala" <Hussain.Mandviwala@airsystemsinc.com>,"Jim O'Rourke" <Jim.ORourke@airsystemsinc.com>, "Joseph Lofft" <Joseph.Lofft@airsystemsinc.com>
Subject: Re: PG&E PEC - Chilled Water System

Hey Ryan,

I wanted to follow up with you regarding the chilled water system. I would like to have a clearly defined sequence of operations to control the ice making plant you have there. We want to replicate the sequence that's already in place because we don't want to have to try to reinvent anything here. When you have some time, I would like to discuss this with you and was curious if we would need to involve David Sellers. Please let me know at your earliest convenience.

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kevin.li@airsystemsinc.com

Kevin Li---12/19/2013 12:47:01 PM---Ryan, I want to reach out to you regarding the chilled water system. I wanted to make sure we have

From: Kevin Li/ASI/EMS/EMCORGROUP
To: R2S2@pge.com
Cc: Jim O'Rourke/ASI/EMS/EMCORGROUP@EMCORGROUP, Chris Jenkins/ASI/EMS/EMCORGROUP@EMCORGROUP, Hussain Mandviwala/ASI/EMS/EMCORGROUP@EMCORGROUP, Horacio Cornejo/ASI/EMS/EMCORGROUP@EMCORGROUP, Joseph Lofft/ASI/EMS/EMCORGROUP@EMCORGROUP
Date: 12/19/2013 12:47 PM
Subject: PG&E PEC - Chilled Water System

Ryan,

I want to reach out to you regarding the chilled water system. I wanted to make sure we have a clearly defined sequence of operations to replicate what the system is currently doing before we start our cutover. We certainly do not want to try to reinvent the wheel here on your chilled water ice plant. Let me know when you have some time to discuss.

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[attachment "PROGRAM ICE.doc" deleted by Kevin Li/ASI/EMS/EMCORGROUP]

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