Mentoring Field Technicians; A Learning Experience for Everyone Involved

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Synopsis

Developing field savvy in new recruits to the commissioning industry may be one of the biggest challenges we collectively face. Mentoring can be an important method for conveying this type of knowledge because by nature, experiencing a field process like the events of a construction cycle, the steps in a diagnostic process or the reactions of a system under test takes time. In contrast the recounting of the process can frequently be accomplished in the course of a conversation, perhaps supplemented by a brief demonstration of the concepts in a working system or via other techniques. But to be successful, the mentor needs not only to understand the field lesson; they also need to understand how to convey that lesson to their mentee in a manner that facilitates understanding. This is not as easy as it sounds and frequently presents challenges of its own for the mentor involving people skills and technical knowledge. But, success is not without its rewards as a successful mentoring interaction can yield benefits to both parties that are significantly broader than the resolution of the question that lead to the interaction.

About the Author

David Sellers is a senior engineer with Facility Dynamics Engineering. His background includes over 30 years of experience with commissioning, design engineering, facilities engineering, mechanical and control system contracting, and project engineering in a wide array of facilities. He also provides technical training and develops technical guidelines on retrocommissioning and commissioning field techniques and engineering fundamentals in a number of venues. David has BS in aeronautics with a major in Aircraft Maintenance Engineering from Parks College of St. Louis University and has been blessed with many gifted mentors over the course of his life and career.

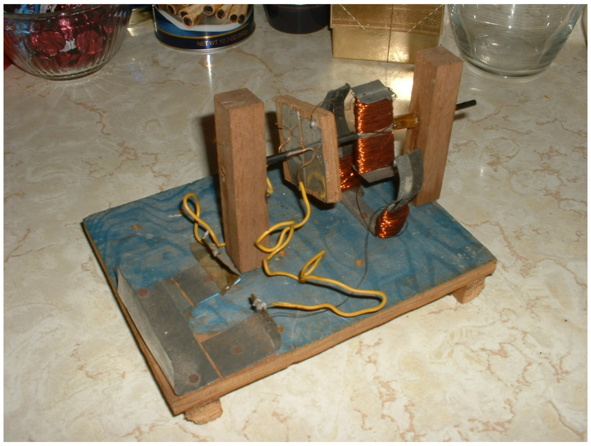

Figure 1: The result of my first technical mentoring experience

Introduction

I recently came across the result of one of my first technical mentoring experiences, a working direct-current motor, which is pictured in Figure 1. The details behind what appears to be a slightly organized pile of junk can be found in a post on my blog[1], but in a nutshell, Dr. Ted Mallick, the mentor behind the picture, helped me to think outside the box and solve what seemed to me at the time to be an insurmountable problem and thus succeed. He was able to do this for two reasons:

- One was that he understood the underlying principles behind what I was trying to do.
- The other was that he was accessible and able to communicate what he knew in a manner that allowed me to discover the answer versus simply telling me the answer.

The results went far beyond the technical lesson and included the joy of discovery, ownership of the solution, and personal affirmation. I've come to think that most mentoring situations have similar characteristics. At the forefront, there is the issue, challenge or question that led to the interaction with the mentor in the first place. But in reality, the interaction between mentor and mentee is much broader and richer than that, bringing with it lessons that are equally if not more important that the driver behind the interaction. And frequently, both parties learn something.

The remainder of this paper has been structured around the insight discussed in the preceding paragraph. Specifically, the paper contains a case study that looks at an experience that was rich in technical and mentoring lessons from early in my career along with some thoughts on why it all matters and how it all worked.

Shuttle Cocks, Functional Testing, and the Ozone Layer

The Experience

Bear in mind as you are reading this that to some extent, it is what one literary great – William Wordsworth, I believe – would call "emotion recollected in tranquility." The event I'm about to describe occurred nearly 30 years ago, very early in my career in the industry. Unlike the things I have been involved with for the past 10-15 years, there are no electronic records and the paper records, if they even exist, are in a storage room back in St. Louis somewhere. Thus, I am at a loss to illustrate some of the things I talk about in detail. But, the events and lessons learned were numerous and pivotal in my career, which is why I am writing about them.

[1] Mentoring and Thinking Outside the Box; A Field Guide for Engineers; www.csemag.com, August 28, 2008.

One of my first projects as a young airplane mechanic become HVAC field technician was the start-up and functional testing of the equipment serving an outdoor ice arena in St. Louis, Mo. This was not your every-day ordinary HVAC system, and the project exposed me to a number of interesting technologies.

- The refrigeration systems were field erected systems, and thus I was exposed to all of the details behind sizing and installing a refrigeration system, including the hardware, with one notable exception which we will get to in a minute.

- The refrigeration systems served a chilled glycol loop. In the winter, the loop was operated in the 15-20°F range and circulated the glycol to a network of piping under the outdoor ice arena for ice making purposes. In the summer the loop was operated in the 42-46°F range and provided air conditioning for the recreation center associated with the ice arena via several chilled-hot secondary circuits.

- Heat was rejected to water cooled condensers and from there, to a cooling tower, which needed to be able to operate year-round and included a freeze protection system that operated by circulating hot water from a small heat exchanger through the basin and distribution piping.

- The compressors, pumps, and cooling tower were staged and interlocked via a relay logic panel complete with safety interlocks, alarm lights, and sequencing lights that illuminated to annunciate failure modes and status.[2]

As you may have gleaned from the preceding bullets, the systems were complex and challenged with a very broad spectrum of operating requirements. The company I worked for at the time had originally become involved in the project when they were retained to do an engineering analysis of the system to determine the cause of the repeated and catastrophic failure of the compressors. In general terms, the report had identified the root cause as being related to inadequacies in the details of the engineering design, particularly the design of the field-erected refrigeration systems coupled with an inadequate start-up and verification process; i.e. the process we currently call commissioning. Related to the latter was a need for detailed documentation of the systems and their controls and an ongoing methodology to ensure the continued performance of the systems over time; a process we currently call ongoing commissioning.

Subsequently, my company was retained to re-engineer the system, and our contract was structured to include rigorous start-up and functional testing of the systems upon completion. We had also been retained to return to the site every three months the first year and every six months the second and third years to re-test the systems and verify performance, including a follow-up report documenting our observations and recommendations.

[2] This was in the late 1970's/early 1980's and direct digital control technology and software based interlocks were just beginning to emerge as the standard way of doing complex logic in buildings.

Initially, the testing and validation effort would be under the scrutiny of Phil Sutherlin[3], the project engineer handling the design and managing the project. But, Phil had taken me under his wing with the ultimate goal being to have me take over the ongoing testing and reporting process. As a result, I found myself out in the field with him learning from a very grounded and hands-on perspective about how refrigeration systems were fabricated, tested and started up.

I also found myself working closely with Don Smith, a service fitter who was about Phil's age and was assigned to the project by the contractor. The project specifications included requirements for the contractor's ongoing involvement with the testing process to support our effort, so Don and I would be working together off and on for the next several years if all went as planned. Don had come up through the ranks in the union and was mature and knowledgeable, with a lot of experience servicing refrigeration equipment. Thus, he was a great complement to Phil's hands-on field based approach to engineering.

While we in the commissioning community have come to consider written test procedures, calibration forms, and start-up checklists as standard operating procedure if not commonplace, at the time of the project under discussion, they were fairly unusual. In reflecting on it in hindsight, I suspect Don was wondering exactly what he had gotten himself into with this kid that was running around measuring things and writing the results down while following a written procedure to the letter. But, he was good natured, easy going, happy to share what he knew, and an enthusiastic participant in the process. I suspect he appreciated, perhaps enjoyed the intent of the process, even if it was a bit more rigorous than what he was used to.

One thing that did trouble him was the procedure we used to verify the compressor safety interlocks, especially the head pressure cut-out switches. A key finding of the engineering analysis was that the original safety devices were unreliable and poorly calibrated with said deficiencies being the root cause behind some of the failures. As a result both Chuck McClure[3] (the principle in charge of the project) and Phil were insistent that the tests I developed verify the safeties by simulating the actual condition that would trigger them, rather than by adjusting the set point to the current operating condition at least to the extent possible with due thought given to the balance between risk and benefit.

Given my safety conscious aviation background, I enthusiastically concurred. Specifically, my test procedure for the head pressure control was something along the lines of the following:

1. Verify the existing head pressure gauge reading by connecting a calibrated test gauge to the same sensing port; document both readings.

2. Verify the setting of the head pressure cut-out switch against the design requirement of 400 psig and document the setting (the piping system rating and relief valve setting was 450 psig).

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[3] Phil and Chuck were among my mentors from day one, and I share some of the things they and others taught me, technically and otherwise in "Mentoring Control Technicians" in the September 2008 issue of *Consulting Specifying Engineer*. Incidentally, my article was one in a series of articles on mentoring that ran in *CSE* in 2008. They all can be viewed on line at www.csemag.com.

3. Station one person at the control panel so they can shut down the system manually if the head pressure switch does not shut down the system automatically.

4. While monitoring head pressure, gradually throttle flow to the condenser until the head pressure begins to rise. Allow the head pressure to rise to the head pressure switch cut-out set point and verify that the switch shuts down and locks out the compressor. If the head pressure switch fails to shut down the compressor when the head pressure reaches its set point, IMMEDIATELY shut down the compressor at the control panel with the Hand-Off-Auto switch[4].

5. Document the results of the test.

6. Return the system to service by gradually restoring flow to the condenser and resetting the head pressure switch once the condenser pressure has dropped back to the normal operating range.

7. If the compressor failed to shut down on the safety control, lock the compressor out and arrange for a service call to investigate and correct the cause of the problem.

I don't know this for a fact, but in hindsight, I suspect Don had been around machinery in the field long enough to have mixed feelings about a test that pushed a refrigeration system's pressure up towards the relief valve setting.

- On the one hand if everything worked the way it was supposed to, there would not be a problem.
- On the other hand, things sometimes don't work the way they are supposed to.
- On the one hand, testing something by pushing it to its limit and having everything work the way it was supposed to can be gratifying and affirming.
- On the other hand performing the test on a regular basis could be tempting fate.

In contrast, I was young and enthusiastic about what I was doing. Plus, I had just come from the aerospace community where things tended to test out very well because, to quote Gene Krantz, "failure was not an option." As a result, I wasn't nervous, not even what I now call "comfortably" nervous and consider a good thing. As you may guess, I was about to learn something about that.

One day towards the end of the first year of the modified system's operation, Don and I met at the ice arena to do our quarterly inspection and testing of the system. As we reached the point in

[4] There was a significant but subtle difference between shutting down the compressor at the starter vs. the control panel. Using the switch on the control panel shut down the compressor by closing the liquid line solenoid valves, which allowed the compressor to "pump down" the low side of the system before shutting down on its suction pressure operating control. Shutting down the compressor at the starter would simply stop the compressor with out closing the liquid line solenoid valves or pumping refrigerant out of the evaporator. This set the compressor up to "slug" itself on start-up among other things, which could cause damage.

the sequence were we tested the head pressure cut-out, Don commented about how he always felt nervous performing this particular test, saying he'd hate to blow a charge in a test mode. I countered (probably as only a young, relatively inexperienced field technician could) that the whole point of the test was to make sure we didn't blow a charge, ever, by proactively verifying everything.

"I can see your point, and I know we've done this a number of times now," Don replied as he began to throttle the flow on the active condenser while I stood by at the control panel with my hand on the selector switch and my eye on the rising head pressure, "but I sure would feel better about this if we had a shuttle cock on the relief valve."

Right about then as the head pressure passed 350 psig, there was a loud pop followed by a loud roaring sort of hiss and the rattle of a pipe vibrating rapidly. "Shut down the compressor and pull the disconnect, and let me know as soon as you've done it!" Don shouted. I didn't really know what had happened but did as Don said and then watched while he frantically cranked the compressor service valves closed. I suspect the entire thing took less than a minute.

"What happened?" I asked as I headed over to where Don was now standing.

"The pressure relief valve let go" he said quietly, with a sad look in his eye while staring helplessly at the errant valve which was still making a hissing sound.

"That's impossible, the gauge was just over 350 psi when you yelled to shut everything down and the valves are set for 450 psi!" I countered, probably a bit defensively, fearing I had misread the gauge and fallen victim to a faulty head pressure control.

"Yeah, that's about what I was reading on my gauge too" he agreed, "but sometimes an older relief valve will drift off its set point, especially if it sees some pressure cycles."

"Can't we just valve it out and save the charge?" I asked.

"Nope, not without a shuttle cock," he said dejectedly. "You can't have a service valve between the relief valve and the system; too dangerous. Anyway, I hope I trapped some of the charge in the piping and evaporator when I valved out the compressor, but I suspect the lion's share was in the condenser. Nothing we can do now but wait for it to bleed off so we can replace the relief valve and re-charge the system, and that's not gonna happen anytime today."

The Technical Lesson and Mentoring Lesson

"So, what's a shuttle cock?" I asked, too young to realize that it may not have been the best time to ask that question.

"Well, it's like this," Don said pulling out the little spiral bound notepad he kept in his shirt pocket.

Don proceeded to make a sketch that was similar to Figure 2 and explained how such a device would allow you to remove and service one relief valve while a second valve remained

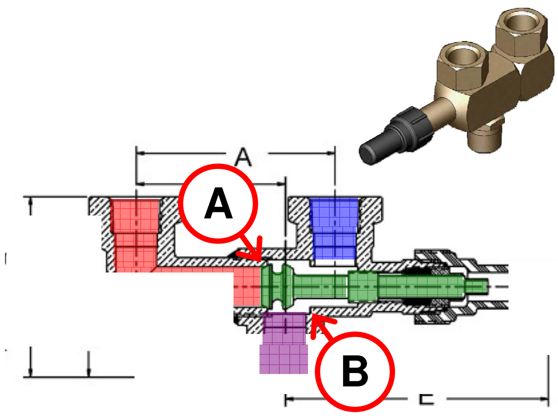

Figure 2: A cut-away and picture of a shuttle cock, also known as a three-way dual shut off valve (courtesy www.muellerindustries.com and www.henrytech.com.)

connected to the system. By the nature of its design, there would always be one relief valve connected to the system even though the device also allowed you to isolate one valve at a time from the system.

Specifically, the device was connected to the port that is shaded purple in Figure 2 is connected to the system while relief valves, each sized for the full required capacity, are connected to the ports shaded red and blue. With the valve stem (shaded green) all the way to the left, the red port is isolated from the purple port while the blue port is connected to the purple port. Thus, a relief valve connected to the red port could be removed and serviced or replaced while the relief valve on the blue port protects the system. When you put a refrigeration wrench on the valve stem and move it from left to right, it first unseats the red port (at A), and for a while, both relief valves are active. As you continue to crank the valve stem, eventually it seats to isolate the blue port (at B). Now the relief valve connected to the red port is protecting the system, and the relief valve on the blue port can be removed and serviced or replaced.

Bottom line; the shuttle cock sure seemed like a good idea, and I found myself wondering why we hadn't put one on the system in the first place. It turned out that I was not the only person to benefit from Don's knowledge. When I got back to the office and brought Phil up to speed on the details of what happened and what I thought we should do about it, his first comment as I recall it was something along the lines of, "Davey, that's why an experienced pipe fitter is worth their weight in gold." He pointed out that Don's quick response had likely saved quite a bit of the charge. He also agreed that the shuttle cock, a piece of hardware that he, like me, was unfamiliar with, was a great idea and that we should be sure to have the contractor include one as a part of the repair to the system that had lost its charge and as a retrofit to the other systems.

The Other Technical Lessons

As you may realize, there were a number of other technical lessons that I learned while working with the ice arena systems; they just weren't as sobering as blowing the charge.[5] Space (and probably your attention span) precludes me from going into as much detail as I did with the blown charge story but some of the more important lessons from a commissioning perspective were the following.

[5] Jay Santos, one of the people I work with at FDE calls events like the blown charge "significant emotional events" and correctly observes that while they can be quite sobering to experience, the lessons gained, if we pay attention, are usually well worth the stress that occurred at the time.

Design Loads are Interesting; Load Profiles are Everything

At about the same time I was working with Phil on the ice arena, I was also working with Bill Coad (one of the principles at the firm I worked at) on a 1960's vintage high rise to develop a systems manual and preventive maintenance program for the HVAC systems. Both projects had tweaked my interest in loads and how they were assessed, and Bill was patently coaching me through my first load calculation, (a manual process at the time).[6] At one point, after answering one of my many questions, Bill said something along the lines of the following:

> *You know Dave, that load you are calculating is probably one of the most useful meaningless pieces of information we develop for a project.*

At first this seemed baffling; how could something be useful and meaningless at the same time? Bill went on to explain that one of the things both our company and the industry had been learning was that the real trick to having successful, efficient processes lay in understanding how the equipment functioned at other-than design conditions. After all, a system that was sized to handle the 2% cooling design condition would spend 98% of its time running at other conditions. And if the design team did not carefully consider what these other conditions might be and develop the system design in a manner that not only addressed the peak load but also the minimum load and all of the conditions in between, then success would be elusive.[7]

This may have been one of the most important things I ever learned in the context of my career as a designer, field person and commissioning provider. What Bill was saying was that the load calculation was useful, if not critical in that all of the equipment would be sized based on its results. But with out expending some effort to understand the <u>*load profile*</u>, the result of the calculation would shed little insight into the day to day operating requirements and challenges the system and facility would face. Thus, in practical terms, it was somewhat meaningless.

Bill's approach of posing the issue as a bit of a dilemma (useful meaningless piece of information) allowed me to wrestle with the concept a bit, and thus come to own it more quickly

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6 I was using the Cooling Load Temperature Differential approach (CLTD), which endeavored to take thermal lags into account by applying factors from tables developed for typical types of construction to conventional heat transfer equations. For instance, to calculate the heat gain through a wall without taking thermal lags into account, one might simply apply $Q = U \times A \times \Delta T$ (Load = Heat transfer coefficient x Area x Temperature Difference) to the wall. The CLTD approach used a modified number for the ΔT term that took the thermal characteristics of the wall, like its mass and color and how long the sun had been striking it and from what angel into account. The factors were developed using digital computing techniques that, at the time took hours if not days to run using the best and fastest technology available. You can still find these tables in the *ASHRAE Pocket Guide,* and occasionally, I use them in the field to help me get a feel for what the load profile for a particular system might look like.

7 The CLTD method was an intermediate step that occurred between a time when loads were calculated manually without much consideration at all for lags, and the techniques we use today which leverage the processing power of personal computers to do in seconds what used to take main frame computers hours or even days. This technology was just starting to emerge as I was learning to calculate loads. At the time, Al Black, another one of my mentors, was in the process of developing the MEDSI loads program that became our firm's standard way of calculating loads, using the first desk top computer I ever saw. His program has evolved to the web accessed engineering software subscription service offered by Engineering Software International (www.esiprograms.com).

and deeply than I might have if he had simply stated it more directly, perhaps in a manner similar to what I wrote in the preceding paragraph.

Reinforcing Concept with Reality

Most educators will tell you that taking a concept you have learned and immediately applying it in a meaningful way will do wonders in terms of improving retention and comprehension. Thus, if we, in our role as mentor or mentee, can identify a pathway to some immediate and practical experience with a concept we have introduced or been introduced to, then the benefits will be great. For me, the practical pathway for understanding loads and load profiles turned out to be the ice arena. This "perfect storm" of operating variables coupled with additional mentoring by the folks at my firm, exposed me to many practical applications of the load profile concept.

When making ice, the ice arena refrigeration systems had to deal with a huge variation in load ranging from the "throttle to the wall" requirements associated with making ice on a mild fall day to virtually nothing once the ice was made and it was cold outside. The fact that the systems also had to operate in the summer against the building cooling load only compounded the dynamics that the system had to deal with.

- Refrigeration loads were all over the map, requiring multiple compressors of different sizes with unloading capabilities.

- A corollary of the first bullet was that the refrigerant flow rates and the related ability to return oil to the compressors [8] was also all over the map.

- A corollary of the second bullet was that refrigerant line sizing was critical for the ice arena systems, especially at points in the system where the piping changed elevation where double suction risers were required.[9]

- A second corollary to the first bullet was that the compressor performance in terms of capacity and power required varied significantly with the seasons as well as the load. Thus, the operating parameters that I observed in my regular test visits varied with the system operating mode; temperatures and pressures that are normal in one mode could be an indicator of a pending problem in another.

- Related to the compressor performance was the performance of the refrigerant control devices, particularly the Thermostatic Expansion Valve (TEV). In this particular system

[8] In most refrigeration systems, the oil lubricating the compressor is exposed directly to the refrigerant. As a result, some of it is carried out of the compressor crankcase and into the refrigerant piping. This in turn translates into the need to size the piping, particularly the vertical piping, in a manner that ensures that the line velocities will be high enough to carry oil back to the compressor *under all conceivable load conditions*.

[9] In general terms, this is an approach that splits the vertical refrigerant piping into two smaller lines, one of which is sized to ensure oil return at minimum load and one of which is sized to carry full load. Cleverly constructed traps use oil that fails to return temporarily as the load drops to block flow to the larger line at low loads. Both the *Trane Reciprocating Refrigeration Manual* and the *ASHRAE Refrigeration Handbook* contain detailed information on this topic for those who are interested.

the TEV had to deal with two very distinct operating conditions with the penalty for failure being slugging of the compressor. Verifying superheat and adjusting it appropriately was critical, and an error could quickly compromise the performance of the system or damage the equipment.[10]

- The cooling tower serving the refrigeration plant needed to operate on a year round basis. This meant that it needed to be large enough to reject the building cooling load on the hot, humid days that are common occurrences during the St. Louis summer. But it also needed to be able to regulate temperature and reject the modest load that might exist on an extremely cold, overcast winter day where the only real load was losses through the slab to grade and gains from diffused solar radiation. And it needed to perform this function without freezing the basin and piping serving it and without icing up the fan blades, which could cause the fan to fail.

- As mentioned early in the paper, the building summer-time cooling loads were handled by the same chilled glycol system that supported ice making in the winter months via a chilled-hot water system. This meant that a coil that served as a heating coil in the winter with relatively large differences in temperature between the air it heated and the warm glycol used to deliver the heat also had to function as a cooling and dehumidification coil in the summer when the driving temperature differentials were much smaller. This made the sizing of the coils and their controls critical. The set points, tuning, and adjustment of the control loops for the air handling systems and the heat exchangers that warmed the glycol were also more critical and sensitive than they would be for a system with independent chilled and hot water circuits. The chilled/hot configuration also introduced the potential for simultaneous heating and cooling into the mix of operational issues that could occur.

Testing Rigor Must Balance Risk with Reward

You will recall that the tests we ran on the ice arena system were fairly rigorous. In most instances, we tried to drive the system towards the failure mode and verify the appropriate response rather than adjusting the set points of the current operating condition and observing the response. There is a significant but subtle difference between the two, both in terms of the issues that will be identified and the risks that are imposed on the system by the test.

In the case of the ice arena, Don and I were testing a head pressure cut-out switch and inadvertently identified a relief valve problem. The real issue was not that our test caused the relief valve to open. Rather, it was that in developing the test, I had not considered the potential to trip a relief valve that had drifted off of set point and planned accordingly. Taking a step further back in the system's evolution, the design had also not considered the potential for a

[10] In a nut shell, the TEV makes sure that all of the liquid refrigerant is boiled off before it reaches the outlet of the evaporator. Failure to do so could result in liquid entering the compressor or "slugging," which will quickly destroy a positive displacement machine and was one of the root causes behind the failures in the original system. The Sporlan Valve website at www.sporlan.com has a wealth of useful, downloadable information on TEV's, superheat adjustment and refrigeration control for those who are interested.

relief valve to open at a lower than rated pressure as there were no shuttle cocks installed originally.

The reality was that the relief valve in question opened up significantly below its rated setting, even if you take the normal specs and tolerances into account. Had the issue not been exposed under test, it is likely that the valve would have let go at some other time, perhaps in the middle of the summer when a major event was being hosted in the auditorium or maybe in the middle of the winter when the facility was hosting an important ice skating event. While the failure under test did in fact result in the loss of some refrigerant (and a commensurate increase in the size of the hole in the ozone layer), Don quickly intervened and minimized the loss. We also learned from the event and made improvements to the system that improved the chances of dealing with the problem more readily were it to happen again. Our improvements also provided a mechanism to virtually eliminate the root cause of the problem by periodic over-haul and testing of the relief valves.

The bottom line is that every test we perform places the system under test at risk. But the difference is that if you are under test, you are in position to do something if things begin to unravel. In contrast, if the issue goes undetected, only to be brought up by “Mother Nature” then the likelihood is high that there will be nobody to intervene and the damage will be much more significant.

When developing a test, it's critical to use good judgment in determining just how far to go, weighing cost versus benefit in addition to attempting to simulate actual failures. For instance, at the ice arena, we did not attempt to cause the compressor to lose oil pressure to check the oil pressure switch for a number of reasons, including risk to the compressor and complexity of the test procedure. Rather we lowered the safety’s set point below the current operating condition and verified that it shut down the compressor. This verified the functionality and integrity of the interlock circuit as well as most of the internal workings of the switch (see Figure 3).

Specifically, the test we performed verified the functionality of everything from the set point adjustment mechanism through the compressor starter. It did not:

- *Directly verify the calibration of the switch:* But, by watching the pressure at which the heater was energized as the set point was adjusted and comparing it to the set point scale, we could gain a pretty good feel for the accuracy of the switch.

- *Directly verify the integrity and the bellows and sensing lines controlling them:* But, if the bellows or lines had failed, they would have triggered numerous other failures that would shut the system down, including loss of oil pressure (because it would be running out of the system) and loss of refrigerant charge, which would show up as a low suction pressure safety trip.

While it was technically possible to provide valves and taps in the sensing lines in a way that would allow us to simulate a problem with the lines or the bellows and thus, verify the integrity of the entire system, it was a complicated arrangement and test process. In addition, it introduced the potential for other problems that could lead to failures, including an actual loss of oil pressure if a sensing line was valved out for a test and then not valved back into the system afterwards. Thus, the steps required to test the cut-out switch system in a way that verified the integrity of all

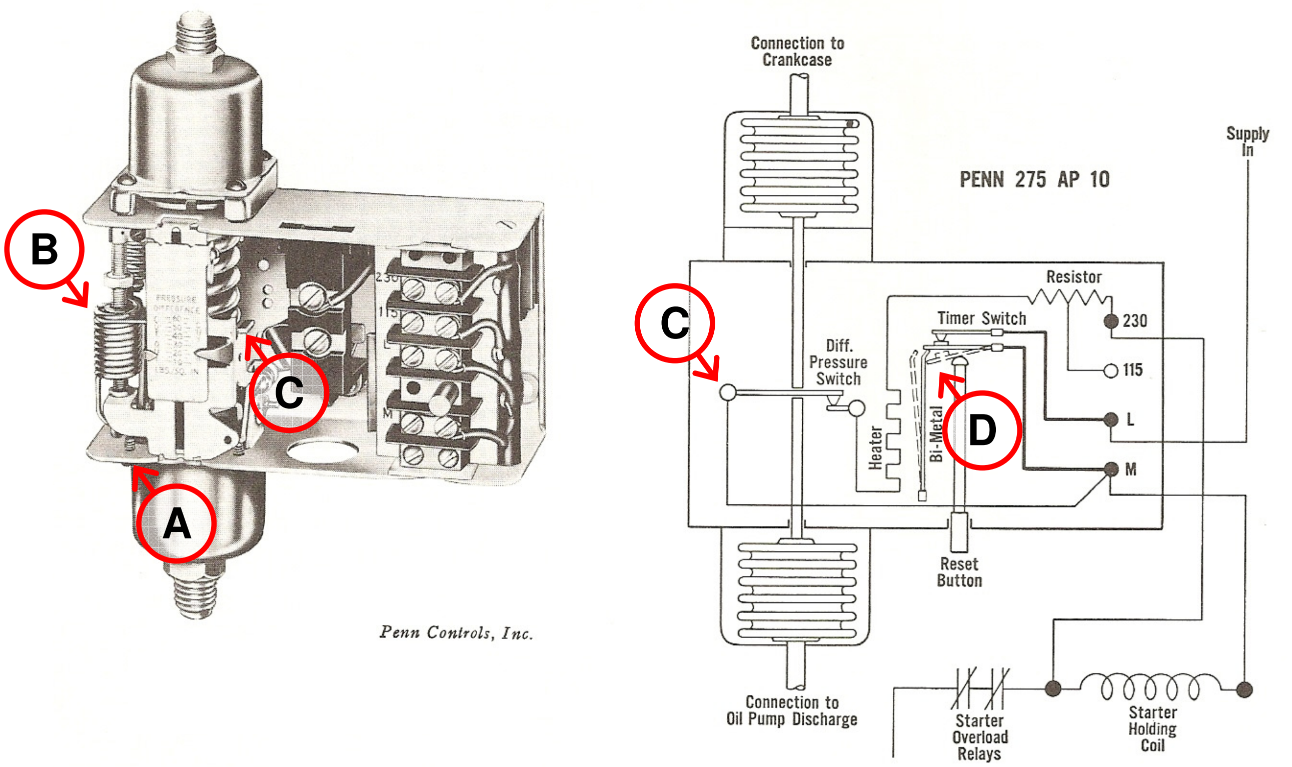

Figure 3: Low oil pressure switches need to incorporate a time delay to allow the equipment they serve a brief period of time to start with no or low oil pressure. Thus they are a bit more complicated than your average switch. Adjusting the set point screw (circle A) of this refrigeration pressure oil pressure safety changes the spring force (circle B) on the lever that controls the contacts (circle C) and thus the force balance between the contacts, the compressor oil pressure, and the compressor crankcase pressure (the reference point for the oiler pressure). If the oil pressure drops below set point, the contacts keep the heater energized, which in turn, heats a bimetal strip. If the oil pressure stays low enough for long enough, the bimetal strip warps allowing the contacts between terminals L and M to pop open, de-energizing the compressor control circuit and shutting down the compressor. When the compressor control circuit is de-energized, the heater is too. As a result, the bimetal strip straightens back out. But, since the contact is in the open position, it is trapped below the curved tip of the bimetal strip (circle D). To re-close the contact, someone has to push the manual reset button, forcing the contact past the curved tip on the bimetal strip, thereby locking the circuit closed until the next loss of oil pressure. (*Image scanned from the Trane Refrigeration Manual,1966 edition, page 48, published by the Trane Company in the interest of the Air Conditioning Industry.)*

of its elements had the potential to cause a real failure of a complex, expensive machine. And the potential for a misstep made such a result more likely than the actual failure of the components such a test would verify.

Contrast this with testing another common safety device found in many HVAC systems; the freezestat.[11] I've seen people test this device in a number of ways ranging from:

- *Pushing and releasing the reset button,* which verifies that the switch is in the circuit but does little to verify its calibration, the functionality of set point adjustments, and internal circuitry or the element.

- *Raising the set point above the current operating temperature,* which verifies the internal components and to some extent verifies the sensing element but can be difficult to accomplish given the limited range of adjustment.

- *Draping ice filled bags over several feet of the sensing element,* which verifies the integrity of the internal components, the element, and the elements response characteristic (responds to temperatures over a short section of its length).

In this case, performing the more rigorous test is not that much more difficult than the simplest one, does not require any modification to the switch or its sensing mechanism to allow the test to be performed, and verifies the full functionality of a critical safety device.

The Mentoring Lessons

The Obvious Lessons

I'm sure many of the mentoring lessons associated with my experience were obvious to most readers from the context of the story.

- Don didn't say, "I told you so." Nor did he let a bad situation that was the result of a procedure he did not totally agree with become worse. Rather, he did his best as quickly as he could to minimize the loss. Once he addressed the problem, he calmly and patiently answered a question that probably should have been asked much earlier or much later ("what's a shuttle cock?"). And his demeanor in doing it certainly helped calm down the young and somewhat panic stricken field technician he was working with by focusing on what we could fix rather than what we couldn't fix. Staying "calm under fire," focusing on solving the problem rather than assessing blame, and recognizing the impetuousness of youth for what it is (where you used to be before you became wiser) rather than calling me an "idiot" all are powerful mentoring techniques that have been demonstrated to me by my mentors time and time again.

- Phil was comfortable enough with himself to praise Don's field savvy and also acknowledge that there was something he didn't know to someone who held (and still holds) him in very high regard. In addition to teaching me something, his actions only

[11] For those from warmer climates who may not be familiar with a freezestat, it is a manual reset switch with an averaging style element that is designed to respond to the coldest temperature over any 1-2 foot section of the element. It's typically applied in air handling systems to protect water coils and the building from freezing. It's set for 38-40°F with its element strung across the AHU cross section, downstream of any preheat coils but upstream of the rest of the system. When tripped, the freezestat shuts down and locks out the AHU it serves.

increased his stature to me. On more than one occasion, I've seen someone in Phil's position do the exact opposite in such a situation, focusing the blame on their benefactor to distance themselves from liability and preserve their image among other things. Phil's response to the problem also made me more comfortable to go to him with a question about something that I didn't understand which undoubtedly saved the day on many occasions. Being comfortable with whom you are, demonstrating integrity, being fallible and human, letting your mentee teach you something, and giving credit where credit is due are also powerful mentoring techniques as well as examples of how to live a life with integrity as a cornerstone.

- Frequently, in the commissioning arena, we find ourselves on a team composed of people with theoretical knowledge that has its roots in a classroom or a text book complemented by people with practical knowledge that has its roots in field experience. This can be a powerful, positive combination, but also can be complex from a social and relationship standpoint.

  While I can't say for sure, I strongly suspect Don's lack of comfort with the rigorous head pressure switch test had its roots in a similar bad experience in the past; i.e. he knew from having "been there" that aging relief valves can lift at well below their rated pressure. But, since I was in charge, he didn't expand on his reluctance during our brief discussions of the topic, either because he figured I had thought about it (I hadn't), he figured I knew more than he did about it (I didn't), or he figured I had a plan in place to deal with the problem should it occur (obviously not the case). Or, maybe he had been told by one to many engineers to "do it my way because I'm in charge" and was reluctant to go down that path again because it was intimidating, disrespectful, or both.

  What ever the reason, Don's reluctance to voice a more detailed version of his opinion coupled with the impetuousness of my youth and the somewhat arbitrary command and control structure (the engineer is in charge of the field staff) were all likely links in the chain of events that led to our "discovery."

  For me, there are several lessons here. One is the obvious one; for group efforts to be successful and fully realize the potential that each player brings to the table, the atmosphere needs to be respectful and congenial with room *and time* for everyone to express and discuss their opinion. The "time" part of the preceding can be particularly challenging in today's fast past, schedule and budget bottom line driven projects. But frequently, a little time spent involving everyone in the discussion up front can save both hours and dollars down the road by preventing avoidable problems.

  The less obvious lesson is to simply believe in yourself; if you are uncomfortable with the way something is heading, then there probably is a good reason for that, at least in your perspective. If you bring it up for discussion, then you may discover any number of things, including:

  - *Your concern is shared by others* who are glad you had the courage to mention it,

- *Your concern is a valid concern* that had not been previously recognized, or
- *Your concern had been recognized and is addressed* by a part of the procedure you are not familiar with.

The "Behind the Scenes" Lessons

There were also a number of mentoring activities that occurred behind the scenes that are worthy of mention.

- The technical knowledge gained regarding system dynamics and load interactions were not gained solely of my own volition. The knowledge was gained because experienced people took the time and provided the resources to foster the knowledge and allow me to learn. Phil took me out in the field and showed me the wheres and whys of the design, equipment, and hardware. And when he wasn't around and I had a question, any one of a number of people in the office would take the time to fully answer it as well as the ones that spun off of it.
- In my quest to rigorously test the systems, initially fostered by my instructions from Chuck and Phil, I actually figured out a way to simulate an oil pressure failure rather than perform the test of the oil pressure switch by cranking the set point up. But, it was complicated technically and pretty risky on a number of fronts as discussed previously. Phil and Chuck each spent some time helping me understand that, after first congratulating me on how thorough I had been. As a result, I was affirmed and reined myself in, rather than feeling foolish and like I had let folks down.
- Don wasn't the only one from the contracting side to share his world and knowledge with me. Paul Bott, the project manager for the contractor, would always make a point to take me under his wing when he was on the site, usually buying me lunch, answering questions, and regaling me with stories from his own past and the things he learned from the experiences.
- Similarly, some of the sales representatives involved with the equipment on the project went out of their way to make sure that I had the information I needed to properly understand and test the equipment, and have all my questions answered and then some. On this particular project, Bill Hittler, the Sporlan Valve representative was more than generous with his time and information, demonstrating the proper measurement and adjustment of superheat to me out in the field and providing me with a catalog that was more than just glossy sales brochures. It still occupies a prominent place on my reference shelf.
- Those who have been around the commissioning and operations field for a while know full well that controls are key to success. At the ice arena, the relay panel that sequenced the compressors, cooling tower, and other elements in the system was crucial to success and a key focus for ongoing testing. The panel was my first exposure to complex relay logic and initially was very intimidating. Fortunately, it had been designed by Tom

McCarthy, one of our electrical engineers and a master of the art. Like Phil, Tom went out of his way, both in the field and in the office to help me learn the electrical side of the business and its hardware and theory. In particular, I enjoyed Tom's way of conveying knowledge, which frequently revolved around the trials and tribulations of Harry Schnoffinlotz, a fictitious, generic, electrician whose woes were all the result of poor design by an uninformed electrical or controls engineer. I strongly suspect my penchant for telling stories can be traced to my amusement and admiration for the ones Tom told.

Mentoring the Masses

Given the phenomenal growth occurring in the commissioning industry, one of the biggest challenges we face may be identifying ways to convey the field lessons learned by experienced practitioners to the new generation entering the industry. As a result of my many positive experiences as a mentee, I've come to believe that mentoring of the novice practitioner by the more experienced can be a powerful tool for meeting this challenge. But to meet the growing need for knowledge, I believe we need to develop techniques to accomplish this en masse in addition to pursuing one on one mentoring opportunities when they present themselves.

I have been fortunate enough to be involved in several training venues where we have been experimenting with different approaches for accomplishing this and in closing, thought I would offer some of our insights for your consideration.

Pictures are worth a Thousand Bullet Points

Frequently, training classes are accompanied by PowerPoint® presentations where-in the presenter's points are summarized by a bulleted list. While useful to focus talking points and helpful as a memory jogger when the materials are consulted at a later date, graphics depicting the concept can be powerful tools for conveying the same information in a more meaningful way.

Figure 4 is from a slide I use in several classes I teach where I want to emphasis the importance of understanding the load profile a system will see, both on daily basis and a seasonal basis. When I first stated teaching this concept, I had several slides with bullets and tables that highlighted key points and compared one condition as a percentage of another. But, I have found, at least for the audience I am trying to reach, that a well thought-out graph or an appropriate photograph from the field, or even an animation can convey my point or points in a more powerful context.

That said, a poorly thought-out graphic can be worse than a list of bullet points (or a blank slide for that matter). Many people, including myself, have found the works of Edward Tufte[12] to be particularly enlightening and inspiring in terms of understanding how to explain things graphically with eloquence.

[12] See *The Visual Display of Quantitative Information, Visual Explanations,* and *The Cognitive Style of PowerPoint,* all by Tufte.

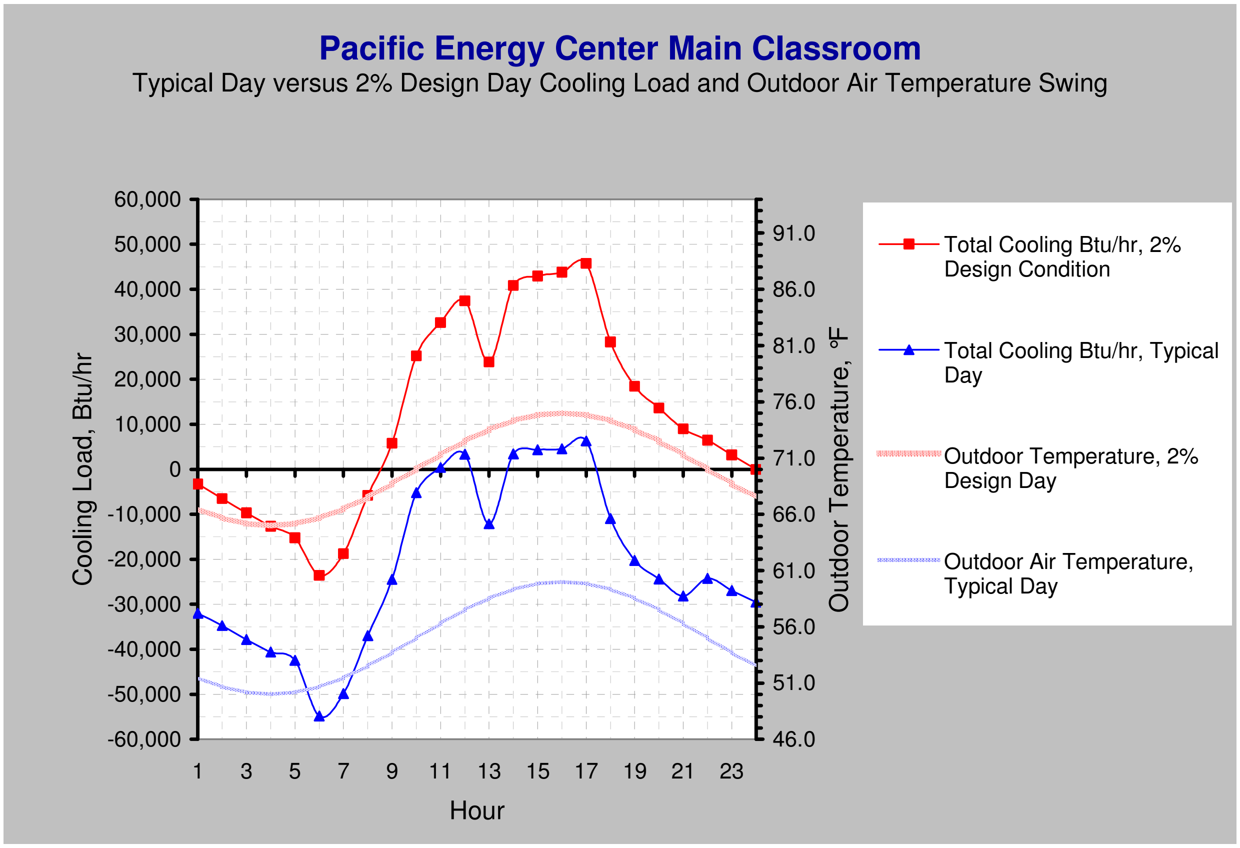

Figure 4: This hour by hour load calculation for a classroom in San Francisco where I frequently teach illustrates how dynamic HVAC loads can be, both on a daily basis and on a seasonal basis.[13]

Real World Experience with Technical Issues Connects the Dots

More and more frequently, I find myself looking for opportunities and methods that allow me to take a classroom full of people outside the training room and expose them to a working example of what we are talking about in lecture. The staff at the Pacific Energy Center, in particular, Ryan Stroupe, has been very supportive of this approach by allowing us to turn their facility into a hands-on lab, where-in the students perform real-time, hands-on commissioning on the systems in the facility, as illustrated in Figure 5.

[13] The load is assessed for a full class of 80 people with a space temperature of 70°F. Note how in the mild climate, even on a design day, the transmission losses through relatively poor Southeast facing glass, combined with the ventilation load associated with 80 people results in a net heating load early in the day. On a typical day (for more than half of the year in San Francisco, it's between 50 and 60°F) the high ventilation requirement and transmission losses result in a net heating load most of the time.

Figure 5: Students in a hands on existing building commissioning class performing a pump shut-off test. The smiles are folks having a good time and are generated by the dots connecting.

One of the challenges associated with doing this is that the student to teacher ratio needs to be kept fairly low for a number of reasons, including being able to maintain some measure of control over the learning experience, being able to deal with real time events and issues as they come up, and keeping things safe.

Recently, in an effort to deliver a field experience to a broader audience, Ryan and I tried shooting a video clip of me performing a pump shut-off test with a tachometer monitoring the pump speed.[14] This allowed us to supplement lecture content where-in we were discussing how centrifugal machines interact with their drivers with visual evidence of the variation in slip with load. And, while we are still awaiting a call from the Academy of Television Arts and Sciences nominating us for some sort of award, the feedback forms from the class indicated that the experiment was successful, which will likely encourage us to do a bit more filming.

In addition to being entertaining, research suggests that active learning strategies like performing a field test or watching a video and discussing it can dramatically improve comprehension and retention. This is partly because the field experience repeats the lecture content in a different context. But it's also because it allows the students to process the information in a different way, by working with it using a different sensory system.

Stories of Real World Experiences are Engaging

Tom McCarthy was wise in conveying his engineering wisdom via the adventures of Harry Schnoffinlotz; stories are engaging. I've also found that if you can't provide a real world experience in the form of a lab session, then telling a story about a pertinent real world experience that you had can be almost as good. This technique also has benefits on other fronts:

- *It can put you at ease:* I discovered this by accident the first time I went to do a training session with Karl Stum while working for PECI. Early in my session, someone asked me a question that was best answered by recounting a field experience. A few sentences into my story, I realized that my shaking knees and quavering voice had all but disappeared.

- *It establishes a connection:* Telling a story on yourself, especially one in which the machinery bested you, reveals your human side. I think that revealing your human side

[14] If you are curious, you can view the result of our effort on YouTube at the following link: http://www.youtube.com/watch?v=1zWJgBjm_U0.
The actual demonstration of slip starts at about 3-1/2 minutes into the video.

allows your mentees to identify with you more readily and makes you more approachable.

- *It adds color to potentially dry topics:* Face it, even if you are interested in engineering, you have to admit that a discussion of the physics behind it can occasionally be a bit dry. But, telling a story that illustrates the concepts can liven things up, engaging the mentees by grounding the theoretical example in real world practicality.

Conclusion

If I had to pick a key phrase or concept from what I have written to summarize the concept of mentoring, I think it might be that it's about living life with integrity as a cornerstone. For the mentor, this involves demonstrating these aspirations to those around you as you go about your day-to-day life. For the mentee, it involves aspiring to them (and not being too hard on yourself if you occasionally miss).

Finally, as a mentee, you are gaining the knowledge and tools you need to be the future mentor to someone coming up through the ranks. So remember those who have blessed you with their knowledge, and share the gift they have given you when the opportunity presents itself. It's likely that the impact you will have will be broader and longer lasting than you realize and as a result, the world will be a bit of a better place.

Additional Reading

It occurred to me as I wrote this that beyond the technical content, resources for some of the philosophical content might be valuable. What follows is a brief list (in no particular order) of some books and writings that have influenced my thinking either about our relationships with each other or the planet (or both; the longer I am around, the more convinced I am that they are inseparable).

- *Light Emerging* and *Hands of Light* by Barbara Brennan.
- *Black Holes and Energy Pirates: How to Recognize and Release Them* by Jesse Reeder.
- *The Four Agreements: A Practical Guide to Personal Freedom* by Don Miguel Ruiz.
- *Touch the Earth* by T. C. McLuhan.
- *Circle of All Nations Vision Statement* by Elder William Commanda, available for download at http://www.angelfire.com/ns/circleofallnations/brochure_-_march_2003.pdf