Rube Goldberg Winner – Early Temperature Control Systems

by Bill Holmes, P.E.

Are you familiar with Rube Goldberg or the Rube Goldberg competition for engineering students at Purdue? Once a year a contest is held to see which team of students can come up with the most complicated way to perform a very simple task, like opening a beer bottle and pouring the contents into a mug? Well, five minutes and 127 steps after the sequence is initiated, if everything works right, the beer is in the mug with a perfect head on it. If you have ever seen a video of some of the winners, you may have a feel for what some of the older temperature controls systems were like. If you haven't, it would be worth your time to do a search on U-Tube for the contest. It is really amazing and very creative. When some of those students graduated they went to work for Johnson or Honeywell or Barber-Colman designing temperature controls systems for buildings and unfortunately, judging from the older systems I ran into in the field, they must have relied solely on their Rube Goldberg experience when designing them.

How temperature control systems are designed

When I first started in the business, those systems were electric, pneumatic or combinations of the two; no PC-based or electronic controls were available. In 1974, when I went to work for an engineering firm I discovered the method that design engineers use for designing control systems; you call the rep who sells the controls and they design the system for you; the method that is still used today. There were a couple of reasons to do that. The first was of course, the average design engineer could look at a drawing of the pneumatic system and the only intelligent question they could ask was where's the beer mug at the end? Or maybe where is the end; or the beginning? No normal human being could understand one of those drawings. And if any of them actually ventured into the field and opened the door on one of the control cabinets, they were even more bewildered. If everything was installed exactly like the drawing, they couldn't possibly relate what

they were seeing in that cabinet to the drawing in their hand. More than likely though, what they saw was a far cry from what had been originally installed. Various maintenance people or contractors trying to get a piece of equipment to operate had made unauthorized modifications over the years.

The second reason was that design engineers were on a budget; their time was money; that's all they had to sell. If they could let an engineer for the controls company design the control system at no charge; that was time they saved. Less of their time meant more profit on the job. It's standard practice and makes a lot of sense if managed properly. There is no way a consulting or design engineer can be an expert on everything. He or she has to rely on the experts who design and manufacture the equipment they are specifying. The problem is when they just give a free reign to the people who design and also sell the system. When it is a system that they don't really understand themselves, that's a big problem. And temperature controls systems are black magic, completely mysterious. Most engineers are afraid to touch them in the field for really screwing something up. And the specs provided to the designer by the controls company are often written in a way to try to exclude anyone else from qualifying to bid; or at the very least, limit bidding to only a couple of the largest companies. Of course if some of their proprietary controls are already in the facility, the specs are written for them to be the "sole source". What owner in their right mind would want to have to deal with two different makes of control systems in the same building?

A contractor brave enough to tackle a control system

I had been to a seminar in Atlanta put on by the Association of Energy Engineers (AEE) and heard a presentation from a contractor who was doing the same thing I was now hoping to do in the business I had just started. He was going into existing buildings, finding problems and correcting them to reduce the energy consumption. He showed a picture of himself standing in front of a control panel holding several components he had removed; he said they weren't necessary. So I thought if he could do it, so could I. I had been working in the Quinco Mental Health Hospital for

a few weeks trying to figure out how things were being controlled. I had studied the temperature controls drawings which were, as I recall, written in Sanskrit. I had looked at all of the individual controls as well as the devices that were being controlled but still had almost no idea why things were doing what they were doing. I even took some of the controls home and took them apart.

I had asked the maintenance people, the contractors and anyone I could think of and gotten no help. But none of them really understood the system either. I really couldn't afford to pay Johnson Controls $100 an hour to send in a technician to help me. Plus I had learned in other projects that most solutions provided by Controls companies involved adding more controls. Of course the salesmen always wanted to do that; it was how they made their money and assured an ongoing stream of revenue because the more complex the system was, the more the building was tied to the Control Company's service. The guys in the field normally didn't care about selling, they usually just wanted to fix the problem. But they had been trained by the controls company so they were generally rather myopic when it came to seeing solutions; just add more controls

I had studied everything I could, asked everyone I knew for help, spent hours and hours in the building and still didn't understand a lot of what was happening. But I had to do something. I was being paid to produce results, to save energy; my only fee was a percentage of actual documented savings, and I couldn't do it by leaving the things the way they were. What else could I do? I decided to do something and see what happened.

Pneumatic Control Panels

There were three temperature controls panels on the wall in the boiler room maybe 3 feet wide by 3 feet high and 12" deep. When I swung open the hinged door on each panel I was faced with about 20 different controllers mounted on a perforated back plate. There was black plastic pneumatic (compressed air) tubing and electrical wiring running everywhere. If the contractor in Atlanta could fix these things, surely I could, too. David was with me; my best student who had started

working for me part time. Thirty years later he still remembers watching me in disbelief as I took a pair of side cutters and started through each panel, cutting every tube and electrical wire. Then I took a screwdriver, unscrewed every controller and put it all in a pile on the boiler room floor. I was sweating realizing that I had no idea at all what the hell I was doing plus it was hot in that boiler room and I could hear those boilers rumbling as they were surely building pressure getting ready to blow us to pieces any second. I had probably cut the only line that had been preventing them from exploding. So David and I just waited. We looked at each other and we looked at the huge pile on the floor. I took some pictures of the empty panels and everything I had removed from them. David tried casually to move closer to the exit door hoping I wouldn't notice. We were in a basement room with no windows, not really a comfortable place to be right then.

Guess what happened next? Unbelievably, absolutely nothing. I can't remember a single change in the operation of any of the equipment. Apparently, over time, the building maintenance people and the contractors, in order to keep the equipment running and the building as comfortable as possible, had just wired around or bypassed every single one of the controls. Plus the controls company may have sold some "optional" controls that weren't really essential. The panel had P.E. switches, E.P. switches, various setpoint controllers and a number of controls that are known in technical terms as "thingamajigs". The building had a chiller that made cold water that was circulated through cooling coils in two large air handling or fan units, one serving each half of the building. It had two large boilers for building and water heating and several circulating pumps. All of the major equipment had integral controls for safety and basic operation.

Although there were simple time clocks in the control panels to turn the fans off and on, they weren't being used. One half of the building housed an in-patient unit that was occupied 24/7 so all of the HVAC equipment for that portion must run continuously. The other half of the building was where the offices and out-patient treatment areas were and it was occupied from about 8 AM to 8 PM on weekdays and until noon on Saturdays. All of the HVAC equipment for that portion was also

being run 24/7. When we first tried shutting off the air handler for the offices, it slowed, stopped and then started to turn backwards. The way the ductwork had been designed and installed, it really couldn't be turned off. When it was, all of the air from the other fan, the one for the in-patient unit, instead of going to the unit, short-circuited back through the office fan instead. We ended up modifying the controls for some dampers in the main ductwork to correct that problem.

The boilers were running 365 days a year and so was the chiller and all of the pumps; not unlike many of the building that we would encounter through the years. Finding heating and cooling systems fighting each other, both running at the same time, serving the same areas is an almost universal problem. Sometimes it is a problem that was designed into the systems from the beginning by the engineer; wrong application, wrong system for the building. Often it had resulted from maintenance people trying to fix a problem or from just the ignorance of someone somewhere along the way.

In this case, we found one of the most glaring construction problems that we ever found. There was one thermostat in one room on the south side of the building that controlled all of the hot water radiators or "perimeter heat" that ran in a continuous loop on both the first and second floors. When the drywall had been installed during the building construction about ten years earlier, a workman had pinched the black pneumatic tubing closed that ran to this thermostat and put the "perimeter heat" into its fail safe or freeze protection mode. The hot water heat had been running full out since the building was built, full heat 24 hours a day, 365 days a year, summer and winter for 10 years. The only way that any comfort control had been maintained was by running the air conditioning system 24 hours a day, 365 days a year to remove all of the excess heat. And this really wasn't an isolated situation although it was one of the worst we found. A big part of our value, something that could not have been done in most cases without instrumentation, was to discover and correct problems that had existed and been hidden for many years, in several cases since the building was built.

Looking back, I guess I may have been really lucky. I was cautious; I wasn't stupid. I wasn't reckless. I made sure the equipment had all of the safety controls required and I didn't mess with those. I took every precaution I could. But if I hadn't heard the presentation in Atlanta at the very beginning of my career, when I just started working in actual buildings, or if I had been working with the owner's money, I might have just followed the traditional approach, paid the control company and never learned about the systems for myself. It didn't turn out too badly, though, by adding an Energy Monitoring System at the beginning of the project and the using the resulting data to assist in simply tuning up the facility through changes in operation, maintenance and control, with no capital projects required, the Hospital reduced their annual utility costs by 59%, the project received the Governor's Award from the State of Indiana was featured in an article in the Journal of the Association of Energy Engineers.

As a side note, another piece of good luck for me was that I had gone to Engineering School at Rose Polytechnic Institute (as it was named at that time) a small engineering school in western Indiana about 100 miles from Purdue. We didn't have a Rube Goldberg Competition. Had we, I might have been able to understand those original control systems and wouldn't have had to gone to all that trouble.