Designing Batch Process Utility Piping

by Anthony J. Curiale, CPD, LEED AP

When I tell folks I am a Plumbing Engineer, they give me that quizzical look that suggests they heard the plumbing part, but can’t make the engineer connection. When I explain exactly what I do, they invariably go, “Oooohhh!” and the next look in their eye suggests, “Boy, you have a boring job!” If all we did was pipe up toilets and make sure it all goes downhill, I would likely agree, but fortunately for most of us, that’s not the way it is. Technology improvements, conservation measures, and public health concerns have reached a crossroads in the current era to allow us some pretty challenging projects and design opportunities. When the unique ones come along, it is worthwhile to relish every minute, lay aside the pressures of schedule and budget, and just create!

I recently had such an opportunity. I had been hired by HLW International as a Senior Engineer, utilizing my experience as a process piping designer to aid in their advance into the vast pharmaceutical market prevalent in the New York/New Jersey area. I was immediately assigned to be involved in the design of a 225,000-square-foot research and development center for a well-known home-products corporation (see Figure 1), located in Suffern, New York, that was to replace their existing 360,000-sf research and manufacturing facility built in the early 1920s and modified ever since. One of my first challenges involved the design of the utility piping for approximately 30 relocated steam and vacuum kettles.

A new laboratory facility design meant a great opportunity for the researchers. Their existing pilot laboratory, used by researchers to develop new products, create trial batches, and test the various properties of products, had become a veritable “spaghetti plate” of piping configurations in a difficult-to-clean environment. As a kettle or blender was needed to develop a formula, a location somewhere in the lab was chosen, and the piping in the vicinity was worked over to provide the heating and cooling at the least possible cost. It is important to understand that in a research facility, a majority of the operating budget pays for equipment. When the opportunity to provide a better, cleaner arrangement presented itself, they desired a final product that could be easily cleaned and concealed the bulk of the piping and controls, so that it was attractive to visitors, and was suited for a variety of uses without the need to modify for each new application.

The first order of business was to learn their process and understand their use of steam, water, and air and how temperature was controlled during the batch process. It was necessary at this stage to call on the services of a process consultant to prepare piping and instrument diagrams (P&IDs) and specify the necessary control components. This work is normally outside the responsibility of the process piping designer and beyond the skill range of most plumbing engineers. After extensive surveys and making detailed sketches of the existing process equipment that would be relocated to the new facility, it was necessary to sit with the owner and establish their wants, needs, and desires. In addition to the above-mentioned items, the researchers desired that the assembly be an arrangement...
that would work for any piece of equipment that might be considered for future installation. The piping must contain plugged outlets for all utilities at every station, even if not needed at the present time. The assembly must be watertight to allow washdown of the facility, without trapping moisture, and should allow good accessibility to the controls, in case future modifications were desired.

I made some preliminary sketches to define the size of the envelope needed to contain the pipework and controls. This was an immediate need, as the project architect had to design a pipe service chase to suit the laboratory and complete the architectural construction documents. The sketches took into consideration the location of the inlet and outlet connections on the kettles, and we decided on a location for the inlet and outlet pipes that would work for all of the equipment. I then used those locations to develop a vertically stacked arrangement of service mains with horizontal branches feeding a common supply and return header inside the chase and single supply and return lines exiting the chase to the equipment. The services they desired in the service chases were compressed air, vacuum, plant cold and hot water, steam, condensate return, and chilled glycol supply and return.

The mains are stacked within and along the centerline of the 30-inch-wide chase; the branches are turned 90 degrees and run parallel to the mains through their respective control valves before connecting to a vertical manifold. This results in three vertical stacks of pipes running the length of the chase. Figure 2 shows the stacked arrangement of the service headers. Note the hot plant water line at the base of the chase on the left. We kept this line low and out of the way because it only feeds a hose station at the end of the chase.

Each manifold has its own supply or return line, a vent plug, and a drain. This arrangement occurs on each side of the chase on 4-foot centers where 12-inch-wide fixed panels allow the equipment supply and return lines, as well as air, vacuum, and drains, to exit the chase. Three-foot long removable panels are located on either side of the fixed panels, which, when removed, expose the valves, controls, and instruments for each assembly. The utility supplies, manifolds, and controls work together to form a “module” that is duplicated at each equipment location. Figure 3 shows the CADD detail of a typical module’s piping, and Figure 4 is a photograph of the constructed product.

Power receptacles and the temperature control panels are mounted on
top of the chase on a 10-inch-wide fixed panel running the length of the chase center. A 10-inch-wide removable panel on either side of this fixed panel gives additional access to the controls and valves from above.

All of my piping layouts were designed using Microstation CADD software and a pipe and fitting application that places actual-size pipe fittings and valves in a two-dimensional drawing file. The application allowed me to design the arrangement without having to make additional sketches or run numbers to check for fit.

When the overall design was complete, I made a full-sized plot of the arrangement. I pinned this on the wall of a conference room, and the facility staff reviewed the accessibility of the components and discussed the operability of the system. In this way, the plant maintenance personnel could see a paper mockup of what they would receive. We were able to determine how wrenches would be spun and identify a few pinchpoints. A few changes had to be made before the construction documents could be prepared.

Some highlights of the overall arrangement include a hot and cold water mixing station with a hose rack mounted on the end of some of the service chases. For this purpose, a separate, full pressure plant water line was run from the riser to the hose station at the end of the chase. Plant hot water was also run in similar fashion (refer back to Figure 2). Another unique feature is a portable kettle station at some locations. A portable kettle station consists of a steam, condensate, and air connection with quick-disconnect fittings arranged such that the owner can wheel a portable kettle up to the position, connect the valves to the jackets with hoses, and manually bleed steam in to heat the jacket. The air is used to run an air-driven motor on the agitator. The hose station and portable kettle station can be seen at the end of the service chase in Figure 5 and again in Figure 6.

During the bidding process, I was surprised to learn that the item that gave the contractors the most concern was where the division between the mechanical and plumbing contract scope took place. Since the installation included steam and water services, it was important that each trade's responsibility was clearly defined. It was decided that the mechanical contractor would fabricate and install the common steel manifolds and all piping out to the equipment, as well as the steam, condensate, and glycol piping in the chases, and the plumbing contractor would fabricate and install all of the rest. The steel pipe was adequately isolated from the copper piping with dielectric unions. During the initial construction of the piping, we insisted on having a mock-up built so we
could see how things would fit together and could work out any unrealized nuances. Schedules being what they are, however, it was decided rather to fabricate one chase and use it for review instead. It actually turned out to be a good idea because we were able to correct some anomalies that might not have been noticed in a mock-up. Once the contractors understood what we were trying to accomplish, the work went smoothly and the chases began to look like the full-sized plot we had pinned to the wall.

Initial startup went relatively well. A considerable amount of condensate accumulated in the steam header within the chase, and it took a while to clear it through the kettle jackets. The probable cause was not having a drip leg and steam trap assembly at the end of the steam runs inside the chases. We just didn't have the luxury of space to plan for them. The project's mechanical engineer and I discussed this at length, and we were confident that since the steam and condensate lines were fed from below (and as long as we pitched the lines back to the risers), the condensate would drain back toward the last drip leg in the mains. We knew there would be an accumulation in the piping after a shutdown and that the steam pressure was sufficient to move the condensate through the jacket and through the module's trap.

We did experience an instance of insufficient water pressure to one piece of equipment, a Becomix®. The incoming plant water line to each chase is furnished with a pressure regulator set at 26 psi to keep from exceeding the kettle's jacket pressure rating. The Becomix®, a packaged kettle unit that has its own built-in set of temperature controls, needs a minimum pressure of 40 psi to operate properly. At the module for the Becomix®, the steam, condensate, water, and air branch lines are arranged as the other stations, but without the control valves or manifolds (see Figure 7). We remedied this pressure requirement by simply connecting the Becomix® water supply to the full-pressure plant water supply serving the hose station on the end of the chase. This was one of the valuable features of this modular design; the services most often needed and the connections thereto are available, and with a minimum amount of work, almost any process scenario could be realized by the owner!

A typical module is designed with the inlet and outlet vertical manifolds straddling the centerline of the fixed panel (refer back to Figure 3). Steam and compressed air supply lines are connected to the inlet manifold, feeding from the left as you look at the module. Plant water and condensate return lines connect to the outlet manifold from the right. Each manifold has a drainline run as an indirect waste to a floor drain outside the chases. Other amenities include a compressed air connection for operating flush bottom valves and agitators and vacuum for process needs. Each utility supply line has a block valve and an automatic valve with pneumatic actuator. Each drainline also has an automatic valve.

When an operator begins a batch process, he mixes his ingredients in the kettle and programs the controller with the necessary temperature limits and heating and cooling times. The programmable controller, when started, opens the inlet air (LCV HPA) and outlet drain valves (LCV P) to purge the jackets of any accumulated water to prevent water hammer and then closes the valves. The controller then opens the inlet steam (TCV LPS) and outlet condensate (TCV LPR) valves to allow the jacket to come to temperature. A thermocouple in the kettle keeps the product temperature in check. When the appropriate temperature is reached and the hold time is expired, the steam and condensate valves close and the inlet plant water (TCV LCW) and drain (TCV W DRAIN) valves are opened, cooling the product. Again, when the product reaches the set temperature, the valves close and the process is ended. It's relatively simple, fully automatic, and worry-free.
The fixed panel has a compressed air line seen at the top in Figure 4. The supply from the inlet manifold is the higher of the two straddling the center, and the drains from this and the two adjacent modules are at the bottom. The automatic valve at the top and left of the fixed panel is the manifold air supply; the valve immediately below it is the steam valve, and the lower valve mounted vertically is the drain. On the right side, the automatic valve about halfway up is the plant water supply; below it is the condensate return valve, and the lowest is the manifold drain valve.

Note that during heating, the flow is into the top kettle jacket connection, and condensate drains from the lower jacket connection; but during cooling, the flow is reversed, with plant water in the lower jacket connection and drain from the top jacket connection. This arrangement echoes the rule of thumb of “hot on top” for piping up heat exchangers. The three automatic valves seen on the extreme left and right of the photo are for the modules to the left and right of this station. It can thus be seen how the arrangement is repeated for each module. Compare the CADD detail in Figure 3 with the installation in Figure 4 to see how the attention to detail ensured a compact installation.

Several design considerations ensuring safety for the operators as well as the building occupants were necessary. The plant water system is separated from the domestic water system with a reduced-pressure-zone backflow preventer. Each compressed air station was provided with an automatic vent-type ball valve that bleeds downstream pressure when closed so the operator is protected when disconnecting a charged hose. Ball valves used were of the three-piece design with blowout-proof stems to assist in maintenance and provide a level of safety. A pressure-relief valve was provided either on the jacket piping or directly connected to the jacket where a connection was available. The relief valve prevents pressure buildup from exceeding the ASME rating on the jacket. A vacuum relief valve is also provided to prevent the jacket from collapsing in case all valves shut while the jacket was charged with steam.

Now, no project is without unique challenges, and this one was no exception. Some kettles used to produce batches of lipstick required a tempered water supply as well as the steam and cold water. An additional branch to the inlet manifold was therefore needed at this location. The tempered water heat exchanger is located on a platform adjacent to the service chase. Additional elevation, needed to account for the platform height, had to be added to the sections of service chase and manifolds at this location. The real challenge here was to locate the additional tempered water supply piping in the service chase without compromising the typical nature of the other services. I utilized the uppermost portion of the pipe rack for this line. This kept it out of the way and allowed a clear path for distribution. Figure 8 shows the raised module that resulted from the unique requirements.

Another area that needed a little creative thinking involved a three-kettle arrangement where there was insufficient floor space to allow for three typical modules. As noted above, a typical module consists of a fixed 12-inch panel with a removable 36-inch panel on either side. The space available at this location did not allow this configuration. There was only space enough for the three fixed panels and two removable panels. At this location, I had to arrange the piping for the two end kettles such that the automatic valves are all accessible from their single removable panel. I achieved this by increasing the height of the service chase. The additional height was acceptable from an architectural standpoint because the service chase is located against a wall instead of as an island configuration,

Note: The supply, return, and drainlines at this particular location, as well as the tempered water line, are approximately 2 feet higher than at other stations to accommodate the adjacent platform elevation. The valved connection at the bottom is for condensate returns from a heated transfer tube.
as the others were. Figure 9 shows the piping arrangement under construction, and Figure 10 shows the completed look. In retrospect, this arrangement afforded the best maintenance access to the automatic valves, as well as provided an excellent space for the temperature control units on the upper face of the fixed panels if needed.

Regardless of which arrangement was used to provide the necessary services to properly operate the kettles, when all has been said and done, the finished product is quite an impressive sight and one that provided our client with a clean and organized look to their pilot lab. As with all complex engineering tasks, a step-by-step development of the design depends on assessing the client's needs, utilizing the space available, and providing a user-friendly, efficient arrangement of piping, valves, and equipment.

Anthony J. Curiale, CPD, LEED AP has well over 40 years' experience in sustainable design, plumbing, fire protection, marine, power, and process piping covering various domestic and foreign pharmaceutical, petroleum, petrochemical, marine, and commercial industries. His career has had him on such high-profile projects ranging from the Trans-Alaska Pipeline Project to the High Line in New York City. He may be reached at acuriale@cosentini.com.