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Allocate new plant focus to steam system design—Part 2

Part 1 of this article, which appeared in the January 2019 issue of *Hydrocarbon Processing*, discussed how new plant construction includes expectations for optimized production performance to achieve targeted profitability. After a capital investment decision is made to build a new plant, it can take years to secure critical items, including property, permits, technology licensors, front-end engineering and design (FEED), staffing, training, engineering and procurement for final design and construction.

Significant focus is placed on the production process itself, analyzing multiple variables that include marketing demand/flexibility, the availability of base materials and decisions on how to sustain or increase high yields. Due to the significant daily production dollars involved, having an operational plant that begins earning profits quickly is a high priority.

Once in operation, plant production is actively managed; however, its heat source, steam, is often not given proactive focus. While analyzing operating plant issues, a common causal thread is that the steam system has been taken for granted not only during operation, but also beginning with original design. Further examination often reveals an expectation that the design firm or licensor utilizes best practices for steam system design. In each of the cases presented, the original design led to many of the issues encountered.

Part 2 will continue the discussion on improving production reliability by managing the design of condensate systems to deal with potential issues prior to installation.

Condensate return hammer. Violent hammer in the condensate return header (CRH) experienced recently by three refinery/petrochemical sites has been tied to the installation of vertical expansion loops in the line. Such severe hammer existed that valves blew off the piping, resulting in a waste for one user of more than 130,000 lb/hr of condensate and creating a huge burden on the boiler steam redirected to heat makeup water.

TABLE 2. Mass volume flash analysis, 650 psig to 60 psig

Fluid	Mass	Specific volume at 60 psig, ft^3/lb	Mass volume	Proportion
Condensate	77.06%	0.0175	0.0135	1%
Flash stream	22.94%	5.84	1.3397	99%

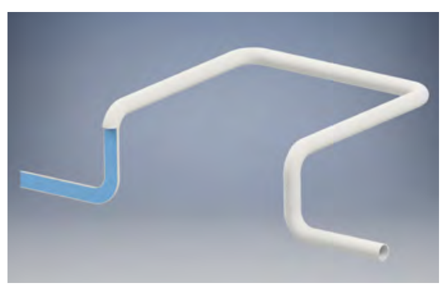

FIG. 17. Piping designers sometimes incorrectly believe that condensate return lines contain only water flow.

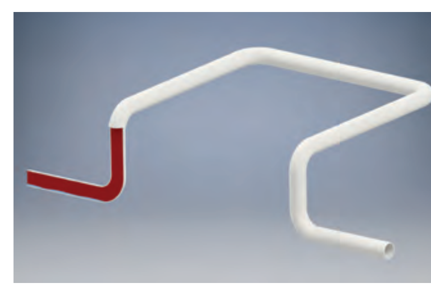

FIG. 18. No vertical expansion loops on condensate return (CR): CR can be mostly filled with flash steam.

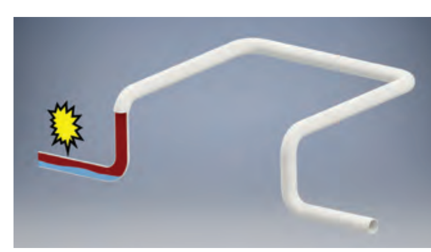

FIG. 19. Danger: Vertical loops on CR cannot drain condensate, and the level can build with no way to move upward.

It is unclear why vertical expansion loops were used in the CRH (by three different design firms) when the end user's best practice specification is clear: condensate in the main header must flow downward by gravity drain. Yet, vertical expansion loops were installed when the new units were built. One possible explanation is that piping designers believed that only condensate exists in a CRH (**FIG. 17**).

However, this belief is inaccurate. CRHs that carry condensate away from equipment and to a flash drum can be filled initially with flash steam by volume. **TABLE 2** provides a mass volume flash analysis for condensate generated from steam at 650 psig discharging into a CRH with a pressure of 60 psig. While less than 23% of the condensate vaporizes, that flash steam can account for 99% of the pipe volume (until it conducts away some heat).

With just 1% of pipe space occupied by water, flash steam flows over the condensate in the header—it is impossible for condensate to "move upward" (**FIG. 18**). Since the condensate cannot flow overhead, its level builds and forms, waves and then the pipe experiences hammer from the collapsing flash[5] (**FIG. 19**). Eventually, the condensate level can rise until the bottom end of the vertical loop is closed off, creating a seal. The condensate can then be propelled upwards. A significant mass of condensate may have collected to seal off the vertical pipe. **TABLE 3** shows the incredible mass of condensate that may have collected to seal off the vertical pipe, and with high-velocity flash steam as a propellent, the resulting hammer at the riser location can be significant (**FIG. 20**).

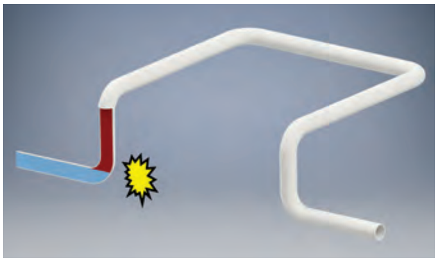

FIG. 20. Vertical loops on CR require the condensate level to build and seal off vertical piping, and hammer is the likely result.

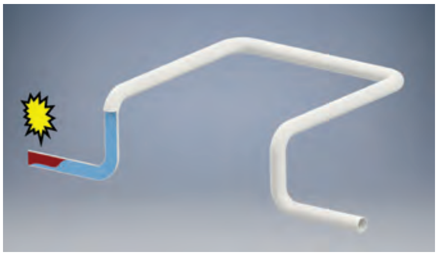

FIG. 21. As condensate rises in a CR vertical loop, some is displaced by low-energy flash steam, which can collapse.

This situation can be worsened when multiple vertical expansion loops exist in the CRH, and if the flash steam is bottled up between risers. The hammer may not remain localized at the riser. As the level in a long run of horizontal condensate subsides, its space can be replaced by wet flash steam, which can collapse from its heat transferring to condensate. The result can be severe shock when the void vanishes and rapidly fills with water (**FIG. 21**).

The amplitude and duration of shock waves can be measured and charted simultaneously with the condensate temperature. The data[6] reveals that heavy shock is experienced as the condensate temperature is just slightly lower than steam (**FIG. 22**). It is recommended to strictly avoid the use of vertical expansion loops in CRH. Even when structural impediments prevent gravity drainage from the intended pipe routing, it can be a better investment to design proper drainage in a downward direction or install condensate pumping stations than to accept vertical expansion loops.

TABLE 3. Mass of 6-in. pipe filled with condensate

Length, ft	Mass, lb
250	2,825
500	5,650

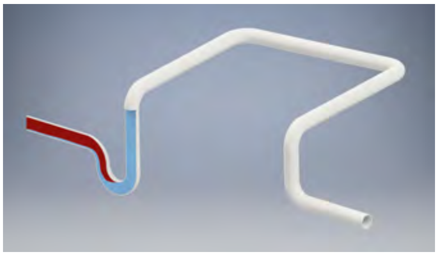

FIG. 23. A DDLS design may help alleviate hammer by reducing condensate buildup in horizontal CR.

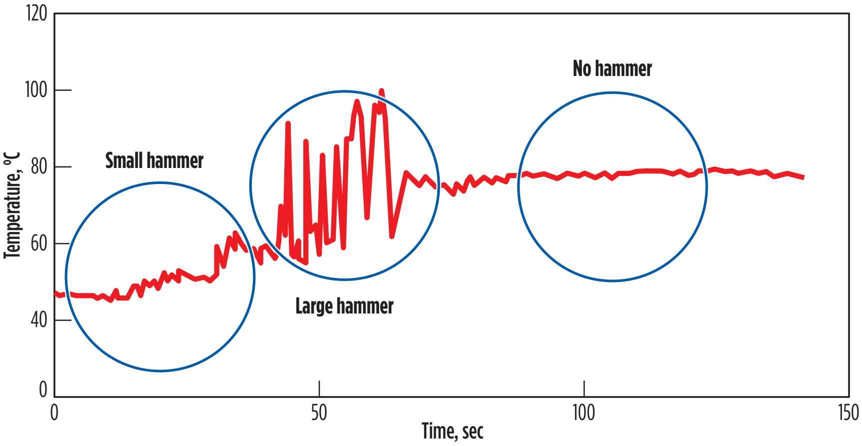

FIG. 22. Measuring the shock of large hammer amplitude and duration shows near-to-steam temperature at steam collapse.

Installed vertical CRH loops.

In a plant where vertical CRH loops were already installed and the site did not want to raise the entire header to stop the hammering, one consideration was the implementation of a drop-down loop seal (DDLS). Lowering the loop below the horizontal piping level can provide a seal that may not require the entire horizontal distance to flood (**FIG. 23**).

A DDLS installation can allow unwanted backflow that can be prevented with the use of a check valve. Over time, that check valve in the main CRH can be damaged from back-slam shock and may justify the use of a bypass around the valve to enable its replacement during operation.

Before implementation, the dynamics of a DDLS concept and other piping measures must be completely analyzed and approved for flow, load, stress, support and velocity calculations[7] to ensure appropriate final piping design.[8]

Flash tank issues.

Two sites also suffered significant hammering issues at the flash drum, indicating two major design items that could be improved. The first issue, experienced in both sites, was flash steam and condensate that entered the tank through multiple inlet nozzles. Neither site had a check valve to prevent reverse flow of flash steam or water in the lower nozzle. The resulting backflow of flash steam and water out of the tank into the CRH led to water hammer.

The second issue occurred in one site: the inlet nozzle to the nearly 16-ft tall drum was reduced from the CRH line size (6-in. line reduced to 3-in. line). The reduction at the tank entry reduced the internal pipe volume by 75% and caused the incoming flash (and live) steam to be bottled up. This led to severe hammer when condensate collapsed steam at the inlet and caused significant nozzle damage (**FIG. 24**). The site eventually made the decision to increase the inlet nozzle size and install a check valve to eliminate both the steam bottle-up and backfill problems (**FIG. 24**).

Stripper reboilers. A Gulf Coast refiner experienced operational difficulty with its stripper reboiler. A walkthrough identified the cause as an improper balancing design between the level pot and the reboiler. The > 20-ft long, > 600 tube, two-pass reboiler was elevated approximately 30 ft above grade with a level pot just 4 ft below. The level pot was used to feed hot condensate to electric pumps located at grade, so the high elevation was required to maintain net positive suction head (NPSHR).

The original design balanced the level pot to the inlet steam side of the reboiler, with the resulting *Px* pressure at both locations (**FIG. 25**). However, the pressure drop in the long tube run (> 40 ft) results in a lower-pressure *Py* at the reboiler outlet. The higher *Px* pressure at the level pot hindered drainage from the lower *Py* reboiler outlet pressure.

Rebalancing the level pot to the outlet side of the reboiler at the downstream side of the channel head results in the same *Py* pressure, removing pressure restriction to flow (**FIG. 26**). The installation requires an appropriate channel head tapping on the reboiler, on the side and near the top of the downstream section. Note that the level pot could not simply be relocated lower because that would remove NPSHA from the pump set.

Takeaway. Steam is the primary heat source for many plants, and improving system reliability can have huge production and earnings benefits. Closely managing the design of steam and condensate headers can eliminate potential issues, rather than dealing with the negative effects after the plant is built. Correct collecting leg design and placement are essential to plant performance.

CDLs should be installed every 100 ft–150 ft on a steam header at the inlet side of flow through expansion loops, vertical risers and downfeeds to equipment. CCBs may mitigate some damage from a wet steam supply until best practice improvements are made. Vertical expansion loops in a CRH may cause severe hammer. Flash drum/tank design should include correct piping size by velocity calculations, including piping downstream of the vent line; a check valve on inlet to prevent reverse steam flow; and an inlet nozzle should be the same or a larger size than supply.

If a steam system is not optimized during the original installation, it is almost impossible for a plant to shut down production to make all necessary corrections. The result is that the process is doomed to run suboptimally for the life of the plant. HP

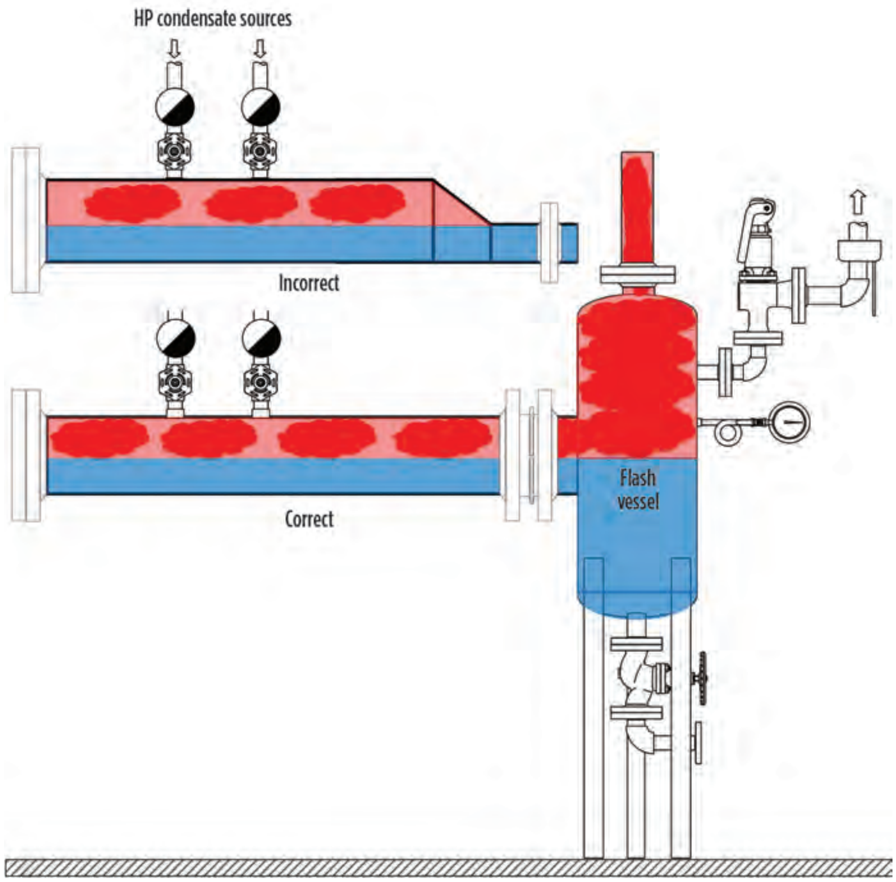

FIG. 24. Nozzle size on a flash drum should be the same as CR size to facilitate entrance of flash steam. Reducing nozzle size at drum inlet can cause flash steam to bottle up, leading to hammer.

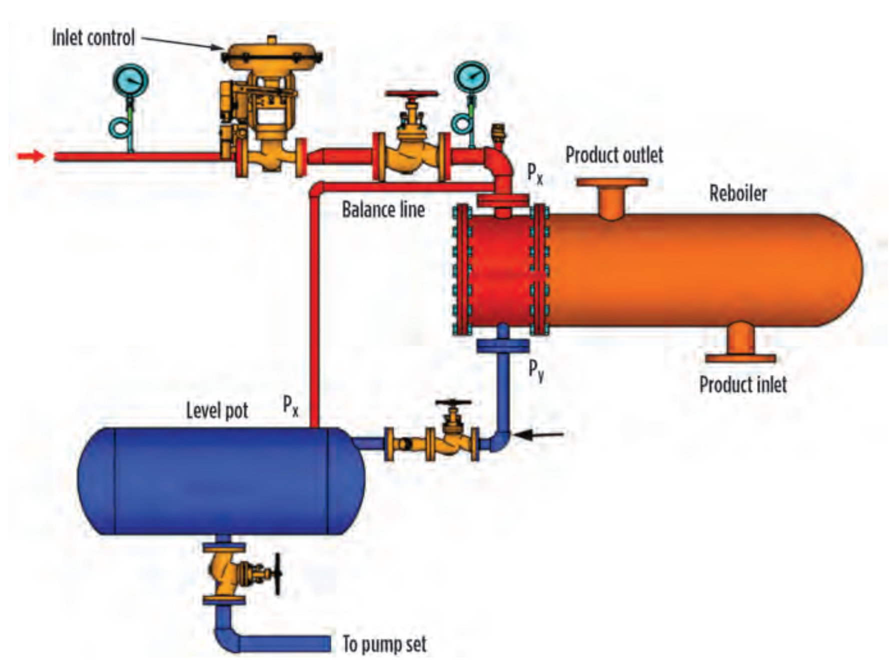

FIG. 25. Balancing the level pot to the steam inlet creates a higher pot pressure than the reboiler outlet.

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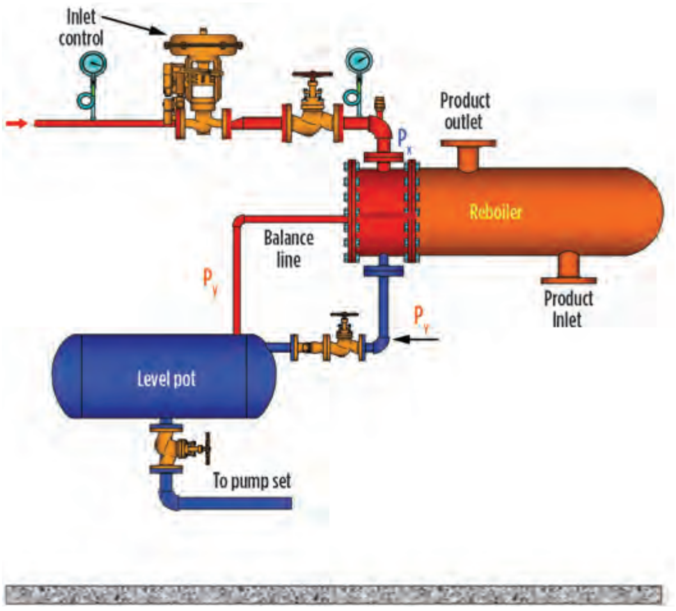

FIG. 26. Balancing the level pot to the downstream side of the channel head equalizes pot pressure with the reboiler outlet.

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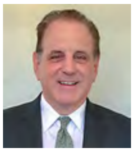

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