What You Ask For Isn't Always What You Get

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Engineers designing equipment for a new process routinely specify the required material of construction. But how can we be sure that the specified material of construction was actually installed? These three incidents illustrate the consequence of installing the wrong material of construction and highlight the need for improved systems to ensure that the proper materials are used.

Incident No. 1 - Wrong Pipe Lining Material

A reportable release occurred during the startup of a new process at a toll manufacturer. The final reaction step of the process involved processing of a boiling organic solvent saturated with acid gases. During the design of the equipment, Polytetrafluoroethylene (PTFE) lined piping was specified for a recirculation loop because of its resistance to both the solvent and the dissolved acid gases. A few hours into the final reaction of the first batch, the recirculation pump was turned on to recirculate prior to sampling. Once the sample was taken, the batch was left recirculating to provide added mixing.

A few hours after the recirculation loop was turned on, local air monitoring alarms sounded, indicating the presence of acid gas fumes in the operating room. As the room was evacuated, a gas cloud began emanating from the area. The plant was evacuated and the local fire department was called. Eventually, the cloud dissipated and it was determined that most of the contents of the reactor had leaked onto the floor and drained to a sump, releasing a vapor cloud containing solvent and acid gases.

Following the cleanup, an investigation was conducted. It was determined that the leak had originated in a section of line that was lined with polypropylene rather than PTFE. After the incident, the rest of the piping was inspected and several suspicious pieces of piping were removed.

Lessons Learned:

- *Is used equipment acceptable in a service?* In this plant, it was common practice to reuse old equipment and piping. The potential installation of old piping or an incorrect material of construction was not considered during the process HAZOP because it was assumed that new piping would be used. Since the incident, the toll manufacturer agreed not to reuse piping for hazardous service. However, it is important to include in a process HAZOP an analysis of potential improper materials of construction.

- *Is the quality of the material acceptable?* Often the quality of materials can vary considerably from one supplier to another. This is particularly true with equipment such as lined pipe, where the composition and thickness of the liner material can vary. For example, we have found reduced thickness and higher permeability of the plastic liner in lined pipe in some developing countries.

- *How is the material of construction identified?* In the incident, the piping was not clearly identified, and the construction contractors assumed that all white plastic lined piping was PTFE lined. Some pipe manufacturers have color-coding systems for identifying lined pipe, but this piping was not color-coded. In the future, the plant will only purchase color-coded lined piping for easier identification.

- *Are there adequate systems in place to ensure integrity?* The plant did not have good systems in place for identifying or testing used pipe. Piping standards and procedures for ensuring that the proper piping was installed were inadequate.

- *Is there sufficient supervision of mechanics and contractors?* The piping was installed by a contractor. Improved supervision of the contractors and mechanics might have alerted the engineers that procedures for selecting piping were inadequate.

Incident No. 2 - Wrong Material of Construction in a Tank

The plant has been there for nearly 20 years, and people who haven't been there from the beginning often wonder about the "short tank." There is a row of tanks in similar service, all of them built at the same time by the same manufacturer, of the same material of construction, with the same diameter. The tanks are identical, except that one of them is shorter (Figure 1). Why is tank number 3 about half the height of the other tanks?

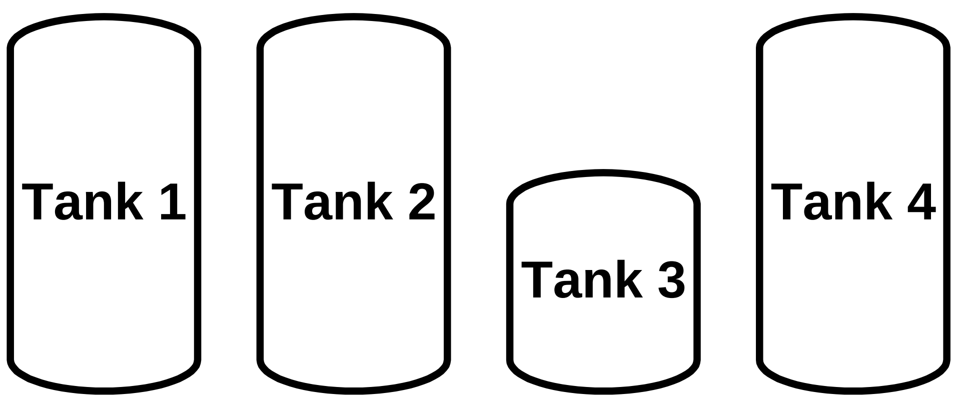

Figure 1: Four tanks in similar service. Why is Tank 3 half as high as the others?

These tanks contain a process intermediate which is corrosive to 316 stainless steel, but 304 stainless steel provides acceptable corrosion resistance. When they were first installed, the tanks were identical. A few months after startup, an operator observed a small leak in the upper part of the side of Tank 3. The tank was taken out of service immediately and inspected. To everybody's surprise, the entire wall of Tank 3 in the area of the leak was found to be "paper thin." This was quite a shock to the process design engineers because extensive corrosion testing had been done during the process development and 304 stainless steel was known to have good corrosion resistance. The severe corrosion of the tank after a few months of service was totally unexpected. Naturally, this discovery lead to concern about the integrity of the other tanks in closely related service, so they were also inspected. None of the other tanks had any evidence of significant corrosion.

A more thorough inspection of the Tank 3 revealed that the corrosion was localized in a particular section of the top of the tank side wall. The rest of the tank, including the top and bottom heads and the rest of the side walls, had no significant corrosion. At this point, samples of the metal in the corroded area were taken and analyzed, and the metal was found to be 316 stainless steel, not 304 stainless steel! Apparently, one 316 stainless steel plate had been welded into the side wall of the 304 stainless steel tank. The tank fabrication records did not indicate any problem, and showed all materials used in construction to be correct. Apparently at least one plate of 316 stainless steel had been labeled and documented as 304 stainless steel by the steel manufacturer, and this plate had found its way into the failed tank.

So, how was the Tank 3 repaired? Fortunately, only a portion of the tank wall, less than half of the total tank height, was corroded. The lower half of the tank, built from 304 stainless steel as specified, had no corrosion, as expected based on the extensive testing which had been done. As a temporary repair which could be done quickly, it was decided to cut the top of Tank 3 off, put the top head back on the reduced height tank, and do the appropriate inspections and testing to meet the vessel code requirements. After this was done, the plant ran just fine, and it was determined that the smaller Tank 3 provided sufficient capacity for ongoing operation of the plant. There was no need to install a new tank of the same capacity as the original.

Lessons Learned:

- There is a lot of value in just "walking around" a plant. In this case, an operator discovered the small leak, notified management, and the plant supervision took appropriate action before it escalated to a much more hazardous situation. We must make sure that we leave time for operators to walk about the plant, to look and listen. This is becoming more difficult in modern, automated plants with a small operating staff.

- Vessel procurement procedures should be reviewed to ensure that they provide adequate assurance that the materials specified are actually used. These procedures may have to follow the material supply chain all the way back to the metal manufacturer.

- More expensive isn't necessarily "better" where materials of construction are concerned. Many engineers consider 316 stainless steel to be a "better" grade of material than 304 because it costs more. Corrosion resistance depends on the material of construction and on the environment, there is no basis for assuming that a more expensive material will be more corrosion resistant. In this case, the extensive testing done before the plant was designed had clearly shown that 304 stainless steel was a superior material for this service.

- The original tanks were too big! One of the principles of inherently safer plant design is to minimize the size of equipment to reduce the magnitude of a potential incident. In this case, the repaired Tank 3 was about half the size of the original tank (and also about half the size of the other tanks remaining in similar service), and yet the plant has run with no problems for nearly 20 years following the "temporary" repair. Clearly, the tanks were too large. The plant could have been built for less money if smaller tanks had been specified, and the plant would have been safer because the inventory of hazardous material would have been reduced significantly. However, existing equipment generally has little difficulty in justifying its continued existence and use, so the other tanks remain in operation as designed.

Incident No. 3 - Wrong Material in a Pipe Fitting

A plant had a serious problem with a Glacial Acrylic Acid (GAA) pipe repeatedly plugging with polymer. The plant had recently made a number of changes including the installation of a new stainless steel pump and feed pipe, and they lamented about how often they had to replace the stainless steel pipe because of blockage with polymer. Over a period of months, a number of company experts tried to assist them in solving this unusual problem. Drawings and operating practices were reviewed, and the experts went through the list of "usual suspects" including:

- preventing reverse flow from the reactor, a possible source of contaminants which could initiate polymerization

- overheating from heat tracing, needed to prevent freezing of GAA (freezing point = 13°C)

- leaving the lines full for long periods of time, allowing slow formation and accumulation of polymer

- mixing GAA with small amounts of water, which increases the likelihood of polymerization (the pipe was often flushed with water)

- inerting the pipe by vacuum from the reactor sucking the GAA out of the pipe, and the pipe filling with inert gas rather than air (the polymerization inhibitors in GAA require the presence of oxygen to be effective)

It wasn't until the plant took a polymer sample and sent it to the research laboratory for analysis that the presence of a high concentration of iron was noted. In this system, certain forms of iron will act as a polymerization initiator and accelerator, increasing the likelihood of GAA polymerization. At this point, the plant looked closely at their system. They finally noticed that there was a small carbon steel fitting on the outlet of the new pump. The corrosion on this fitting was enough to give sufficient iron contamination to destabilize the GAA on almost every pumping. Polymer deposited and grew based on the frequency the line was used. Eventually the line would plug totally and would have to be replaced. When the carbon steel fitting was replaced with a stainless steel fitting, the polymer blockage problems immediately stopped.

Lessons Learned:

Hindsight makes the specific error clear, but, what really caused this incident? There was clear understanding that carbon steel was unacceptable in this service when the stainless steel pump and line were installed. The engineers designed it correctly. But there were problems in the implementation of the design:

- Did someone check the actual installation before the pipe was traced and insulated?
- Were the installers trained on how to make sure the right materials of construction were used?
- Were the right people trained on the nature of the material this pipe would handle, and of what impacts potential errors in material of construction would have?
- Were the parts checked when they were delivered?
- Were carbon steel and stainless steel parts kept separate in the storeroom?

Like many problems, it took multiple failures to cause the high expense of replacing a stainless steel line over and over again.

Conclusions

These incidents illustrate the potentially serious consequences that can result when unacceptable materials of construction are inadvertently installed in hazardous processes. Fortunately, there were no injuries or major environmental damage in any of the incidents described. In all of these incidents, the proper material of construction was specified, but the wrong material was actually used. It is important to recognize and correct the systems failures that allowed these errors to occur. Process hazard analyses should include an identification of process steps and equipment in which installation of the wrong material of construction could have significant undesirable outcomes.