ENGINEERING BULLETIN #176

Failure Analysis: Identifying the Corrosion Culprit

Mishandling may hold the distinction of being the most common cause of premature hose assembly failure but corrosion is certainly a contender. Users often opt for stainless steel when working with corrosive applications or at elevated temperatures where heat can be a catalyst for corrosion given resistance is a signature benefit of these materials. Protection is, however, not the same as prevention. All materials, no matter how corrosion resistant they are, will succumb to the effects of corrosive media over time.

If a hose fails prematurely due to corrosion, how can we determine the cause to avoid a similar outcome with the replacement hose?

CASE STUDY: STEAM HOSE FAILS WITHIN ONE YEAR OF OPERATION

Occasionally, we receive a hose for failure analysis with no visible signs of failure. No bulging braid. No fraying of braid wires. No signs of corrosion. No dents. No weld cracks.

To give an example, have a look at the V-Loop assembly pictured here which looks just fine. Had the user not circled the site of the leak with permanent marker, we would not have been able to locate it through visual inspection alone.

The six-inch assembly was conveying steam at ambient temperature. Maximum working pressure was 165 PSI. The only movement to which the hose was subject was seismic vibration. After a year in service, operators noticed a leak at one end of the hose.

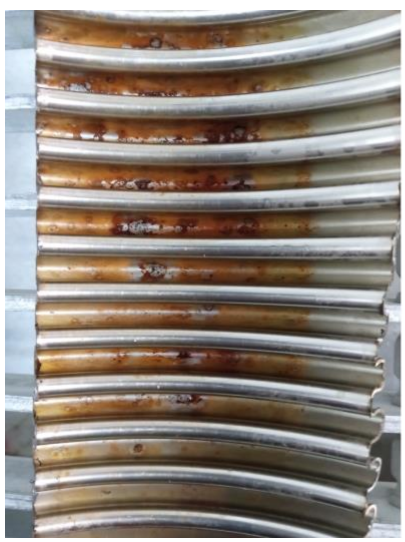
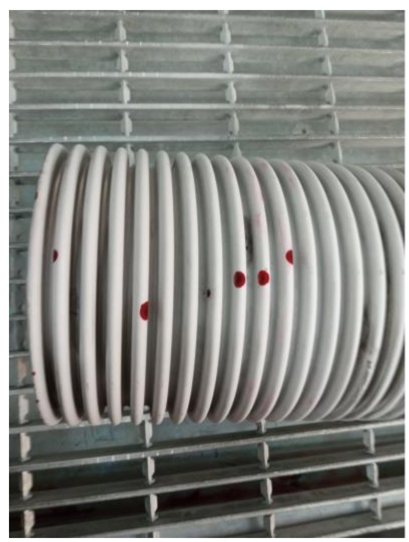
When a hose fails after some time in operation, the cause is likely related to the application rather than to a defect in manufacturing or fabrication. Incorrect installation and improper handling may also lead to premature failure, but we would expect the impact of such oversight to become apparent sooner rather than later though there are no guarantees given the enormous variety of applications and operating conditions.

After visual inspection, the next step in our failure analysis process is to remove the braid and examine the exterior of the bare hose. Corrosion spots were immediately visible upon removing the braid from the V-Loop assembly. Notice what looks like small rust spots on the corrugations.

Since the braid didn't show any signs of corrosion, corrosion presumably worked its way from the inside out. Flow media was likely the culprit. Had the corrosion been caused by environmental factors, whether those be in play due to geographic location (i.e., beside the ocean) or due to sprays, leaks and drips, corrosion would have worked its way from the outside in. This hypothesis was also supported by the fact that welds were of high quality and there was no mechanical damage, meaning there were no other areas vulnerable to chemical attack aside from those spots on the corrugations.

We needed to see the inside of the hose to confirm our suspicion. Extensive corrosion was visible upon cutting the affected hose section open, proving our hypothesis that corrosion was caused by the steam running through the hose. That corrosion was largely confined to one side of the hose suggests steam condensate had been laying inside the hose at some point.

Dye penetrant inspection was then performed to confirm the location of holes. The spots and through holes are symptomatic of pitting corrosion, the most common cause of which in stainless steel is acid chlorides. The steam running through this hose was not simply steam.

With an understanding of the failure mechanism, we considered design inputs like alloy and wall thickness to offer the user a recommendation for the replacement hose. In this scenario it would make sense to consider using 316 stainless instead of 321 as it resists chloride corrosion better thanks to the addition of molybdenum. A hose made with 316 should last longer in the application.

The user could also carry out an analysis of the steam composition for a more accurate picture of which chlorides in what concentration are present.

MITIGATING RISK OF PREMATURE HOSE FAILURE DUE TO CORROSION

There are three key considerations when it comes to avoiding premature failures due to corrosion.

- Alloy selection
- Weld technique
- Storage and handling

CHEMICAL COMPATIBILITY

As the failure analysis case study demonstrates, knowing the composition of flow media is an important input when it comes to alloy selection. Charts like Penflex's corrosion resistance tool can offer guidance.

Another important factor is wall thickness. Where corrosion is present, a thicker wall hose will provide a longer life in the same application than a thinner wall hose made of the same alloy. Corrosion rates, or the speeds at which metals deteriorate, help illustrate this concept.

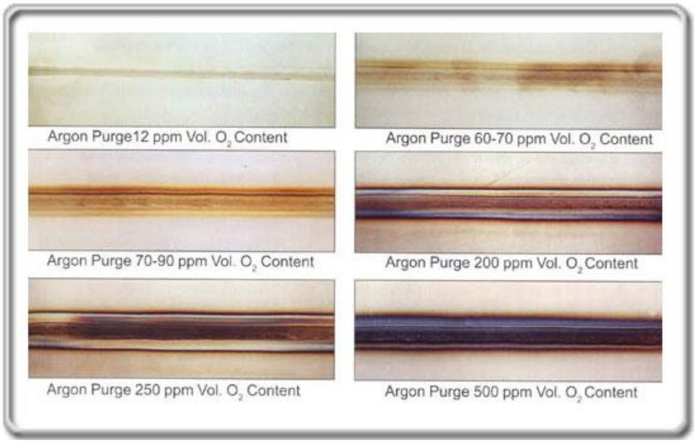
To measure these rates, we use millimeters per year (mm/y) or mils penetration per year (MPY)—a unit of measurement equal to one thousandth of an inch. For instance, at 99% concentration, sulfuric acid moving through a 316 component has a 2.2 MPY expected rate of corrosion. This may not be an issue with a Schedule 40 pipe, but on a 0.010" wall hose, that's 20% of the wall thickness. That is an issue!

Recognizing the array of requirements when it comes to metal hose selection, Penflex offers a wide range of wall thickness across its hose product lines. Consider 4" hose which we make in strip thicknesses ranging from .015" to .035". All else equal, the thicker wall hose will outlast the thinner wall hose in a corrosive application.

When questions are asked about chemical compatibility and expected rates of corrosion, the goal is to identify which material has the potential to deliver the longest possible service life.

Sometimes the circumstances of an application merit the use of a superalloy like Inconel 625 (Penflex 625 Series) or Hastelloy C-276 (Penflex 776 Series). More expensive options, these high-nickel alloys offer a level of corrosion resistance beyond that of the 300 series austenitic stainless steels.

GOOD, CLEAN WELDS

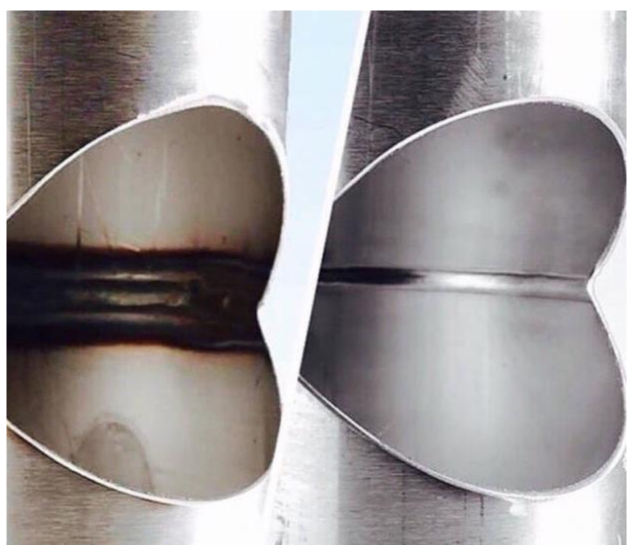


The V-Loop assembly welds were of good quality which allowed us to rule out manufacturing defects as a factor in the corrosion-related failure. Had we seen bands of temper colors alongside the bead penetration, we would not have been able to do so as this is an indication of oxidation. Often taking the form of chromium carbide precipitation, a process that reduces corrosion resistance, oxidation occurs when heat and air combine during the weld process.

Chromium and carbon, which have an affinity for one another, can bond to form chromium carbides at elevated temperatures. This presents a challenge as chromium is a key alloying element in austenitic stainless steels and the one that imparts these metals with their corrosion resistance. When chromium migrates to bond with carbon, its distribution becomes uneven, thereby weakening the ability of the material to prevent corrosion.

As a best practice to prevent this reaction, Penflex purges all welds. Purging, whereby an inert gas is fed onto the top and bottom sides of the weld to remove oxygen, is a proven process that enhances weld quality by decreasing—or even preventing—oxidation. This, in turn, maintains the corrosion resistance of parent materials.

With unpurged welds, the heat-affected zone (HAZ) becomes a potential point of chemical attack which can lead to cracks, leaks and premature failure. In corrosive applications, make sure hoses have purged welds!



Unpurged vs. purged weld

PROPER STORAGE, INSTALLATION AND HANDLING

As mentioned earlier, environmental factors can encourage corrosion from the outside in. And while mechanical damage can lead to immediate cracks and leaks, a wrench applied to the hose or braid collar during installation or dragging the hose along the ground can dent a component or fray the braid, creating areas more susceptible to corrosion.

We encourage users to store hoses inside or under cover, sheltered from rain and snow and better protected from air pollution. If hoses in operation are subject to leaks, spray or splatter from other components, consider some sort of protective covering.

When it comes to proper installation and handling, we've put together a guide to walk users through the important role they play in ensuring long service life. Chief among them, relating to corrosion, are those that focus on handling hose assemblies with care. Metal hoses should be carried or wheeled around job sites in carts to prevent abrasion damage. Draping hoses over railings or allowing hoses to rub against one another leads to the same kind of damage.

Corrosion-induced failures that shorten hose life can be caused by inadequate hose design, subpar welding, incorrect installation, mishandling or some combination therein. Failure analysis helps identify the cause more specifically, allowing us to provide recommendations for replacement hoses that will last longer in service.