CSI | CASE STUDY

FAILURE OF CLEAN-IN-PLACE RETURN PIPING IN DAIRY FOODS PROCESSING

Dairy products are particularly vulnerable to spoilage and the rapid growth of bacteria, making clean-in-place (CIP) systems essential to cost-efficient sanitary operations. CIP systems for dairy processing must meet specific requirements for temperature, cycle time, and chemical concentrations to effectively prevent contamination from harmful microorganisms.

However, **chemicals — which may be needed for effective cleaning — can also lead to corrosion unless systems use appropriate designs and alloys**. Corrosion can occur in CIP system components when chlorides and other corrosives are present.

Appropriate System Design

Proper system design ensures avoidance of low-drain areas and stagnant conditions. The presence of stagnant residual water or residual product at low-drain regions can cause microbe formation that eventually led to pitting.

Appropriate Alloys for Dairy Processing

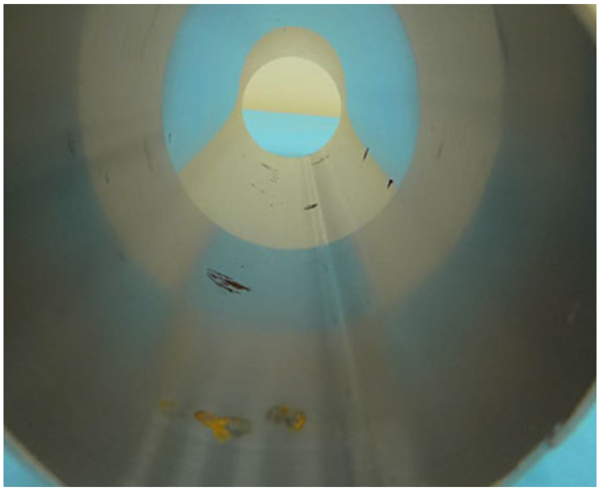
New stainless steel technologies offer **greater corrosion resistance than some existing types,** such as 304L and 316L stainless steels, which researchers have pointed out is more vulnerable to pitting—the appearance of small holes in the metal that can eventually cause materials to crack (Street et al, 2015, p. 251).

Experts have recommended use of super-austenitic stainless steel alloys such as AL-6XN in applications where Chlorides are used (Davis 1994, p. 169).

THE CORROSION CASE

In the case of one cheese processing plant, managers discovered a problem that turns out to be very common: **corrosion caused by chlorides used in their cheese processing**. After only eight months of service, their CIP system showed signs of corrosion in return piping in low-flow and stagnant areas — caused by problems with their system design — where liquid was trapped. Operators detected the corrosion after cleaning-cycle testing, when they noticed a gray slime on the pipe surface. They cleaned and coated the pipe with protective material, and to improve cleanability they increased the concentration of cleaning agents for the CIP cycle to 1%.

Engineers then observed pin-hole leaks in the 304L CIP return lines where flow was low. They replaced the leaking component with 316L stainless steel, which lasted three months before failing.



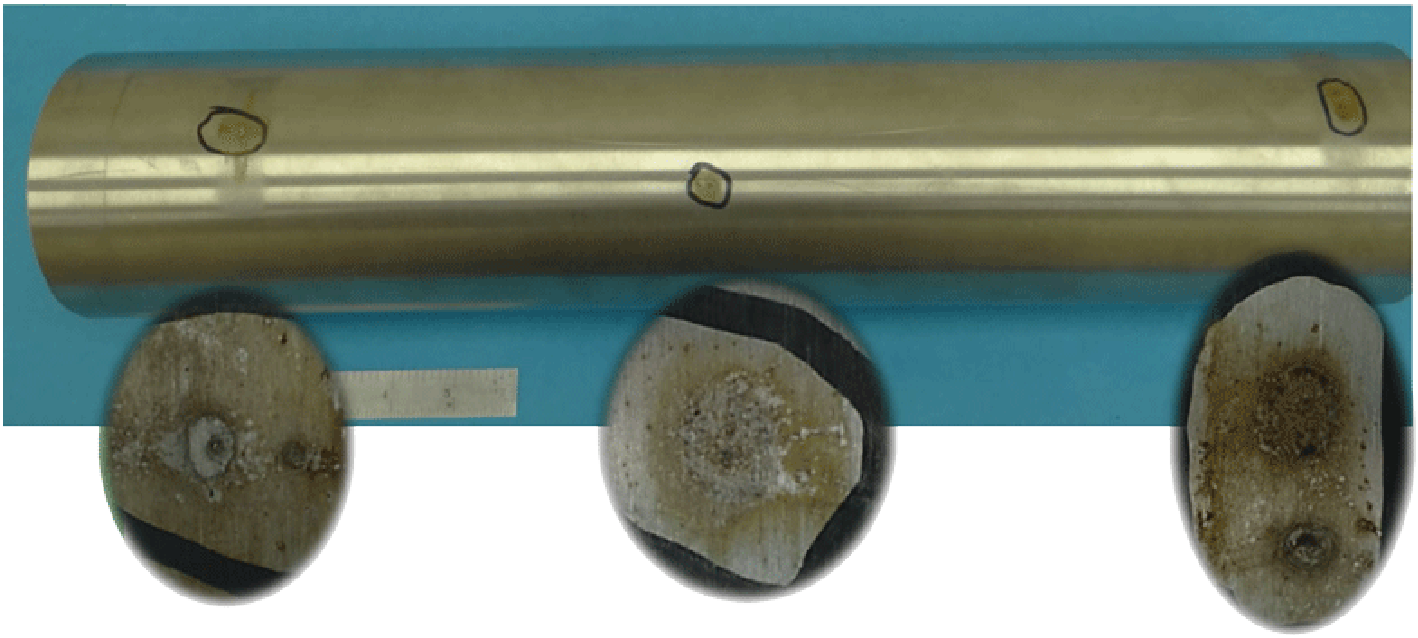
SUMMARY OF CONDITIONS

Original 304L equipment: 8 months in service
- The pin hole leaks observed in the 304 pipe lines at low points caused by system design where liquid could be trapped

Replacement 316L equipment: 3 months in service
- Pipe cleaned and coated
- Cleaning agent: 0.4% -1% solution
- A grey slime appeared on the pipe surface

DISCOVERY AND TESTING

The company reached out to CSI for accurate diagnosis of the causes and extent of corrosion and to confirm chemical and component composition.



The photo of tube sample shows three areas affected by pitting that extended through the pipe walls.

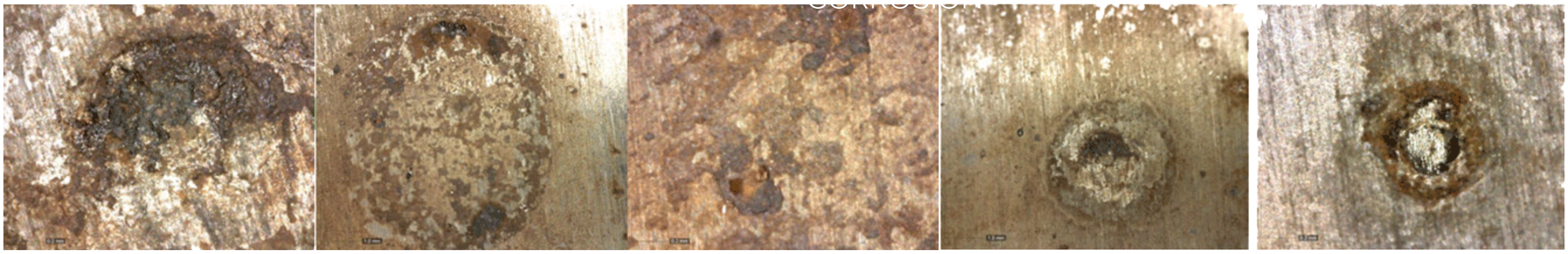
VISUAL EXAMINATION

While visual inspection may reveal where corrosion occurs, **additional analysis is required to determine the type, extent, and causes of corrosion**. Pitting in 304L return pipes—and in the 316L return pipes that replaced them—is visible in the image above. **Pitting occurred in low points where liquid was trapped.** The tube outside diameter (OD) surface showed significant number of pits, some of which were all the way through the wall.

FURTHER TESTING REQUIRED

Further testing was performed in CSI's affiliate lab utilizing x-ray radiation to determine the chemical composition of the metals. The characteristics were confirmed as 304 and 304L from the original pipe.

3D imaging reveals that the surfaces were in fact affected by corrosion and a significant amount of chlorides and sulfur presence. The presence of sulfur could be an indication of sulfate-reducing bacteria which causes microbial induced corrosion.



The digital optical images show pit locations on the OD surfaces.

MICROBIAL-INDUCED CORROSION

Microbiologically Induced Corrosion (MIC) is a reaction between biological growth such as bacteria, algae, or fungi in low-flow or non-flowing liquids and--in this case, stainless steel--that results in pitting or worse.

MIC can eat through processing equipment or CIP systems within days or weeks unless plants take steps to avoid its causes. MIC commonly occurs in cooling water systems, piping, vessels, and storage tanks, with subsurface corrosion that may be more extensive than surface pitting. **Materials such as 300 series stainless steels are especially vulnerable to MIC.**

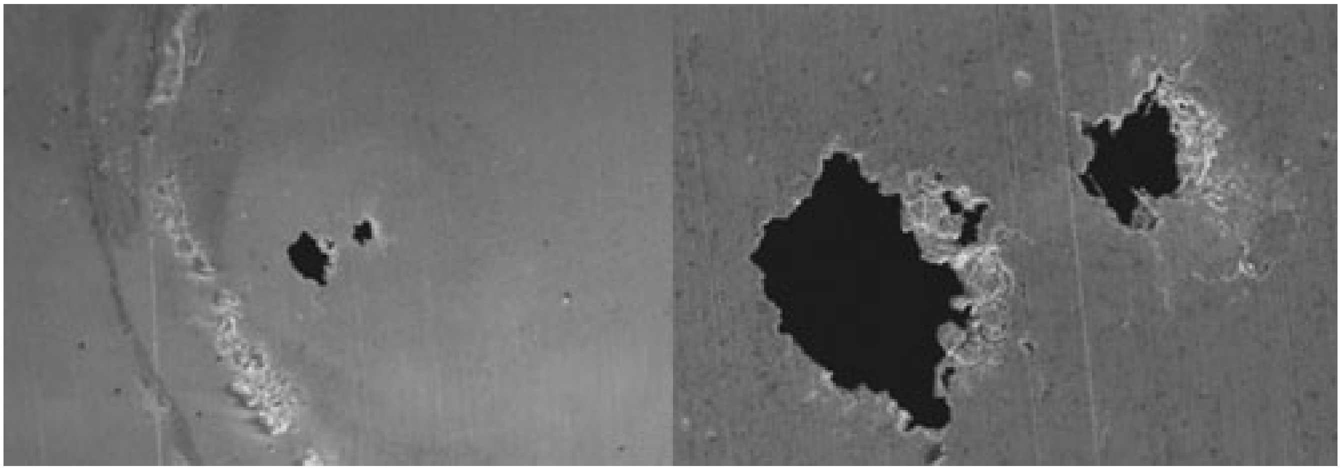
CONCLUSIONS

Visual Examination: The tube outside-diameter surface showed a significant number of pits; some pits went all the way through the wall. Based on the evidence, the failure is consistent with a biologically influenced pitting corrosion mechanism.

The amount of corrosion product observed around the pit is an indication that due to the system design **the pit formed where fluids were not flowing adequately enough to prevent corrosive materials from acting on pipes**. During operating conditions with the pipe operating at full volume, it is impossible for corrosion products to form and stay in place.

Living organisms in food processing can interact with piping materials to create corrosive conditions. Using the term corrosion in the broadest sense, microbes may cause corrosion by

- Chemical attack of by-products of microbial life such as acids, H2S, or ammonia.
- Direct corrosion of metals.

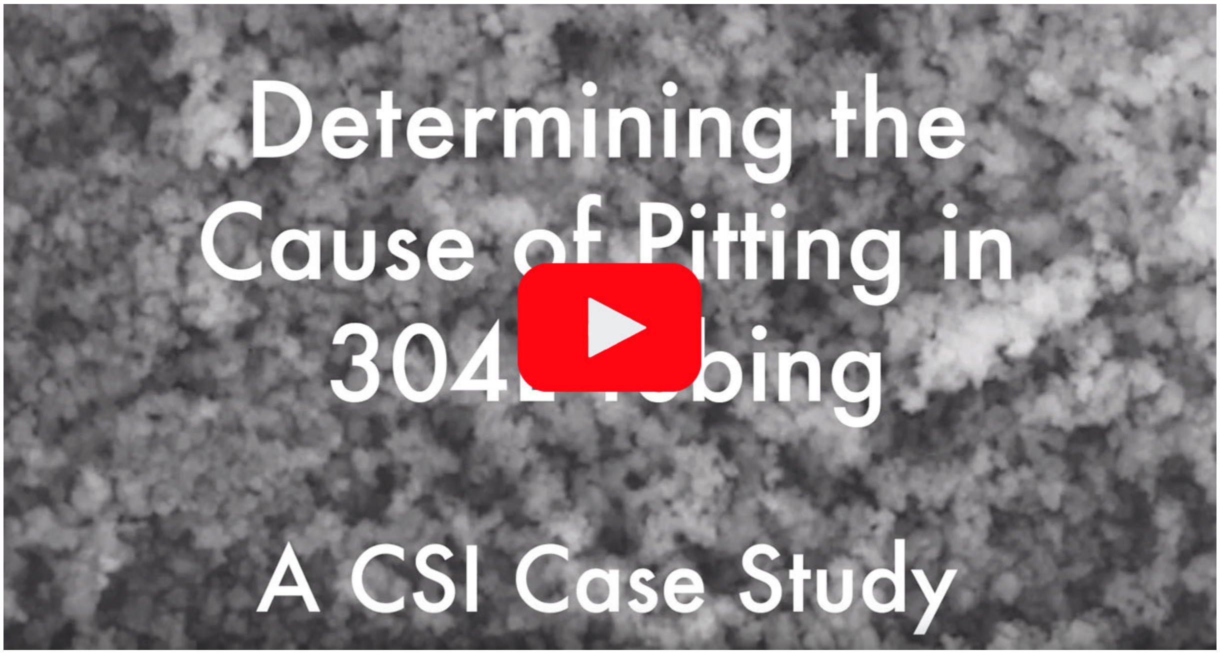


RECOMMENDATION

As an immediate solution, CSI recommended super austenitic alloys containing 6 % molybdenum (AL-6XN® Alloy) for this application, since, AL-6XN® is more resistant to microbial induced corrosion than 300 series.

A long-term solution would include redesigning the system to avoid low-drain areas and stagnant conditions. The presence of stagnant residual water or residual product at low-drain regions during the initial testing was likely the cause of microbe formation that eventually led to pitting.

Additional acid washes may also be needed to eliminate milk scale buildup. Pasteurizers and other equipment containing heating surfaces (known as “hot components”) may require separate cleaning programs from the non-heated components of the system such as tanks and piping.



Click to play Case Study video.

COSTS ASSOCIATED WITH CORROSION

The Institute of Food Technologists associates a variety of costs with corrosion, **including the costs of fouling — or buildup — of unwanted substances on piping or other surfaces**. Corrosion fouling is a specific type of chemical-reaction fouling associated with increased maintenance and fuel costs, and costs of lost production time (Goode et al, 2013, p. 123-124).

How should specifying engineers think about the true costs of less expensive 300-series stainless steel in corrosive dairy processing environments?

Corrosion resistance is the most important consideration when designing from an operational and financial standpoint. The costs of downtime and repair should be factored into decisions about food processing equipment especially when product contains corrosive ingredients such as chlorides used in cheese processing. A more effective design would include corrosion-resistant components using AL-6XN® Super Alloy.

To arrive at the true cost of corrosion, add direct and indirect costs. Food processing companies have to weigh both when designing food processing facilities for operational and financial advantage.

Investment Description	**316L**	**AL-6XN**
Initial Investment (Material Cost)	$25,369.00	$101,479.20
Downtime + Demolition + Replacement Installation Cost*	$96,000.00	
Replacement Material Cost*	$25,369.00	
Totals	$146,738.00	$101,479.20

*The cost comparison shown above is an accurate approximation. Actual numbers vary greatly by application, number, and extent of corrosion incidents.

NOTE

Availability is often a deciding factor when selecting an alloy such as AL-6XN. A product must not only meet the technical standards of application, but also be on the shelf – in all the necessary forms, such as sheet, plate, pipe, tube, bar, and fittings (both sanitary and commercial grade) to complete a project.

Working FASTER
to fight corrosion
Perform complete diagnostics at the first signs of corrosion.

Working SMARTER
to fight corrosion
Calculate true corrosion costs before settling on low-cost alternatives.

Working BETTER
to fight corrosion
Improve corrosion management with corrosion-resistant equipment

REFERENCES

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Goode, K. R., Asteriadou, K.,, Robbins, P. T., & Fryer, P. J. (2013). Fouling and cleaning studies in the food and beverage industry classified by cleaning type. Comprehensive Reviews in Food Science and Food Safety 12. Institute of Food Technologists. doi: 10.1111/1541-4337.12000.

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CSI also distributes a wide range of sanitary processing equipment along with installation materials including fittings, pumps, valves, tubing, and instrumentation.
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