

## White-Paper

# Stainless Steel Trap Corrosion

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### Conclusions and Recommendations

Based on the available data which visual analysis of the corroded traps, the most likely cause of the trap failures is pitting due to attack by chlorides. The source of the chlorides appears to be the high incidence usage of Ultra Clorox<sup>®</sup> Germical Bleach as a disinfectant.

A number of options are available to address this problem. These options include changes to work practices and use of alternative materials of construction. However, no single material of construction is suitable for any and all types of chemical exposure. Any program to address the problem with the traps should include specific guidelines for laboratory drain disposal practices at each laboratory.

Eliminating the use of sodium hypochlorite should be considered. This should greatly reduce the problem with the traps and greatly decrease potential future or long term problems with other parts of the 316L drainage system.

If sodium hypochlorite is used, effects on traps should be reduced by work practices including: minimizing the concentrations by using dilute solutions; minimizing the concentrations by diluting before the solutions are discharged; running clean water through the drains at the same time that any solution is discharged; flushing the drains with clean water immediately after the discharge of any solution containing sodium hypochlorite or sodium chloride; minimizing the temperature of any solutions that are discharged; and discharging solutions only at a high pH.

Alternatively, iodophor based disinfectants might be considered rather than sodium hypochlorite disinfectants as they do not appear to have a deleterious effect on stainless steel pipe. Consideration should also be given to the use of other broad spectrum disinfectants that are less damaging to stainless steel. However, this should be done with careful consideration of the biohazardous agent.

Duplex or super duplex stainless steel alloys such as 904L, 2205, Alloy 255, 6Mo, S32760 provide better chloride resistance than 316L stainless steel. These alloys may provide longer trap service. The use of an alternative alloy for the traps would not reduce any potential future or long term problems with other parts of the 316L drainage system.

The use of thermoplastics such as CPVC and PVDF can generally be used in sodium hypochlorite and chloride service and would eliminate any chloride pitting problem with the traps. However, these materials are not suitable for some types of organic compounds. The use of thermoplastic for the traps would not reduce any potential future or long term problems with other parts of the 316L drainage system

## 1. Background

NIH has many laboratory drainage systems constructed of 316L stainless steel. In general, laboratory drainage systems are used intermittently for a wide variety of hot and cold chemicals and reagents in limited quantities. Although the quantities are relatively small, the concentration of chemical that is put down the drain and that sits in the trap is a variable factor that may influence the rate of corrosion or pitting. Some traps used in these drainage systems have failed. As shown in Figures 1 to 5, the five photographs that were reviewed generally indicate pinhole leaks in and near welded areas.

Several chemicals are used in the laboratory as disinfectants. One disinfectant is a commercial solution of Ultra Clorox® Germicidal Bleach. This material contains 6.0% to 7.35% sodium hypochlorite and less than 0.2% sodium hydroxide by weight.<sup>1</sup> Sodium hypochlorite is manufactured by the following reaction:



Commercial sodium hypochlorite products always contain significant amounts of sodium chloride. Ultra Clorox probably contains 5% to 6% NaCl.

One of the most popular groups of decontaminants for laboratory use are the iodophors, with Wescodyne,<sup>2,3</sup> being perhaps the most widely used. Wescodyne may be diluted 1 to 10 in 50% ethyl alcohol (*a reasonably good decontaminant itself*) to make it a more effective decontaminant. This will give 1,600 ppm of available iodine, at which concentration relatively rapid inactivation of any and all microorganisms will occur.

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<sup>1</sup> Clorox Professional Products, MSDS. April 2002.

<sup>2</sup> Wescodyne Iodophor Sanitizer, MSDS. Johnson Diversery.

<sup>3</sup> Wescodyne Product No. 1038, MSDS. Steris.

A comparison of the effects of chlorine vs. iodine based disinfectants on stainless steel, strongly indicate that there is no effect for iodine based materials. However, in theory, any halogen, e.g. fluorine chlorine, bromine, and iodine, can cause pitting, Corrosion by iodine, the least active of the halogens listed, is very unlikely and the performance of 316L should not be a problem.

The noted disadvantages of iodine solutions are:

- They are not as effective against spores and phages as chlorine. or "They are active against all microorganisms except bactericidal spores and phages"
- They are expensive.
- Iodophors stain porous metal surfaces and plastics.
- Iodophors are severely affected by alkaline conditions above pH 7.

No single chemical disinfectant or method will be effective or practical for all situations in which decontamination is required. Selection of chemical disinfectants and procedures must be preceded by practical consideration of the purposes for the decontamination and the interacting factors that will ultimately determine how that purpose is to be achieved.

## 2. Corrosion of 316L Stainless Steel

Corrosion of stainless steel can be categorized as:

General corrosion;  
Pitting corrosion;  
Crevice corrosion;  
Stress corrosion cracking;  
Sulfide stress corrosion cracking;  
Inter-granular corrosion;  
Galvanic corrosion; and  
Contact corrosion.

A number of factors including a review of Figures 1 to 5 and comparison to published examples of stainless steel corrosion indicate that the traps have probably been affected by pitting corrosion. Pitting corrosion is often but not always associated with corrosives containing chlorine or chlorides. Pitting corrosion is actually a form of very local crevice corrosion that is usually caused by chlorides trapped in stagnant spots. Pitting corrosion has been described as:

“Under certain conditions, particularly involving high concentrations of chlorides (such as sodium chloride in sea water), moderately high temperatures and exacerbated by low pH (i.e. acidic conditions), very localized corrosion can occur leading to perforation of pipes and fittings etc. This is not related to published corrosion data as it is an extremely localized and severe corrosion which can penetrate right through the cross section of the component.”<sup>4</sup>

In general, stainless steel is not recommended for use with sodium hypochlorite. However, whether or not problems will occur and the severity of any problems will be affected by the type of stainless steel, the condition of the stainless steel surface, the length of exposure, the concentration of sodium hypochlorite, temperature, pH, and the presence of other chemicals. For example, the following is a response, by experts, to a question about lowering the pH of a 3% solution from 11 to 7:

“Temperature, type of steel, other impurities or components make substantial difference. However, in general change of the hypochlorite pH from 11 to 7 makes definite and significant increase in corrosiveness. Many grades of stainless steels will suffer from severe pitting and crevice corrosion when continuously exposed to sodium hypochlorite. Sensitivity to attack depends significantly on the surface condition. On a clean and polished surface corrosion

<sup>4</sup> <http://www.azom.com/details.asp?articleID=1177>

attack is less likely than on a surface with various defects resulting from the fabrication. Welds and flanges are attacked preferentially. If your equipment is exposed to the hypochlorite only periodically and well rinsed after it might survive but the risk of corrosion is higher when the pH is decreased to 7.”<sup>5</sup>

Based on available information it is very likely that sodium hypochlorite and chlorides are major contributors to the leaks that have developed in some 316L stainless steel traps.

### **3. Potential Corrective Actions**

Each laboratory situation may be different. In addition, some options can only be characterized as likely improvements that may or may not completely eliminate the problem. The best method with the highest probability of eliminating the problem with the traps would be to adopt a conservative approach that implements a number of corrective actions.

#### **3.1. Eliminate or Greatly Reduce the Exposure to and the Effects of Sodium Hypochlorite and Sodium Chloride**

Eliminating or greatly reducing exposure to sodium hypochlorite and sodium chloride should eliminate or at least greatly reduce the problems that have been encountered with the traps. One advantage of these options is that they will also reduce the potential for longer term damage to other parts of the 316L drain system.

##### **3.1.1. Eliminate the Use of Sodium Hypochlorite**

If the use of sodium hypochlorite is eliminated, corrosion of new stainless steel traps should be greatly reduced or virtually eliminated. Although, chlorine based disinfectants are considered to be the most generally effective disinfectants, other liquid disinfectants are available. Replacement of sodium hypochlorite with iodine solution, Iodophors, alcohols, phenol and phenol derivatives, quaternary ammonium salts, and formalin, or approved combinations of these chemicals with a known kill capacity, could be considered. These alternative disinfecting agents would not affect 316L stainless steel. However, whether or not these materials can be used will depend upon the effectiveness for each specific biohazardous agent, the ease of use in each specific situation, material handling issues, and any potential hazards to staff. Whether or not these alternative disinfectants, can replace sodium hypochlorite is beyond the scope of the present study. A site and agent specific evaluation of each laboratory situation would be needed to determine whether or not the use of sodium hypochlorite could be eliminated.

<sup>5</sup> <http://www.hghouston.com/Technical%20FAQs/TFAQ009.html>

### 3.1.2. Selection of Alternative Disinfectant

Selection of any given disinfectant will be influenced by the information derived from answers to the following questions:

1. What is the target biohazardous agent(s)?
2. What disinfectants, in what form, are known to, or can be expected to, inactivate the target biohazardous agents?
3. What degree of inactivation is required?
4. In what medium is the biohazardous agent suspended (i.e. simple or complex, on solid or porous surface, and/or airborne)?
5. What is the highest concentration of biohazardous particles anticipated to be encountered?
6. Can the disinfectant, either as a liquid, vapor, or gas, be expected to contact the biohazardous agent and can effective duration of contact be maintained?
7. What restrictions apply with respect to compatibility of materials?
8. What is the stability of the disinfectant in use concentrations, and does the anticipated use situation require immediate availability of the disinfectant or will sufficient time be available for preparation of the working concentration shortly before its anticipated use?

The primary target of decontamination in the laboratory is the biohazardous agent under investigation. Biohazardous agents exhibit a range of resistance to chemical disinfectants. In terms of practical decontamination, most vegetative bacteria, fungi, and lipid-containing viruses are relatively susceptible to chemical disinfection. The non-lipid-containing viruses and bacteria with a waxy coating, such as tubercule bacillus, occupy a mid-range of resistance. Spore forms and unconventional (slow) viruses are the most resistant.

A disinfectant selected on the basis of its effectiveness against organisms on any range of the resistance scale will be effective against organisms lower on the scale. Therefore, if disinfectants that effectively control spore forms are selected for routine laboratory decontamination, it can be assumed that any other organism generated by laboratory operations, even in higher concentrations, would also be inactivated.

### **3.1.3. Reduce the Effects of Sodium Hypochlorite and Chlorides**

Reducing the deleterious effects of any chemical requires due diligence on the part of the investigator and the development and implementation of stringent Standard Operating Procedures that are stringently followed.

Several methods to minimize the effect of sodium hypochlorite and sodium chloride are available as follows:

- Minimize the concentrations by using the lowest dilution of disinfectant known to effectively kill the agent in use;
- Minimize the concentrations by diluting before the solutions are discharged;
- Run clean water through the drains at the same time that any solution is discharged;
- Flush the drains with clean water immediately after the discharge of any solution containing sodium hypochlorite or sodium chloride;
- Minimize the temperature of any solutions that are discharged; and
- Discharge solutions only at a high pH.

### **3.2. Replace the Traps with New Traps Constructed with Alternative Materials**

In conjunction with ending or reducing the use of sodium hypochlorite, it may also be necessary to replace traps that have already been damaged. Once pitting has started, it is difficult to stop the process. Even traces of chlorides may result in continued pitting once pitting has started. Therefore, replacement of potentially damaged traps should be considered.

Two general classes of materials may eliminate or reduce the problems with the traps. Different grades of stainless steel should provide better resistance against pitting. However, it is not possible to conclude that alternative grades of stainless steel will eliminate the problem. In addition, traps made of certain types of thermoplastic materials would eliminate the pitting problem. However, it is not possible to select a material that will provide protection in all types of service for any chemical. For example, thermoplastics may offer good protection in sodium hypochlorite service but they can be damaged by chlorinated solvents. Materials of construction for each trap should be selected using specific guidelines for drain disposal of chemicals and associated procedures. In addition, replacement of the traps does not provide any protection against long term problems that may occur with the overall 316L drainage system.

### 3.2.1. Alternative Grades of Stainless Steel

Stainless steel is a metal alloy containing more than 11.5% chromium and more than 50% iron. Chromium makes these alloys “stainless” by forming a chromium oxide film on the metal surface that improves corrosion resistance. Other typical alloying elements are molybdenum, nickel, and nitrogen. There are several general types of stainless steel. In addition, a huge number of stainless steel grades have been developed to achieve different machining, forming, welding, and corrosion resistance properties. These different grades include hundreds of names based on proprietary names and numerous naming conventions including AST, UNS No., BS, DIN, NF and EN.

This study focuses on austenitic and duplex stainless steel. The 300 series of stainless steels, which contain approximately 18% chromium and 8% to 14% nickel, are the most common austenitic stainless steels. Type 316L stainless steel contains approximately 16% chromium, 10% nickel, 3% molybdenum, and 0.06% nitrogen.

Duplex stainless steels contain a mixture of austenite and ferrite structures. The two phase structure of duplex stainless steel provides higher resistance to pitting and stress corrosion. The mostly widely used duplex stainless steel, type 2205, contains 22% to 23% chromium, 4.5% to 6.5% nickel, 3.0% to 3.5% molybdenum, and 0.14% to 0.2% nitrogen. Some manufacturers classify stainless steels with 25% to 26% chromium as super duplex stainless steel.

“The Pitting Resistance Equivalent number (PRE) has been found to give a good indication of the pitting resistance of stainless steels. The PRE can be calculated as:

$$PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N$$

One reason why pitting corrosion is so serious is that once a pit is initiated there is a strong tendency for it to continue to grow, even though the majority of the surrounding steel is still untouched.

The tendency for a particular steel to be attacked by pitting corrosion can be evaluated in the laboratory. A number of standard tests have been devised, the most common of which is that given in ASTM G48. A graph can be drawn giving the temperature at which pitting corrosion is likely to occur, as shown in Figure 6. This is based on a standard ferric chloride laboratory test, but does predict outcomes in many service conditions.



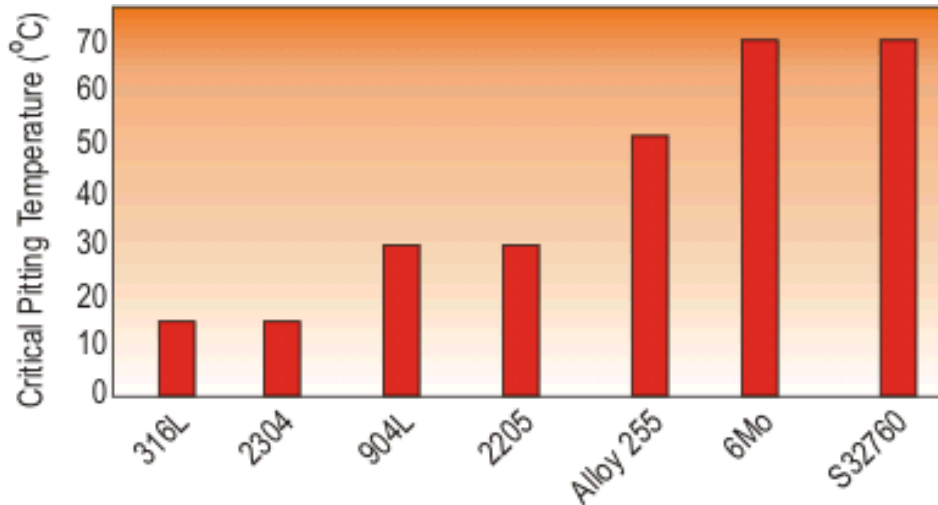


Figure 6. Temperature at which pitting corrosion is likely to occur  
(Based on a standard ferric chloride)

Type 316L, 2304, and 904 are austenitic stainless steels. Type 2205 and Alloy 255 are duplex stainless steel while 6Mo and S32760 are often classified as super duplex stainless steels.

Type 904L, 2205, Alloy 255, 6Mo, S32760 or any duplex or super duplex stainless steel will provide better pitting resistance than Type 316L stainless steel. However, the actual performance in any laboratory will be affected by the chemical exposure, chemical concentration, pH, and temperature. Therefore, replacement of a trap with a higher grade of stainless steel may or may not provide a significantly longer service life and that service life may or may not be adequate.

The performance of stainless steel traps can also be affected by welding procedures. First, there should be no welding defects such as cracks, porosity, inadequate penetration, or non-metallic intrusions. Second, consideration should be given to treatment of the weld to remove surface heat tint or scale formed during welding as these oxides and areas of low chromium concentration will affect corrosion resistance. The second issue can be addressed by passivation techniques such as electro-chem heat tint removal and some form of pickling using an acid solution.<sup>6</sup>

Stainless steel is resistant due to the rapid formation of a protective chromium oxide layer on the surface of the alloy. In some situations, stainless steel passivation is needed to completely form this layer. Passivation is described as follows:

<sup>6</sup> [http://www.hghouston.com/ss\\_clean.html](http://www.hghouston.com/ss_clean.html)

“According to ASTM A380, passivation is "the removal of exogenous iron or iron compounds from the surface of stainless steel by means of a chemical dissolution, most typically by a treatment with an acid solution that will remove the surface contamination, but will not significantly affect the stainless steel itself." In addition, it also describes passivation as "the chemical treatment of stainless steel with a mild oxidant, such as a nitric acid solution, for the purpose of enhancing the spontaneous formation of the protective passive film."

### **3.2.2. Thermoplastic Materials**

Thermoplastic materials are materials that soften when heated and harden when cooled. There are a variety of thermoplastic materials available including ABS, PVC, CPVC, PVDF, and polypropylene. Selection for the best material for a given application depends on the chemicals that must be handled, temperature, strength requirements, and other factors. This discussion focuses on CPVC and PVDF.

Both CPVC and PVDF are not affected by sodium chloride solutions. In addition, in drainage systems they are generally suitable for temperature near and above 200 °F and they have excellent resistance to strong acids as well as bases and alkaline solutions. However, their performance can be affected by some organic solvents. PVDF is extremely expensive.

All the references consulted during this project indicate that CPVC has excellent resistance to sodium hypochlorite. One reference indicates that PVDF is not suitable for sodium hypochlorite service while others indicate that PVDF is suitable for sodium hypochlorite. More detailed information on PVDF indicates that it is suitable for handling 5% sodium hypochlorite at temperatures above 200 °F as long as the pH is less than 11.

Both CPVC and PVDF can be adversely affected by some organic chemicals. CPVC and PVDF are reported to have excellent chemical resistance to many water soluble chemicals, such as alcohols, at low concentrations. However, these materials may be adversely affected by chlorinated or aromatic hydrocarbons, esters, or ketones.

Figure 1: Trap Photograph 1

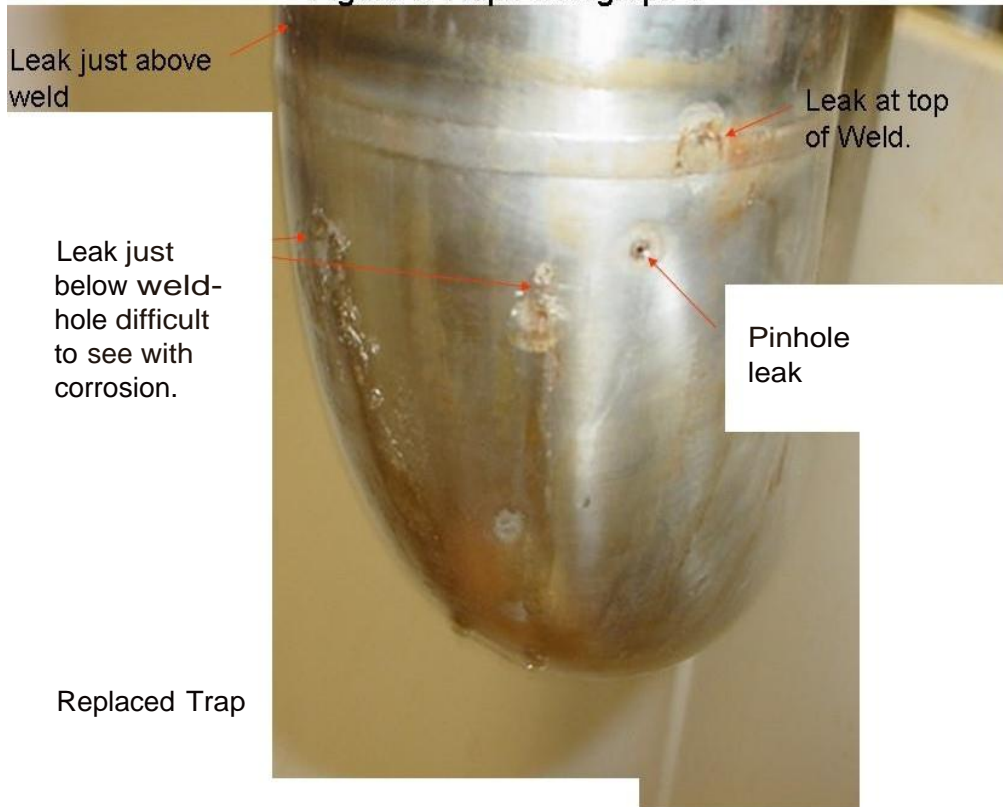
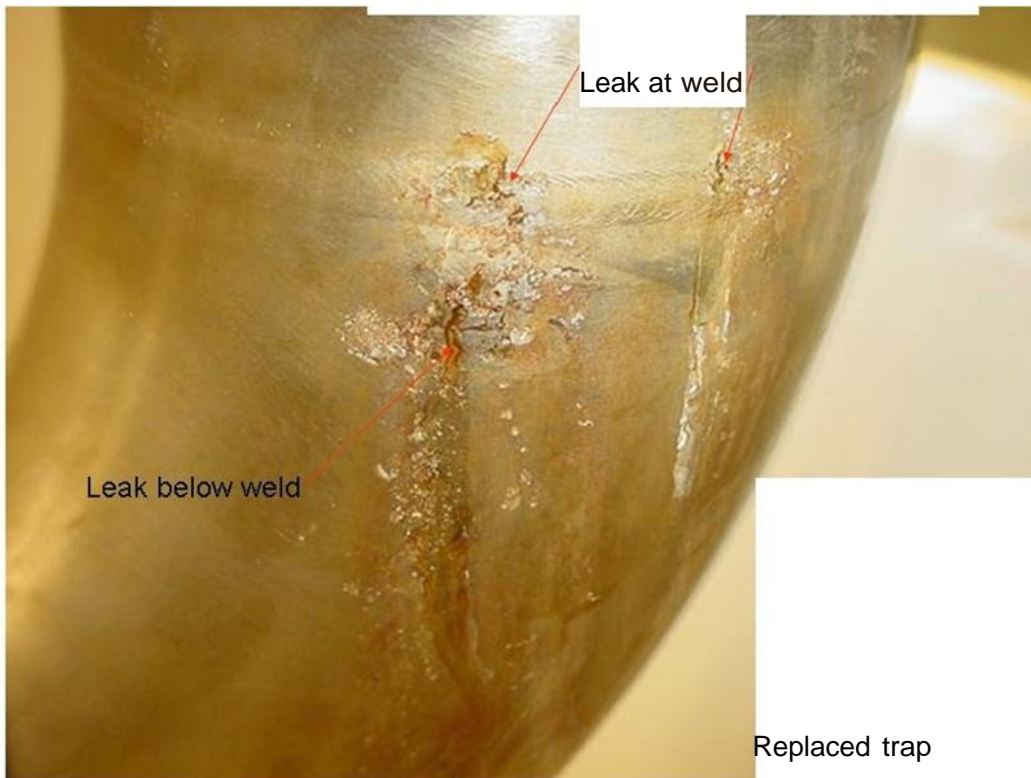
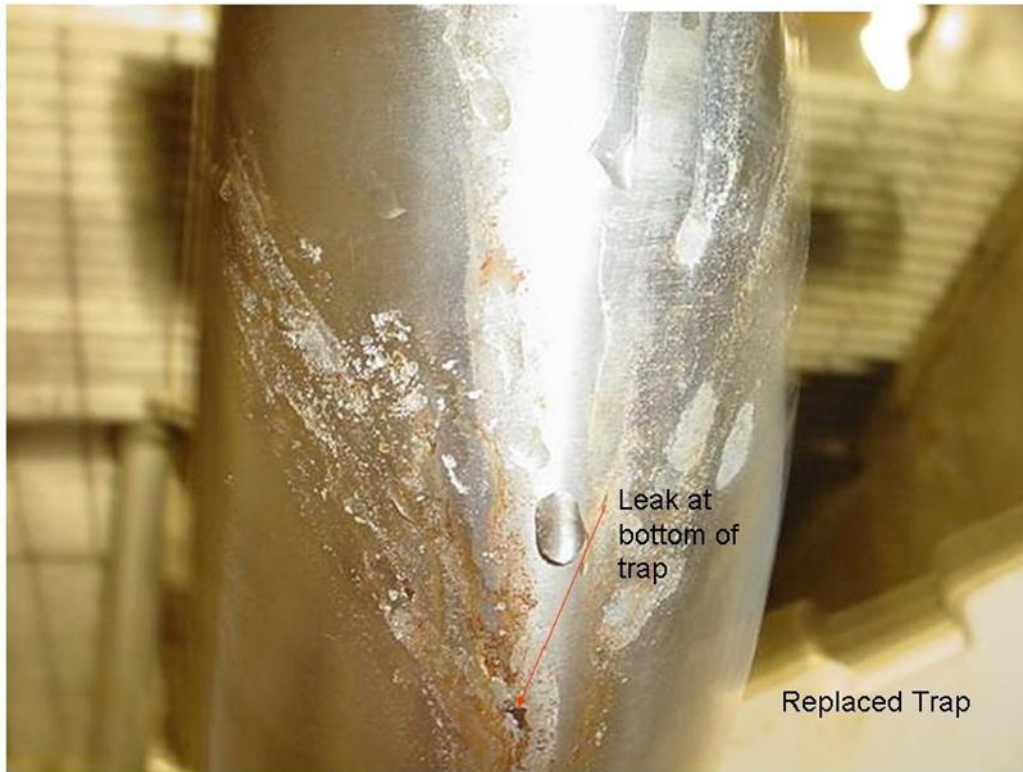


Figure 2: Trap Photograph #2



**Figure 3: Trap Photograph #3**



**Figure 4: Trap Photograph #4**

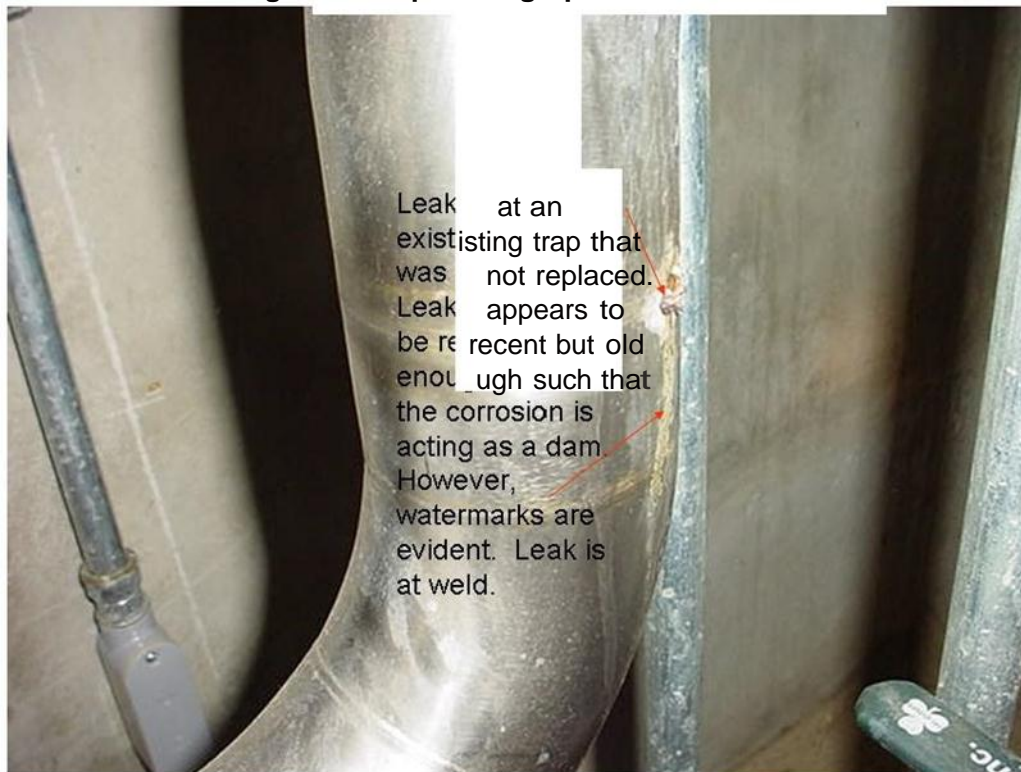


Figure 5: Trap Photograph #5

