# Technical Bulletin

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## *COIL CORROSION BY EROSION*

**Introduction**

For the coil designer, coil corrosion can seem to be one of life's great mysteries. Combinations of metals in coil construction along with wide variations in operating environments can make the mechanisms of corrosion complex to say the least. When movement of a corrodent over a metal surface (i.e. through coil tubes) increases the rate of attack due to mechanical wear and corrosion, the attack is called Erosion Corrosion, and is considered a "localized" form of corrosion. Failure of water coils due to erosion of tube surfaces can many times be avoided with proper coil design.

**Erosion**

Conditions that cause erosion corrosion in coils typically involve fluids moving at high velocity, solids in suspension, marked turbulence, and impingement. Erosion corrosion occurs most frequently in water coils near the inlet end of tubes or headers along the first 2 to 6 inches of the inside surface. It may occur, however, along the whole length of the tube surface. It results in clusters of deep pits which are usually undercut on the downstream side and in many cases take on a horseshoe shape. To avoid erosion corrosion, the following steps should be taken:

*<u>1. Make the proper choice of tube materials</u>*. Colmac has the ability to make coils from a variety of tube materials, including: Copper, Cupro-Nickel, Steel, Stainless Steel, and Aluminum. Limits for velocity of fresh water flowing in tubes and headers are shown below:

**Maximum Tube/Header Velocity for Various Materials**

| **Material** | **Maximum Velocity, fps** |
|---|---|
| Copper | 6 |
| Cupro-Nickel (90-10) | 8 |
| Steel | 10 |
| Stainless Steel | 15 |
| Aluminum | 4 |

Note that certain materials, i.e. Copper, Steel, and Aluminum, will experience severe pitting when exposed to brackish water / sea water and are not recommended. Velocity limits for Cupro-Nickel, and Stainless Steel with brackish / sea water are the same as fresh water (shown above).

*<u>2. Limit fluid velocities.</u>* The velocity of the fluid flowing through coil connections and tubes is limited by proper selection of connection and header sizes, and by choosing a minimum number of feeds in the coil circuiting. The following table shows maximum allowable water flowrates in gpm for various connection (and header) sizes.

**Maximum Connection/Header Flowrate (gpm) for a Variety of Materials**

| Connection / Header Size, inch | Copper | Cu-Ni | Steel | Stainless Steel | Aluminum |
|---|---|---|---|---|---|
| ¾ | 8 | 10 | 13 | 19 | 5 |
| 1 | 14 | 18 | 23 | 34 | 9 |
| 1-1/4 | 21 | 29 | 36 | 54 | 14 |
| 1-1/2 | 31 | 41 | 51 | 77 | 21 |
| 2 | 55 | 73 | 91 | 137 | 37 |
| 2-1/2 | 86 | 114 | 143 | 214 | 57 |
| 3 | 123 | 165 | 206 | 309 | 82 |
| 4 | 219 | 293 | 366 | 549 | 146 |
| 6 | 494 | 658 | 823 | 1234 | 329 |

Coil circuiting must also be designed to limit the flowrate per feed in order to keep fluid velocity below acceptable limits. Maximum allowable water flowrate per feed is shown below for various tube sizes and materials.

**Maximum Tubeside Flowrate (gpm/feed) for a Variety of Materials**

| Tube O.D. , Inch | Tube Wall, inch | Copper | Cu-Ni | Steel | Stainless Steel | Aluminum |
|---|---|---|---|---|---|---|
| 3/8 | 0.016 | 1.8 | 2.4 | 3.0 | 4.5 | 1.2 |
| 3/8 | 0.032 | 1.5 | 2.0 | 2.5 | 3.7 | 1.0 |
| ½ | 0.016 | 3.2 | 4.3 | 5.4 | 8.1 | 2.2 |
| ½ | 0.025 | 3.0 | 4.0 | 5.0 | 7.5 | 2.0 |
| ½ | 0.035 | 2.8 | 3.7 | 4.6 | 6.9 | 1.8 |
| 5/8 | 0.018 | 5.1 | 6.7 | 8.4 | 12.6 | 3.4 |
| 5/8 | 0.025 | 4.8 | 6.4 | 8.0 | 12.1 | 3.2 |
| 5/8 | 0.035 | 4.5 | 6.0 | 7.5 | 11.3 | 3.0 |
| 5/8 | 0.049 | 4.1 | 5.4 | 6.8 | 10.2 | 2.7 |
| 1 | 0.035 | 12.3 | 16.4 | 20.5 | 30.8 | 8.2 |
| 1 | 0.049 | 11.6 | 15.5 | 19.3 | 29.0 | 7.7 |

Colmac CoilPRO engineering software automatically calculates header and tubeside velocities and prints a warning whenever the above limits are exceeded.

*3. Eliminate entrained or separated air.* Air bubbles in the circulating water contribute to the damaging effect of erosion-corrosion. Proper purging and elimination of air from the waterside of chilled and hot water systems is essential to prevent this type of corrosion. Air can also be drawn into the suction side of pump piping if leaks are present and pressures are lower than one atmosphere at that point in the system.

*4. Eliminate sediment and contaminants.* Entrained sediment and other solid contaminants will accelerate erosion corrosion, and will effectively lower the threshold velocities at which erosion begins to occur. In the case of very low velocities, sediments will be deposited in tubes and may contain or accumulate corrodents which initiate and sustain other types (chemical and/or electrochemical) of localized corrosion. Sediments and suspended solids must be removed by filtering the circulating water.

Erosion corrosion in water coils can be prevented by taking the proper steps during design and operation. Use the guidelines described above to minimize the possibility of "coil corrosion by erosion".

Earlier in this article, erosion corrosion in water coils was discussed and guidelines for proper coil design were recommended. Erosion corrosion can also occur in steam coils. Design strategies for steam coils are somewhat different, and are described below.

**Erosion**

Steam can be very corrosive in coils when it is improperly treated, or misapplied. Proper steam piping and coil design are critical for good coil operation and long coil life. Corrosion issues in steam coils can involve both chemical, and mechanical factors. This article will focus on erosion as a form of corrosion.

Two types of erosion corrosion that can occur in steam coils are described below. Just as with water coils, steam coils can experience erosion corrosion from excessive tubeside velocity. Also, if condensate is allowed to remain in the coil and become subcooled during idle periods or at shutdown, when live steam is again admitted and contacts the condensate a phenomenon called "thermal shock" will take place.

Velocity Limits

For a given steam flowrate in pounds per hour (lbm/h), steam velocity decreases as pressure increases. This is due to the increase in steam density as pressure increases. Care must be taken to size coil connections and headers for the minimum anticipated operating steam pressure. This approach will insure that the coil is designed to handle the maximum velocity condition. Colmac recommends sizing steam coil connections for velocities not exceeding 6,000 feet per minute. This guideline not only minimizes the chances for erosion to occur, it also reduces steam noise. The following table shows maximum allowable steam flowrate versus connection size:

**Table 1**
**Maximum Steam Flowrate (lbm/h) vs Pressure**

| **Connection Size, inch** | **Steam Pressure, psig** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **5** | **15** | **25** | **50** | **75** | **100** | **150** | **175** |
| 3/4 | 59 | 86 | 114 | 180 | 245 | 309 | 436 | 499 |
| 1 | 105 | 154 | 202 | 319 | 435 | 549 | 774 | 886 |
| 1-1/4 | 164 | 240 | 315 | 499 | 679 | 857 | 1210 | 1385 |
| 1-1/2 | 236 | 346 | 454 | 719 | 978 | 1234 | 1742 | 1994 |
| 2 | 419 | 615 | 807 | 1278 | 1739 | 2195 | 3097 | 3546 |
| 2.5 | 654 | 961 | 1261 | 1996 | 2717 | 3429 | 4839 | 5540 |
| 3 | 942 | 1384 | 1816 | 2874 | 3912 | 4938 | 6968 | 7978 |

Type FS Steam Coils

Type FS Steam distributing coils can experience erosion corrosion in the outer tube wall where high velocity steam leaves the inner tube orifices. Limiting steam loading per tube to a maximum allowable value based on velocity will mitigate this type of erosion corrosion.

Use Table 2 below to find maximum condensate load per tube based on inner tube velocity of 8,000 fpm. Note that type FSL coils use 3/8 x 0.016 inner tubes, and FSX coils use 5/8 x 0.018 inner tubes.

**TABLE 2**
**Maximum Condensate Load (lbs/hr tube) for Type FS Coils**
**Maximum Steam Velocity = 8,000 fpm**

| **Coil Type** | **Steam Pressure, psig** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5.0 | 15.0 | 25.0 | 50.0 | 75.0 | 100.0 | 150.0 | 175.0 |
| FSL | 18 | 27 | 35 | 55 | 76 | 95 | 135 | 154 |
| FSX | 51 | 76 | 99 | 157 | 214 | 270 | 380 | 435 |

Keeping FS coils clear of condensate is also critical to avoiding combined erosion and thermal shock (see below) at the orifice outlets.

Thermal Shock

When condensate is allowed to remain in a steam coil after shutdown or during idle periods it becomes subcooled (cools to a temperature lower than steam temperature). If live steam is then introduced into the coil and contacts the subcooled condensate, the live steam will violently recondense into the condensate. Tiny bubbles of the live steam are injected into the condensate at the steam-condensate interface where they collapse with tremendous destructive force. This process, called "thermal shock", is very similar to cavitation in pumps where local pressures in the pump body are allowed to fall below the vapor pressure of the water being pumped. In the case of thermal shock, erosion corrosion occurs where the collapsing steam bubbles contact the tube surface resulting in severe localized pitting. Thermal shock is prevented by properly designing steam piping to thoroughly eliminate all condensate from steam coils both during operation, and after shutdown.

**Summary**

Erosion corrosion can be caused by a variety of reasons and can appear in both water and steam coils. Proper matching of materials to type of fluids used, and velocity requirements is important. Correct coil connection and header sizing, along with selection of circuiting will prevent erosion due to velocity effects. Finally, steam piping must be designed to keep steam coils clear of condensate. Following these guidelines should minimize the possibility of *"coil corrosion by erosion"*.

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