Hot Water Recirculating Systems, IS 97-02

Prevention of Velocity Effects = Erosion corrosion and Cavitation

In response to inquiries regarding corrosion in hot water recirculating systems due to velocity effects, the CCBDA is providing the following information concerning factors which may affect the service life of copper tube and fittings in such systems.

A typical hot water recirculating system in a multi-unit residential or commercial building consists of a piping loop in which hot water, from hot water tanks or boilers, is kept circulating by one or more pumps. This permits hot water to reach most points in the building within relatively short periods of demand time.

Investigations of copper tube and fittings samples taken from hot water recirculating systems have identified several factors which contributed to the corrosion:

1) Water velocities exceeding 5 feet per second.
2) Undersized distribution lines, creating high velocities.
3) Oversized circulating pumps with no bypass, creating excessive velocities.
4) Multiple and/or abrupt changes in direction (see Photo 1).
5) Failure to remove the burr on the inside of the tube after cutting.
6) Improper solder or brazed joints.
7) Improper use of throttling valves for system balancing.

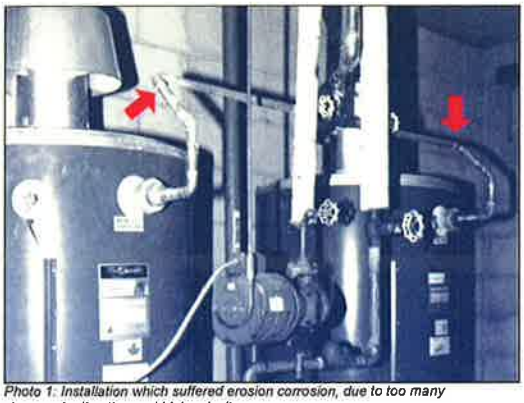


Photo 1: Installation which suffered erosion corrosion, due to too many changes in direction and high velocity.

Excessive Velocity

Excessive velocity in a hot water recirculating system is typically the result of using an oversized pump, or undersized distribution lines.

There are several choices for corrective action to eliminate the problem of erosion corrosion. All are based on reducing the water velocity or eliminating the excessive turbulence at connections and fittings. Options include a bypass around the pump to reduce its effective output, a smaller capacity pump, or a throttling/balancing valve downstream of the pump to restrict the flow, and larger tube sizes in the areas affected.

Temperature Effect

In addition to reducing the flow, it is good practice to limit domestic hot water to a maximum temperature of 60° C (140° F), since increasing the temperature of potable water can change its corrosive effect on copper and other materials. Erosion corrosion can also occur in cold water lines, but it is less common. It is good practice to observe the recommendations presented here in both hot and cold water supply systems.

Erosion Corrosion

The pressure loss of a flowing fluid due to friction varies approximately with the square of the flow velocity. As the velocity increases, the abrasive effect on the tube wall increases, and erosion of the tube may occur. The extent of erosion caused by excessive velocity is dependent upon the physical characteristics of the tube material or impediments to flow on the tube wall, such as burrs on the tube ends, blobs of solder, or mineral deposits.

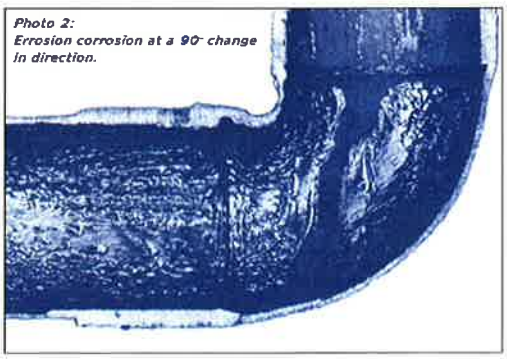


Photo 2: Erosion corrosion at a 90° change in direction.

Erosion corrosion occurs at locations where turbulence develops in a system. This turbulence interferes with the normal protective film formation on the inside of the tube and also erodes the copper surface at that point. Turbulence can be caused by excessive velocity, sudden changes in direction and flow obstacles such as burrs and solder blobs.

Erosion corrosion is readily identified from the characteristic appearance of the damaged surface.

Figure A: Laminar flow.

A typical damaged surface has deep horseshoe pits with the open ends facing downstream (see **Photo 2**).

The attack is typically most severe just downstream of a joint or obstruction in the system.

In some cases, the attack progresses downstream, because as the pitted areas develop they in turn promote increased turbulence.

Sometimes the attack is so severe that the entire surface is rough, and the characteristic horseshoe pits are not clearly seen but thinning of the tube wall becomes evident.

Where the velocity conditions are less severe downstream from the zone of severe turbulence, laminar or streamline flow may return, so that this section of the tube will not show attack.

Figure A shows smooth laminar flow which occurs in straight unobstructed sections of tube or changes in direction at lower velocities.

Figure B shows turbulence caused by a sharp change in direction at high velocity.

Figures C and D show erosion corrosion caused by burrs and solder blobs respectively.

The phenomenon of cavitation can occur in systems when the flow velocity is high and either the direction of flow is sharply changed or is obstructed by a burr.

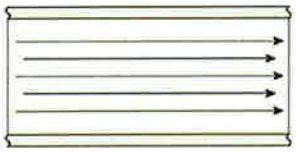
In a fitting, the centrifugal force flowing around a short bend radius at high velocity causes an increase in pressure at the outer portion of the bend and a resultant lowering of the pressure at the throat.

The pressure in the low-pressure area at the inside of a bend can drop below that of atmospheric which permits bubbles to form.

The bubbles in turn collapse when they flow into a normal pressure area.

They collapse with enough force to erode microscopic pieces of metal if they are close to the tube wall.

This action may continue until perforation occurs through the wall of the tube or fitting.



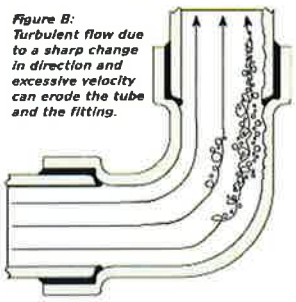


Figure B: ***Turbulent flow due to a sharp change in direction and excessive velocity can erode the tube and the fitting.***

Figure C: Turbulent flow due to burrs on the end of the tube can cause erosion downstream.

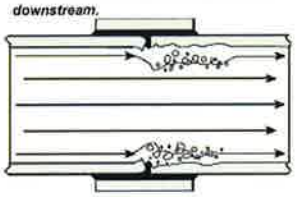
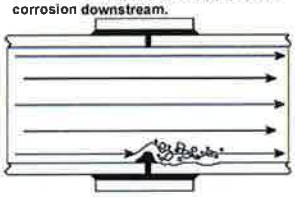


Figure D: **Turbulent flow due to a solder blob on inside of the tube can cause erosion corrosion downstream.**



Recommendations

Local plumbing code requirements must be observed when applying these recommendations to individual installations.

1) Design all hot water recirculating systems to keep velocities below 5 feet per second for temperatures up to 60°C (140°F). Flow maximums should not exceed 3 to 4 feet per second for temperatures greater than 60°C.
2) Avoid abrupt changes in direction wherever possible.
3) Deburr all tube ends before joining.
4) Make all solder joints according to ASTM B828, "Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings."