Prevention

1. Adjust the intensity, duration and frequency of the water contact from water cannons to prevent excessive exposure of the bare steel tubes to water.
2. Periodically inspect desuperheaters and maintain the water spray nozzles and liners so that water will not be running into downstream piping.
3. If water ingress is suspected, then inspection downstream is recommended.

Bulletin Board

DAVID N. FRENCH METALLURGISTS
Corporate Headquarters
2681 Coral Ridge Road
Brooks, KY 40109
Phone: 502.955.9847 Fax: 502.957.5441
www.davidnfrench.com

DAVID N. FRENCH METALLURGISTS
2681 Coral Ridge Road
Brooks, KY 40109

DAVID N. FRENCH METALLURGISTS

View From the Penthouse

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Thermal Quench Cracking

Repeated contact of water with a furnace side tube surface or a steam side surface can result in thermal quench cracking. The severity of cracking depends on the difference in temperature and the rate of temperature change.

Water cannons are frequently used to remove deposits from water walls and increase the heat flux. Thermal quench cracking may result. Water can also contact tubes if it is introduced to the boiler by a sootblower. Within steam-filled tubes, unplanned exposure to water may occur due to leaks into the system, high drum levels, or because desuperheaters are not functioning properly.

Mechanism

Temperature changes cause contractions or expansions in steels. If the temperature change is slow, then these changes in length would occur gradually throughout the structure. However, if the temperature change is rapid, then temperature gradients will be present and the material will be internally stressed to accommodate the length differences. These stresses can fatigue or even tear the material apart. One rule of thumb states that the difference in temperature between the water and the hot surface must be less than 200 F degrees to avoid thermal quench cracking. The origin of this guideline may involve a back-of-the-envelope calculation of stresses induced. If a surface layer experiences a 200 F degree temperature decrease, then using the coefficient of thermal expansion for steel, the contraction of the surface layer would be 1.34×10^{-3} in/in. If this strain is multiplied by the modulus of elasticity (E), then a stress of 40,200 psi would be induced in that

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contracting layer. This is just over the yield strength for SA-210 carbon steel. Some objections can be made to this simple model and the rationale that cracking occurs if the yield stress is exceeded. Stresses less than the yield stress may, if applied many times, cause fatigue damage. And notches in the surface may intensify stresses locally at flaws, weld toes or other surface changes. Temperature differences of 75 or 100 F degrees have reportedly caused thermal fatigue cracking. Cracking is typically a network of surface cracks or it may follow a change in cross-section. Surface notches such as machining marks, weld toes or sharp corners may serve as initiation sites for thermal cracking because stresses are concentrated at these locations.

Figure A

Figure A illustrates cracking that propagated from grinding marks on a tube. The thermal stresses, in combination with residual stresses and operating stresses, cause initiation of the cracking. Cracks propagate transverse to the applied stresses. Low cycle fatigue results when there are large plastic strains due to large changes in temperature or large differences in thermal expansion between two components. In extreme cases, it may be called thermal shock.

In high cycle fatigue, stresses are lower, such as those induced by intermittent wetting. The wetted surface contracts rapidly, but the metal underneath does not. This induces a large biaxial tensile stress in the surface. As the water evaporates, the surface reheats and the stresses decrease. The result over time is a crazed appearance, with many cracks. Water draining into a steam-filled header repeatedly quenched the header surface, causing craze cracking, **Figure B.**

Figure B

Appearance

The cracking may be circumferential or longitudinal or a combination of both (like craze cracking), depending on the stress. Tubing de-slagged by a water cannon experienced thermal fatigue on the OD. Cracking was dagger-shaped, transgranular, and oxide-filled, **Figure C**.

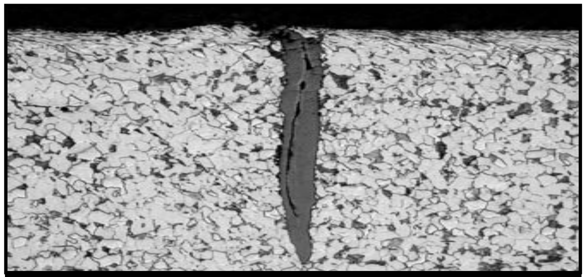

Figure C

The oxide, having a larger volume than the metal it replaced, may jack open the crack, increasing the crack propagation rate. Water ingress to a superheater loop, from a malfunctioning desuperheater, resulted in similar cracking as illustrated in **Figure D**.

Figure D

Inspection and Repair

The majority of tubes that have failed due to water cannon thermal quench cracking have been at the far outboard locations of the water cannon spray, where the spray is at an acute angle to the surface. Thorough inspection is required, going at least three feet beyond the periphery of the water cannon spray zone. Periodic inspection of desuperheaters is needed to ensure that the internals are intact, and the nozzles are working properly. Piping inspection is recommended to identify areas where water ingress may be occurring. Damaged tubes should be removed because it is difficult to be sure that all cracks have been removed. Grinding and weld overlaying will probably not be a good repair, and may only create residual stresses that lead to subsequent failure.