SPRAY COOLING BOF HOODS

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INTRODUCTION

UCAR® Spray-Cooled Systems are furnace components that utilize a nonpressurized water cooling process. UCAR Carbon Company has provided spray-cooled equipment commercially as an engineered product since 1986. With over 150 installations in steelmaking shops worldwide, spray cooling has demonstrated its effectiveness for equipment cooling under the most difficult conditions.

UCAR Spray Cooling began with electric furnace roofs. During the past ten years it has evolved through continuous improvement and development to a product capable of a wide range of cooling applications in the steel industry. Today, UCAR Spray Cooling is being used for electric furnace roofs, shells and elbows, off-gas duct systems, ladle furnace roofs, combustion chambers, AOD and BOF Hoods.

The purpose of this paper is to present the principles of design and operation of spray cooling as they relate to the BOF hood, including its benefits of safer operation, lower maintenance, and increased life over conventional cooling systems.

PROCESS FEATURES

Spray cooling performs its cooling function at atmospheric pressure utilizing spray nozzles to supply cooling water to the hood. Each nozzle is located and sized to provide the required amount of cooling water for the varying heat loads throughout the hood.

The primary benefits of spray cooling are:

- ✓ Operating at atmospheric pressure minimizes the amount of water that can escape the hood if there is a leak. This feature reduces the hazard of water and steel mixing and the subsequent need for an unplanned shutdown for repairs.
- ✓ Thermal stress fatigue cracking is minimized by constructing the hood of free standing plate that is thin and less constrained.
- ✓ Efficient use of cooling water by customizing it to the varying heat loads throughout the hood.
- ✓ Cooling remains constant. Distribution of cooling water within the hood is through noncorrosive piping that is not part of the heated surface. The factors that can influence the unbalanced flow of cooling water in conventional hoods such as corrosion, sediment buildup, and vapor pockets are not present with spray cooling. Additionally, cooling water is supplied to the entire hood at the same temperature as the inlet water temperature.

HOOD CONSTRUCTION

Spray-Cooled Hoods are made up of cylindrical sections. Sectionalizing the hood controls the film of water cascading down the inner shell, and also facilitates shipping and installation. A section is comprised of an inner and outer shell. The inner shell is the hot plate that is in direct contact with the off-gas. The outer shell surrounds the inner shell forming an annulus. At each end is a closure piece that connects the inner shell to the outer shell (Fig. 1). The area between the two plates is referred to as the spray chamber. Access to the spray chamber is through quick-opening hatches located on the outer shell. The hatches allow inspection of the spray system and inner shell. The hatches are also located to enable removal of spray bars should it be necessary to perform maintenance

The outer shell is the structural component of a Spray-Cooled Hood. It carries the load of the hood to which all supports are attached. The inner shell is attached to the outer shell at the ends. There are no other connections between the inner and outer shell other than openings needed for penetration through the hood. This construction provides the minimal amount of restraint to the inner shell during expansion and contraction. Since the system operates at atmospheric pressure, thin material can be used for the inner shell. Both of these design features serve to minimize thermal stress fatigue cracking.

The primary material used for the inner shell in UCAR Spray-Cooled equipment is carbon steel pressure vessel plate. Factors such as thermal conductivity, allowable stress, workability and cost effectiveness have demonstrated that, for most applications, a carbon steel suitable for use at elevated temperatures is preferred.

There are two basic considerations in the selection of material thickness for the inner shell. They are:

1) a material thickness that minimizes thermal stress fatigue cracking, and
2) a material thickness that provides the highest margin against wear.

Following is a sample determination of the proper material thickness for a given heat load to a spray-cooled hood:

Heat Load to Hood = 200,000 BTU/HR/SQ. FT.		
Material: Carbon Steel, less than 0.5% carbon content		
Calculated thermal stress for 1/4" thick shell	=	19,600 psi
Calculated thermal stress for 3/8" thick shell	=	29,400 psi
Calculated thermal stress for 1/2" thick shell	=	39,200 psi

From the graph (Fig. 2), it can be seen that the cycles to failure for 1/4" thick material exceed 100 million, for 3/8" it's approximately 1.5 million cycles, and for 1/2" it's approximately 200,000 cycles. For an expected 200,000 btu/hr-sq.ft. heat load, this analysis would indicate that the 1/4" or a maximum of 3/8" thick material should be used. Further up the hood where the heat load reduces and more wear may be occurring due to changes in the hood's configuration, thicker material can be considered. Minimizing thermal stress in the various aspects of hood construction has enabled UCAR to practically eliminate the incidence of cracking in the BOF hood sections supplied.

SPRAY SYSTEM

The spray system (Fig. 3) is made up of noncorrosive piping and nozzles. All nozzles are removable by means of detachable spray bars that connect to a header pipe. The header is fed by a single inlet. The entire piping system is attached to the outer shell of the hood so that the inner shell can be replaced easily without affecting the arrangement of the nozzles.

The amount of flow to a given section is determined by the size of the nozzle used, the quantity of nozzles, and the pressure at which water is supplied. In addition to the amount of water supplied to the equipment, these variables affect the efficiency, effectiveness and reliability of the system.

Spray nozzles produce the turbulence needed for good heat transfer by impingement rather than by velocity as in conventional cooling systems. This means that effective heat transfer can be achieved at virtually any flow rate. Cooling water can be supplied more accurately based on the varying heat loads in the hood, enabling highly efficient use of water.

Cooling water supply can also be easily adjusted. By removing the spray bars in the affected area through an inspection hatch, more water can be added by either replacing existing nozzles with larger capacity nozzles or adding more nozzles. The use of camlock connectors makes for easy spray bar removal.

COOLING WATER

The cooling water requirement for a spray-cooled hood is determined based on expected heat loads. The quantity of cooling water required is controlled by the amount of temperature rise allowed between the inlet and outlet of a section for a given heat load. Increasing the rate at which cooling water is supplied lowers the temperature rise. Correspondingly, lowering the rate of cooling water increases the temperature rise.

Cooling water is supplied to the equipment at a rate sufficient to minimize film boiling. The process does not rely on vaporization for cooling. A cooling water temperature rise between inlet and outlet of 50° F and a maximum outlet temperature limit of 160°F is considered ideal. This ensures adequate cooling water exists for the normal heat flux as well as sufficient margin to accommodate transient hot spots.

Spray nozzles are sized and located to provide the required cooling water flow to handle the heat load as it varies throughout the hood. As a preventive measure, nozzles are arranged to overlap. If a nozzle should become blocked, adjacent nozzles provide back-up cooling.

The cascading film of water that adheres and flows along the inner shell assists in the cooling process by smoothing out water distribution. It also provides reserve cooling capacity.

From a cooling standpoint, the primary advantages of spray cooling over conventional cooling are:

1) the elimination of the source for high pressure, high volume water leaks,
2) the ability to effectively transfer heat at low flow rates,
3) the consistency and uniformity at which cooling water is provided, and
4) the ease in which cooling water supply can be adjusted based on hood requirements.

COOLING WATER QUALITY

The cooling water quality required for spray cooling is comparable to the water used for other water-cooled equipment in the plant. Since water temperatures are kept low and supply water is distributed through a noncorrosive piping system, water quality requirements are minimal.

In order to minimize the potential for nozzle blockage, solid particles should be less than 1/32" in diameter. This is accomplished by installing a mechanical strainer at the beginning of the noncorrosive piping that feeds cooling water to the hood.

SUPPLY WATER SYSTEM PIPING AND INSTRUMENTATION

Cooling water is supplied to a Spray-Cooled Hood through parallel circuits (Fig. 4). A main feed pipe is installed to carry water to the hood location. From there, a header pipe located near the hood distributes water to the hood sections. Each section has a single inlet with a flow control valve and pressure gauge. The strainer, which would typically be common to all sections, is installed close to the hood.

Downstream of the strainer noncorrosive piping is used to ensure rust does not contaminate the supply water. Also, downstream of the strainer is a flow measurement device. The flow measurement device is used primarily as a sensor to alarm for a low or high flow condition.

A temperature sensor is installed in the discharge outlet of each section to monitor discharge water temperature. The discharge temperature monitor and flow meter are connected to a PLC or alarm panel.

HOOD ASSEMBLY AND INSTALLATION

Hood sections are supplied fully assembled and ready for connection with adjacent sections. Each section is supplied with bolted flanges. One end of the section has its flange positioned and welded completely during fabrication, and the flange at the other end is shipped loose. The sections are hoisted into position and joined. Once alignment and fit-up are achieved, the loose flange is welded in place.

Sections are supplied complete to minimize on-site assembly. However, sections can be assembled in the field should building structure interferences exist or the configuration of the hood require it to be supplied in smaller pieces.

HOOD MAINTENANCE AND REPAIR

INSPECTION

On a day-to-day basis, no maintenance is required. Periodic inspection is recommended to ensure the system is operating as designed. This consists primarily of a visual inspection of the spray chamber and a check of the flow and temperature monitoring equipment.

Inspection of the hood should take place when it is possible to reduce cooling water flow. A reduction in flow is necessary to allow for visibility within the spray chamber. A hood inspection consists of opening several of the hatches in a section and confirming that spray patterns are uniform with no signs of blockage, and that the condition of the inner shell is normal.

REPAIR

If a crack or hole does occur, the amount of water leakage is minimal. This makes it possible to schedule most repairs during a planned shutdown.

Repairs can be made quickly from outside the hood. Temporary repairs consist of welding up a crack or installing a patch plate over a hole when limited time is available. Access to the inner shell is accomplished by cutting a window in the outer shell. Permanent repairs are made on a down day when time allows for the damaged material to be removed and replaced, and the inner shell is brought to like-new condition.

Spray-Cooled Hoods are designed for refurbishment. The inner shell, which will eventually wear out, can be easily replaced. The other components of the hood, i.e., spray system and outer shell, will last indefinitely. Since there are no attachments to the inner shell, other than the connection at the ends, replacement is quick and low in cost. The inner shell is simply cut free by removing the weld at the end faces. Once free, the old inner shell simply slides out and the new inner shell slides in and is welded to the end faces.

BOF HOOD EXPERIENCE

The first Spray-Cooled BOF Hood Section was commissioned in September, 1993. Reports received over a period of 3 1/2 years described maintenance as minimal. Cited events consisted of the repair of four small cracks about 1 inch in length, the replacement of worn nozzles, and the welding of patches over eroded spots.

In the summer of 1996, Removable Hood Sections were installed on two other furnaces. Overall, the appearance of all three hoods has been reported excellent. The hood sections have shown no signs of thermal fatigue cracking, severe wear, or distortion.

CONCLUSION

UCAR Spray Cooling has proven its effectiveness in BOF Hood applications from actual experience in the toughest environment for a hood. The reasons for its success are based on established engineering principles. These elements, plus UCAR's success in the supply of spray-cooled equipment throughout the steel industry over the past ten years, confirm the benefits of spray cooling.

UCAR® Spray-Cooled Technology is covered by one or more patents - U.S. Patent Nos. 4,715,042; 4,813,055; 4,815,096; 4,849,987; 5,115,184; 5,330,161; 5,327,453; 5,444,734; 5,561,685 and foreign patents.

References

Mark's Standard Handbook for Mechanical Engineers, 8th Edition, Baumeister, Avallone, Baumeister, McGraw Hill Publishing, pg. 5-9, Fig. 17.

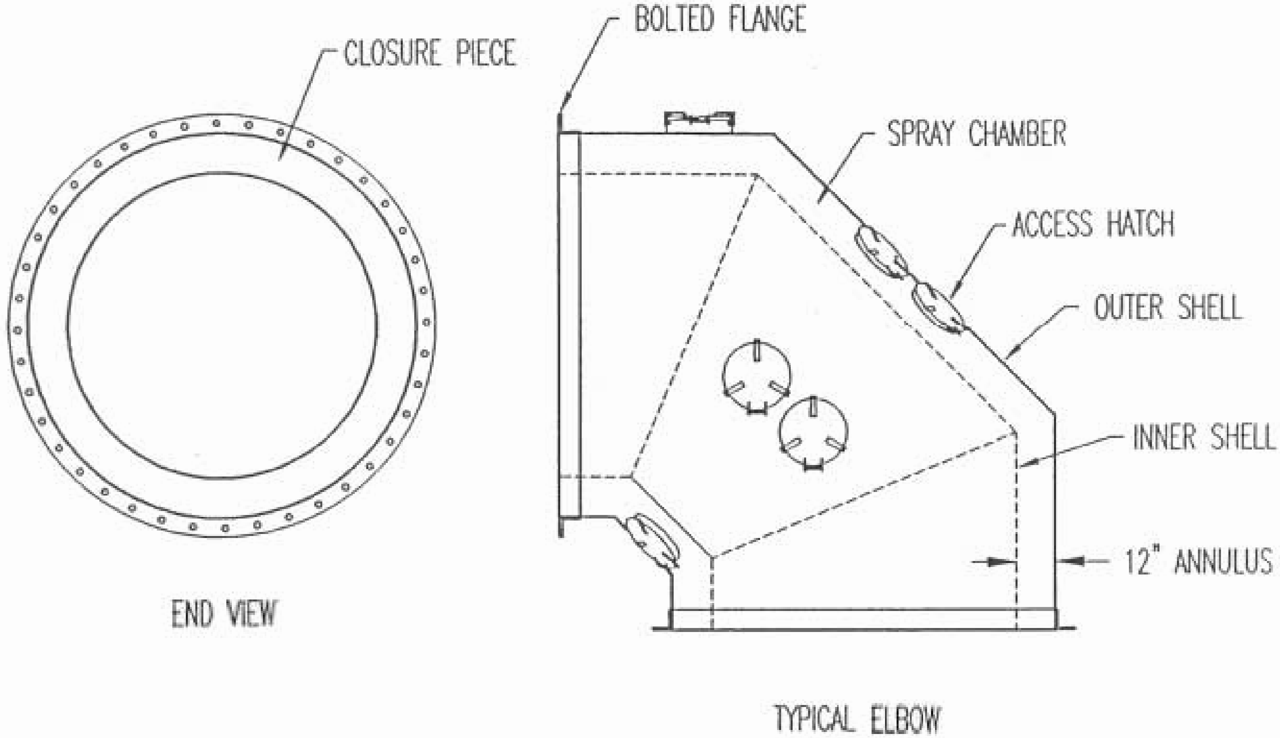
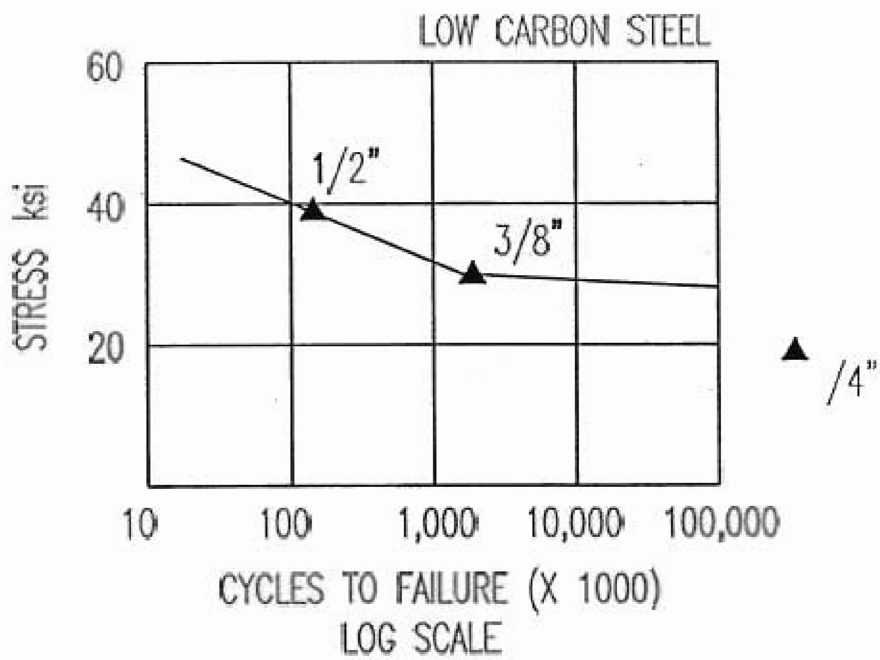
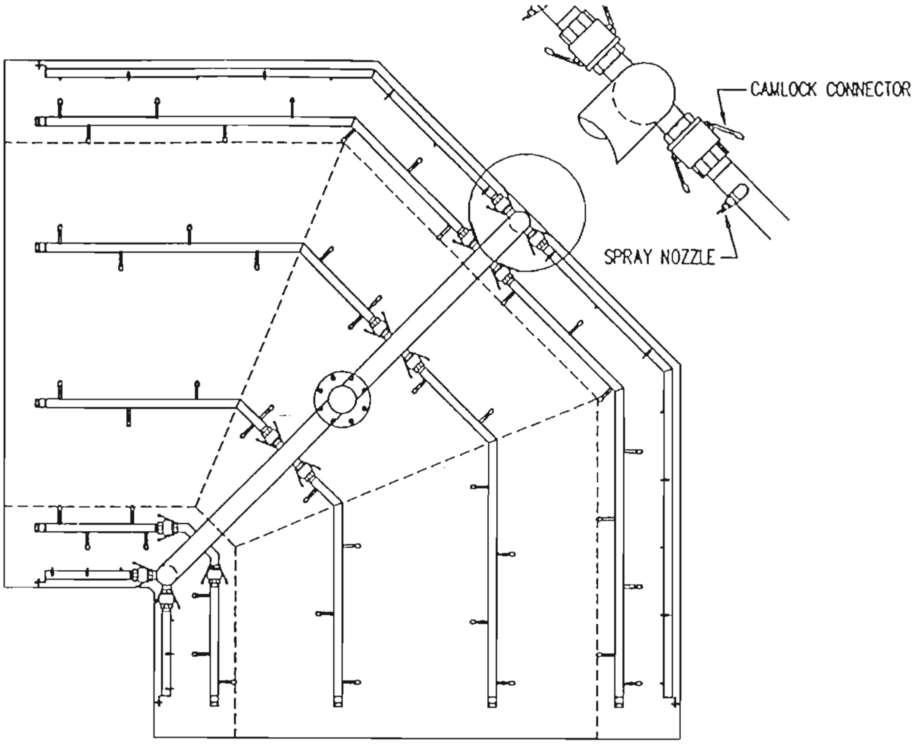


Fig.



FATIGUE DIAGRAM

Fig. 2



TYPICAL SPRAY SYSTEM ARRANGEMENT

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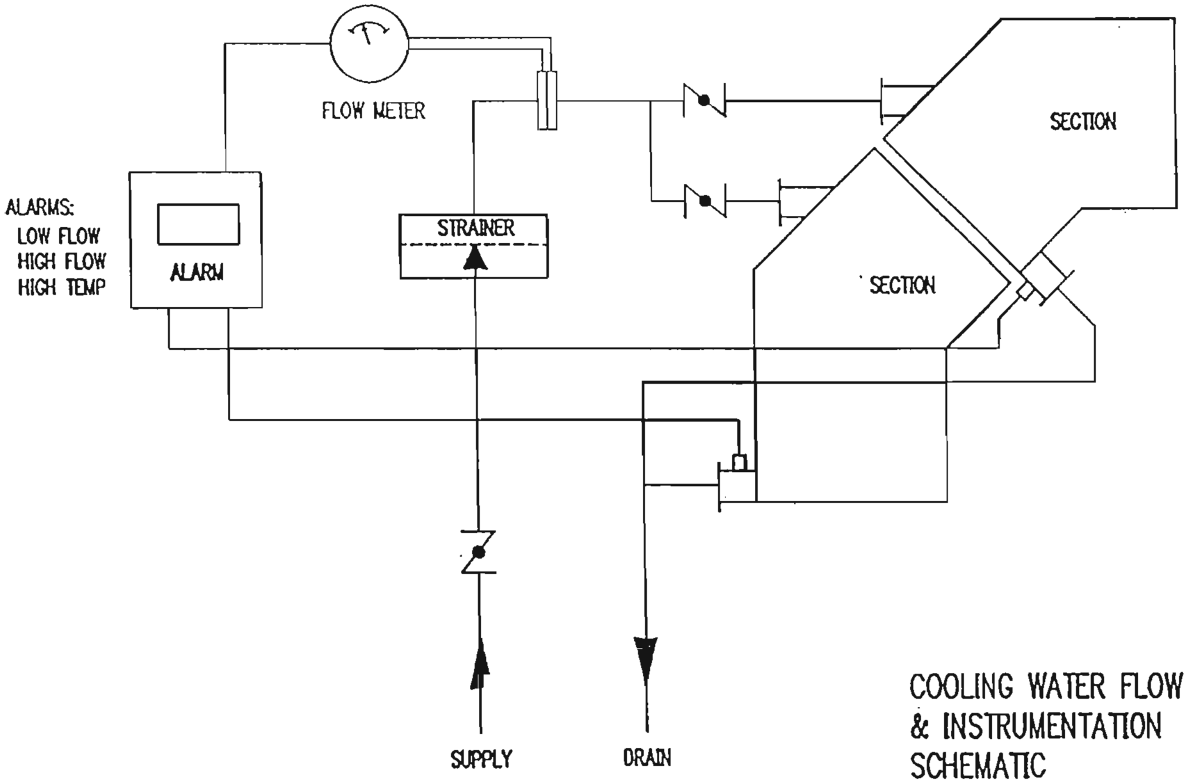

COOLING WATER FLOW
& INSTRUMENTATION
SCHEMATIC

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