PEIRCE SMITH CONVERTER HOOD IMPROVEMENTS AT BHP COPPER

Ovidiu Pasca and John Bryant
BHP Copper
Arizona, USA

Paykan Safe and Brian Wiggins
Gas Cleaning Technologies
Dallas, USA

ABSTRACT

Several improvements in converter equipment and operation at BHP Copper have reduced converter cycle time as necessitated by increased flash furnace output. This high intensity operation of the Peirce Smith Converters has had a major impact on the dust handling and off-gas cleaning systems.

Changes in converter cycle time and campaign life as result of the process and equipment improvements are discussed in a separate article A new converter hood design is reviewed with respect to thermal analysis and hood performance.

INTRODUCTION

BHP Copper Metal intends to successfully modernize the existing flue dust handling system and contain primary off-gases in each of the four Peirce-Smith converters.

The primary objective of the project is to comply with State guidelines and regulations for the transfer of copper bearing material containing lead and arsenic contamination. Flue dust must be contained and transferred in a safe and environmentally acceptable method, namely no open handling. Presently, dust generated in the four Peirce Smith converters accumulates in hoppers fitted to the primary off-gas hood (hopper A) and stub flue (hopper B).

A stationary puncher shack was not possible because the “A” hopper blocked the view of the operator. Thus the operator had to ride the traveling punch car.

CONVERTER HOOD MODIFICATIONS

The existing converter hoods consist of hollow carbon steel jackets bolted together to form an enclosure around the converter mouth. The jackets are cooled by flooding with water from a closed loop cooling tower circuit. The hood design includes a vertical back wall and abrupt transition into the stub flue; this causes large chunks of dust to build up due to splashing and recirculating gas flows inside the hood.

The bottom of the hood is fitted with a transition (“A” hopper) into a chute where dust is discharged through a clam valve while the converter is being turned around. Hopper A is in close proximity to the converter mouth, thus a significant amount of molten metal splash reports to this hopper. This caused plugging in the hopper chute and thus required excessive manual labor and dust handling to clean it out between converter cycles.

Converter #6 hood was modified by installing a steeply inclined back wall as shown in Figure 1. This modification creates a smoother transition into the existing stub flue thus reducing the buildup due to recirculating gas flow patterns. The selected design consists of a new fitted, steeply sloped back wall inside the existing hood vertical side walls.

The benefits and impact of the hood modifications are as follows:

• Improved gas flow pattern	-reduces dust recirculation and buildup in the hood. -improved converter draft.
• Eliminates "A" hopper	-eliminates current dust buildup/blockage in the hopper. -allows for stationary punch car operator. -eliminates air infiltration from the hopper.
• Flue dust can slide into converter mouth	-reduces handling of large dust chunks.
• Spark shield life	-reduced warping/better sealing by water cooling

Figure 1 – Modified Converter Hood Outline

Two design scenarios were considered:

- Replace the entire hood with a new properly shaped design
- Remove the existing vertical back wall and retrofit with a sloped wall fitted inside the side walls

The removal of the side panels was complicated by the fact that six of these panels supported most of the hood load. Removal of these panels would require the hood to be temporarily supported and new structural supports installed on an incline to accommodate hood thermal growth. In order to eliminate these complications a design which the sloped back wall fitted inside the existing side walls was used. Thus the existing side wall jackets were not removed and continue to provide the structural support for the hood. This solution was simpler, less expensive and quicker to implement. This connection required close attention during detailing.

The selected design required the least structural modifications and was implemented during a converter rebuild relatively easily/quickly. The modification will be used to assess the benefits of the new hood shape. In order to minimize the impact on the jacket cooling water system, side wall jackets not (or partially) exposed to high heat flux were piped in series.

Areas of concern and where particular attention to detail was required were:

- Obtaining a good seal between the sloped wall and existing vertical jackets;
- Access/logistics for replacement of water jackets;
- Connection detail to the existing stub flue, and existing back wall modifications;
- Structural support of the sloped wall;
- Maximum practical size/weight for the new sloped panels;
- Access for easy switching of jackets to air cooling (emergency only);
- Effect of emergency air cooling on jacket integrity;
- Supply/return water header piping modification for new jacket tie-in.

THERMAL ANALYSIS

Existing Water-Cooled Hood

Table 1 summarizes the previous hood heat load based on the design heat removal in the cooling water. The actual local heat flux will of course vary about the 10,000 Btu/hr.ft2 average, likely being higher near the bottom of the hood and lower near the top.

Table 1: Measured Hood heat Removal

Cooling water Flow rate	mixed inlet temp	outlet temp	Total heat removal	Hood surface area	Average heat flux
800 gpm	110°F	150°F	16 M Btu/hr	1600 ft2	10,000 Btu/hr.ft2

In the previous design, the gravity-fed cooling water flows in a single pass through the entire cross section of each jacket, resulting in relatively low water velocities inside the jackets, and consequently relatively low convection heat transfer coefficients. Table 2 summarizes the heat transfer calculations for a typical previous jacket.

Table 2: Old Hood Jacket Design Analysis – Typical Jacket

Cooling water Flow rate	typ. Channel area	water velocity	water heat transfer Coefficient	max water temp	max. non-boiling heat flux
12.9 gpm	36 x 3.125”	0.04 ft/s	22 Btu/hr.ft2.F	150°	22 x (212-150) = 1,360 Btu/hr.ft2

The maximum non-boiling heat flux, reported in the last column, represents the maximum heat flux that the jacket can be exposed to without experiencing local boiling in the water passage. Clearly 1,360 Btu/hr.ft2 is well below the measured average heat flux of 10,000 Btu/hr.ft2, indicating that boiling is occurring throughout the current hood.

Boiling of this nature, called nucleate boiling, does not usually produce any observable steam. The steam bubbles generated are quickly entrained and condensed by the bulk flow. When implemented properly, it can be an effective form of heat transfer, resulting in very high heat transfer coefficients. However, when hard water is used, deposits can build up on the inside surface of the jackets reducing the efficiency of the heat transfer, and leading to jacket overheating, leakage, and eventually failure.

New Jackets and Water-Cooled Spark Shield

For the new sloped jacket wall and water-cooled spark shield, nucleate boiling will be a more serious concern:

1. Due to proximity to the converter mouth, this zone of the hood will experience the highest heat fluxes. Excessive boiling in these jackets can lead to steam blanketing, a condition where the production of steam due to nucleate boiling exceeds the capability of the bulk flow to entrain the produced steam bubbles. This creates a "steam blanket" on the inside surface of the jackets that suddenly reduces the heat transfer efficiency, leading to jacket overheating and failure.

2. The sloped orientation of these jackets will tend to cause any produced steam to stay at the upper hot surface, causing the onset of "Steam blanketing" effects at lower heat fluxes than would be expected on the vertical wall.

For these reasons, avoiding any boiling in the new sloped wall will be an important component in achieving long jacket life – more important than for the existing vertical walls. Consequently, the new jacket design is based on avoiding boiling at the design heat flux**,** representative of the maximum expected local heat flux. This is achieved by introducing baffles into the jacket design to increase the cooling water velocity, and thus heat transfer. In the case of the spark-shield, velocities are increased even further by going to a tube-wall type construction.

Determination of a local design heat flux requires analysis of the heat transfer mechanisms involved. The two primary mechanisms combining to produce the heat loading on the hood are:

1. Radiation from the highly emissive converter off-gas

2. Solidification and cooling of entrained molten material that is splashed/dropped onto the relatively cold hood surfaces

Secondary mechanisms, including radiative heat transfer from the converter mouth, and convective heat transfer from the converter off-gas do not significantly affect the observed heat loading, and have been neglected in the development of this design basis.

Radiation from Converter Off-gas

The radiative heat flux from the converter off-gas depends on the gas temperature, and the inside surface temperature of the hood. The following graph presents the calculated relationship for a water-cooled hood surface with varying degrees of surface build-up.

Figure 2 - Calculated Converter Off-gas Radiative Heat Flux to Water-cooled Hood for different buildup thickness (inches)
basis: gas emissivity = 0.95, buildup K=10 Btu.in/hr.ft2.F

Even thin layers of frozen build-up can significantly affect the radiative heat transfer at high gas temperatures. When the gas temperature is below 1200°F, however, radiative heat-flux is relatively insensitive to build-up thickness. From Figure 2, for the target mixed gas temperature of 1200°F, the radiative heat flux is about 10,000 Btu/hr.ft2.

Solidification and Cooling of Molten Metal

The heat content of hot material impinging on the bottom jackets and particularly the new water-cooled spark shield may contribute significantly to the heat flux. This additional heat load is difficult to calculate accurately, but can be reasonably estimated based on the known collection rate of solids from hopper A. Assuming complete solidification and cooling of this material from 2200°F to 250°F (equivalent to about 490 Btu/lb), The equivalent heat flux is summarized as follows:

Table 3: Estimated Heat flux Due to Impinging of Hot Material

Mass rate of material	total heat content @ 490 Btu/lb	impingement area	equivalent heat flux
10-36 lb/min	300,000-1,000,000 Btu/hr	est. 160 ft2	2,000-7,000 Btu/hr ft^2

In the above calculation, an estimate of the impingement area is required to back-calculate a heat flux. 160 ft2 represents 10% of the total hood area, or about half of area of the new sloped section. The calculations indicate that, although the total heat load due to impingement of hot material is a relatively small component of the total heat removal of the hood (less than 10%), the local flux on the affected jackets can be significantly increased.

Thermal Design Basis

Adding these heat flux estimates and applying a reasonable safety margin to avoid boiling, while still maintaining reasonable system pressure losses, the following design basis were used:

Table 4: New Sloped Wall Thermal Design Basis

	Cooling water req'd	Number of jackets	Total cooling water	Channel velocity	heat transfer coefficient	max water temp	max non-boiling heat flux
Spark Shield	30 gpm/ jacket	3	90 gpm	2.3 ft/s	610 Btu/hr.ft2.F	150°F	37,820 Btu/hr.ft2
Slopped Jacket + Transition	30 gpm/ jacket	9 + 1	300 gpm	1.0 ft/s	310 Btu/hr.ft2.F	150°F	1 9,220 Btu/hr.ft2
			390 gpm				

The converter hood cooling water system configuration is presented in Figure 3.

Since the new jackets were baffled for higher velocity, they represent more pressure drop then the existing circuit. In order to avoid water flow balancing problems, a branch circuit was tied into the existing water circuit dedicated to the sloped wall and spark shield. The flow rate through this circuit was “tuned” by the water column height on the discharge header. Thus water flow balancing with the existing hoods was achieved without valves.

Figure 3 – Converter Hood Cooling Water System Configuration

COMPUTATIONAL FLUID DYNAMIC MODELING (CFD)

The existing hood and proposed change were modeled using computational fluid dynamics (CFD) and some of the results are shown in Figure 4. The results show the flow pattern improvement with the new sloped hood due to:

- The converter off-gas recirculation in the new hood is eliminated
- Pressure drop in the hood is reduced
- Converter off-gas temperature is increased due to a tighter hood design and reduced air infiltration

Figure 4 – CFD Velocity Profiles for Original and Modified Hood Configurations

PERFORMANCE OF THE NEW WATER-COOLED HOOD

The performance of the new converter hood design on #6 converter has met all the original design criteria and has operated well since startup. There has been no buildup of flue dust on the steeply sloped back wall or the water cooled spark shield of the new hood which were the greatest concerns during design. Even when the converter is full and blowing at a high volume, the splashing material at the converter mouth does not stick to the back of the collar. However, there has been some buildup occurring at the transition between the sloped back wall and the modified stub flue. This buildup is occurring on the flat spot on the bottom of the expansion joint that joins the hood to the stub flue. This will be corrected in the next design by extending the last water jacket next to the expansion joint beyond the flat spot to prevent flue dust from sticking.

Some dust measurements were conducted to compare the converter dust characteristics between the old and new design. The total dust carryover was similar however for the new system the dust reporting to “B” hopper is fine free flowing material thus easily handled and would eliminate open dust handling.

The temperature measurements at the stub flue indicate that the converter gas is noticeably higher compared to the original levels which is due to better converter draft and reduced air infiltration in the system.

CONCLUSIONS

The redesign of #6 converter hood has been a success. The elimination of the “A” hopper has provided a cleaner work environment by minimizing the handling of flue dust directly below the punching platform. It also has eliminated a potential hazard to employees when buildup had to be removed from the “A” hopper. The punch car tracks are now completely accessible from all directions behind the converter which enhances maintenance access and operator visibility. The draft on the converter has increased since the “A” hopper clam door can no longer leak. This newly designed hood with one hopper discharge has provided the basis for a closed looped flue dust injection system which will return the fine flue dust back to the converter as it is being generated. The injection system is currently under design. Based on the success of the #6 converter hood modification there are plans to retrofit the remaining three converters with the new hood design.