THE IMPLEMENTATION OF ULTRALIFE™ COPPER CASTING TECHNOLOGY IN THE EAF

Gary Slaven[1], Allan MacRae[2], Lou Valentas[3]

[1] Falcon Foundry, 96 Sixth Street, Lowellville, OH 44436
[2]MacRae Technologies, Inc., 1000 Silver Maple Lane, Hayward, CA 94544
[3]Berry Metal, 2408 Evans City Road, Harmony, PA 16037

Abstract

Water-cooled copper castings with a novel copper alloy pipe are now operating in high heat load areas in many EAF's, Smelting Furnaces, and Blast Furnaces. The patented cast copper to copper alloy pipe coil combination has demonstrated a superior design verses other technologies, to improve heat transfer and to extend the service life of the castings. The new castings will be described, as well as the fundamental advantages of the copper alloy, as compared to existing designs.

Introduction

In an EAF, water-cooled panels are frequently used to stabilize refractory corrosion over the depth of the slag bath. Spray cooled pipe and machined copper panels are capable of removing more heat than a falling film of water on the outside of the shell. However, spray cooled wall panels can suffer distortion and cracking, and their slag retention is minimal. Water-cooled pipe panels offer slightly better slag protection, but if a water-cooled pipe panel develops a leak, the amount of water lost to the furnace can be significant with the high pressure.

Machined copper panels offer excellent heat transfer and slag retention characteristics and have been historically used in EAF hot spots as well as many Blast Furnace and Smelting applications. Unfortunately, the welded or threaded plugs are susceptible to water leaks after prolonged use.

Copper castings have been installed in several furnaces to replace both water-cooled pipe and spray cooled panels initially in the furnace hot spots, and spreading throughout the furnace. By using an internal pipe coil (Figure 1), there are no plugs inside the furnace which can leak.

Using properly designed pockets on the hot face, the cast copper block forms a relatively stable hot face accretion. Thermal peaks are reduced, thereby increasing casting life, reducing maintenance requirements, and reducing the electrical energy for melting lost to the cooling system.

UltraLife™ copper castings[1] have been introduced with the following features:

- High conductivity high purity cast copper, for excellent heat transfer.
- Internal pipe coil with patented copper-nickel pipe, to maximize heat transfer and eliminate welded plugs.
- Hot face pockets to hold slag or refractory, to form a stable hot face lining.

[1] UltraLife™ is a registered trademark.

Pipe Technology

Based on testing, copper-nickel pipe coils (Patented, Patents Pending) achieved a metallurgical bond with the cast-around copper. De-bonding of the pipe from the copper due to thermal cycling is reduced due to a combination of improved bond and reduced stresses compared to nickel-copper pipe.

Nickel-copper (e.g., Monel) pipe coils have been and still are used for the manufacture of copper castings for metallurgical furnaces, for the following reasons:

- Pipe coils do not have to be cooled during casting such as with copper pipe, which can limit the bond between the pipe and the pipe coil, as well as generate steam and significant forces if the pipes are cooled with water.
- Copper wets the surface of the nickel alloy, thereby establishing good contact between the cast copper and the pipe coil.
- Elimination of plugs inside the furnace, compared to drilled and plugged blocks.
- The internal pipe can help to arrest a crack should it penetrate the hot face of the copper, as Monel is stronger than the cast copper.

Now, with the selection of copper-nickel (CuNi) for the pipe coil, the following additional advantages are realized versus Monel:

- Thermal expansion of the pipe more closely matches the cast copper; hence shear stresses at the interface of the pipe to the cast copper are reduced significantly. Further, de-bonding due to thermal cycling between the copper and the pipe coil is reduced considerably.
- The pipe is metallurgically bonded to the cast copper, thereby improving heat transfer.

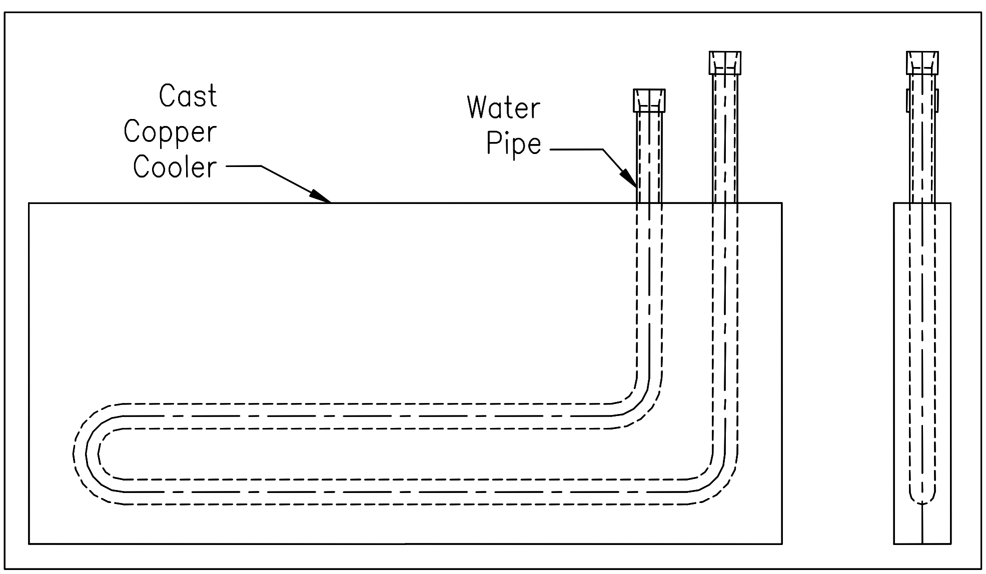

Figure 1: Simple Cast Block with Internal Pipe.

Testing of Cast-In Pipe Coil

Full-size production pieces were cast using Monel and copper-nickel pipe. A sketch of samples taken from these castings is included in Figure 2. Figure 3 is a sample with one corner cut away.

Based on examination of micrographs (Figures 4 and 5), there is a diffusion layer about 20 to 100 microns thick between the outside of the copper-nickel pipe and the cast copper [References 1 and 2]. A significant layer was not found around the Monel pipe. This was the first indication that a metallurgical bond was achieved between the copper-nickel alloy pipe and the copper.

Samples taken from castings with Monel and copper-nickel pipe were tested using ultrasonic testing (UT), as shown in Figure 6. It was found that using Monel pipe, UT results normally corresponded to the outside of the pipe. However, with the copper-nickel pipe, UT results corresponded to the inside of the pipe.

When an x-ray is taken of a casting with Monel pipe coils, the outside of the pipe is relatively easy to distinguish. With the copper-nickel pipe, however, it is very difficult to demarcate the interface of the pipe and the cast copper.

Results from these traditional test procedures all point to the copper-nickel pipe being well bonded to the copper. An illustrative test was developed, in which a 50 ton hydraulic ram was used to push the metal ring out of a sample of cast copper (Figure 7). In Figure 8 the complete Monel pipe segment (ring) is visible, with little copper bonded to the outside of the pipe. By comparison, it took many times the force compared to Monel to dislodge the copper-nickel pipe segment in Figure 9. Further, the copper-nickel had a considerable amount of copper bonded to it, and part of the ring remained in the host copper.

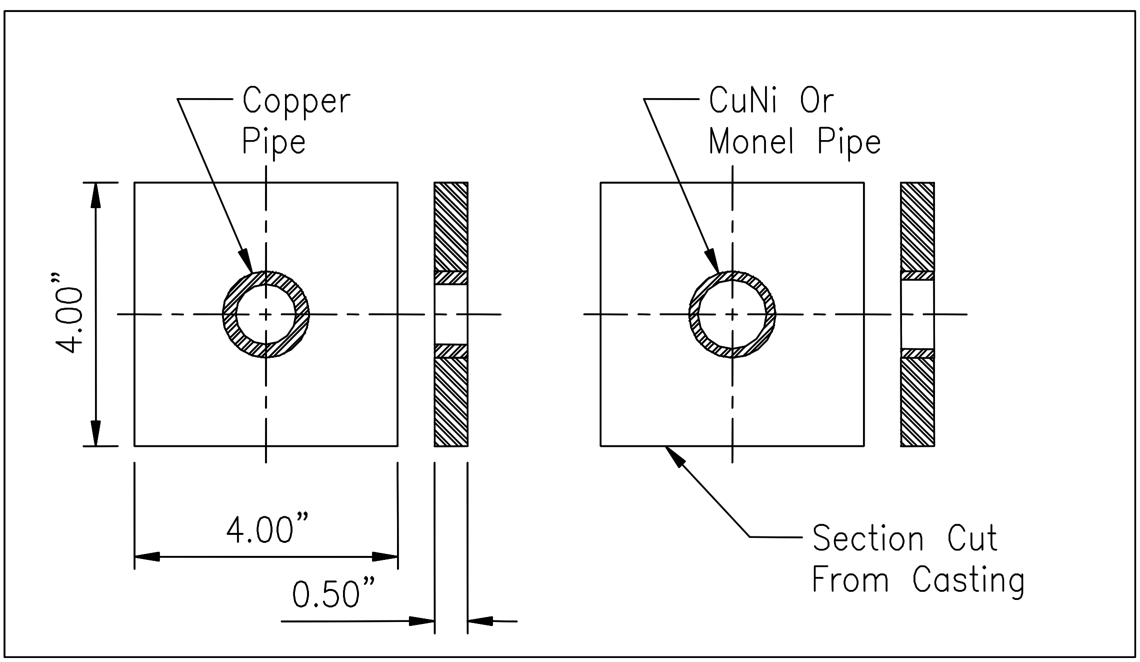

Figure 2: Samples from Production Castings.

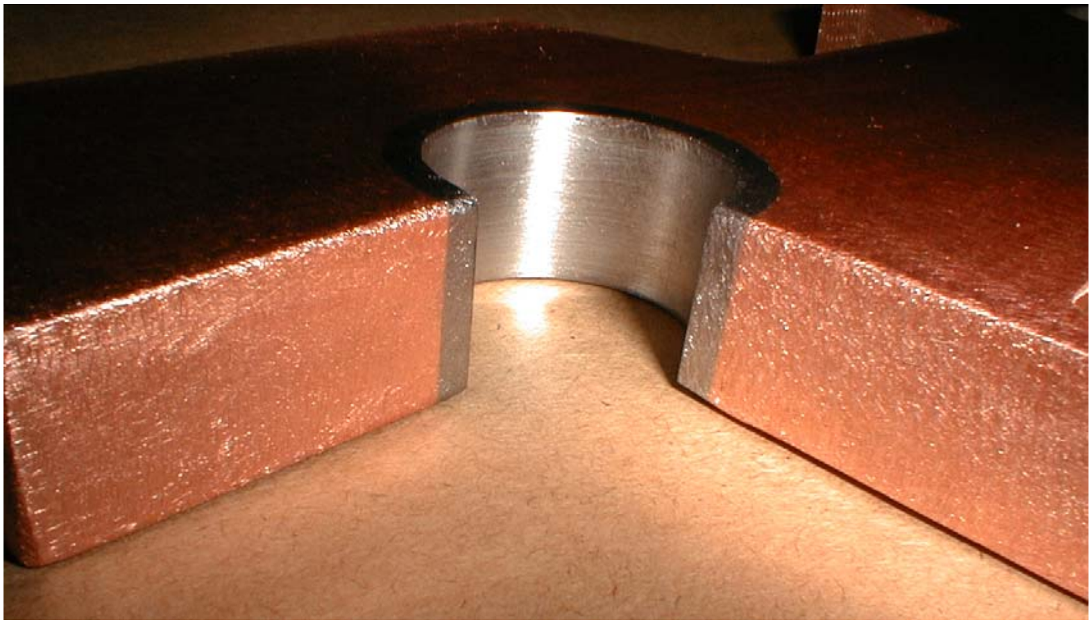

Figure 3: Cut Sample from Production Casting.

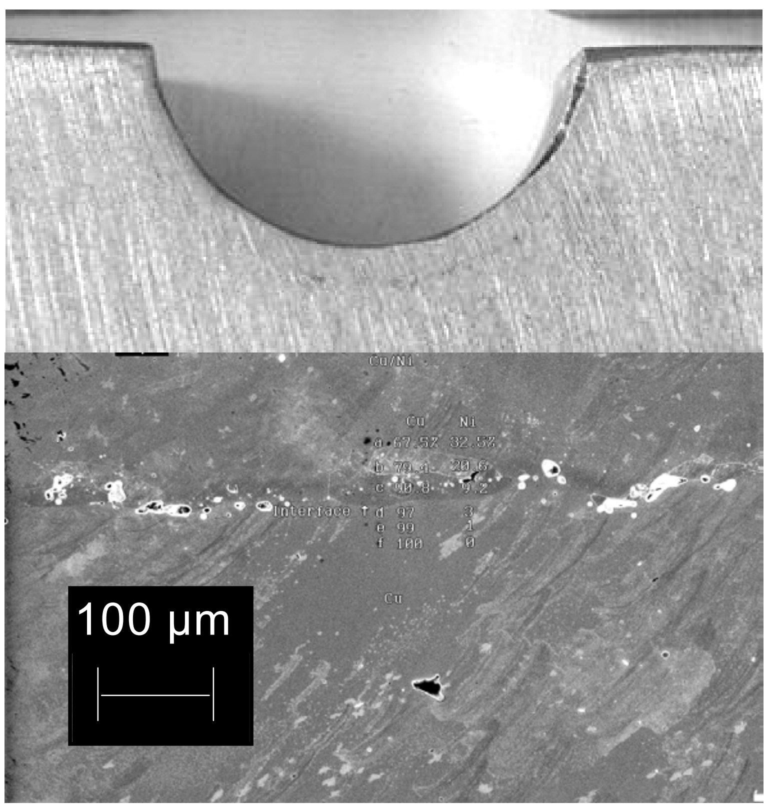

Figure 4: SEM for Interface of Cast Copper to CuNi Pipe.
The CuNi pipe is on top, and the cast copper is on the bottom.

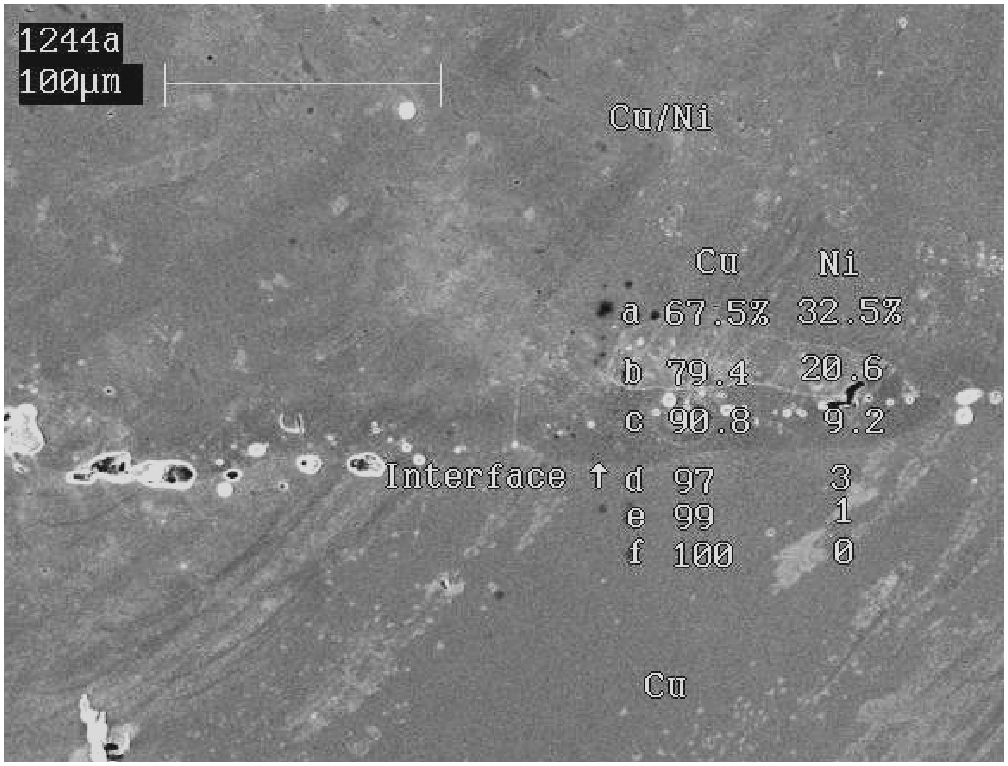

Figure 5: Enlarged SEM for Interface of Cast Copper to CuNi pipe (Enlarged Scale). The CuNi pipe is on top, and the cast copper is on the bottom.

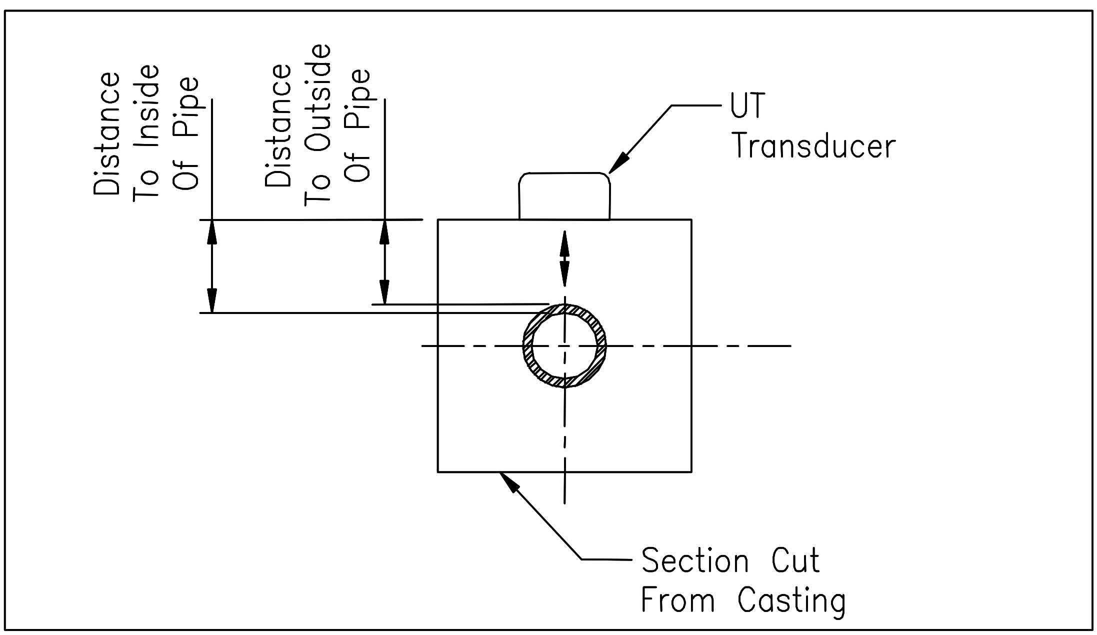

Figure 6: Ultrasonic Testing Arrangement for Cut Samples.

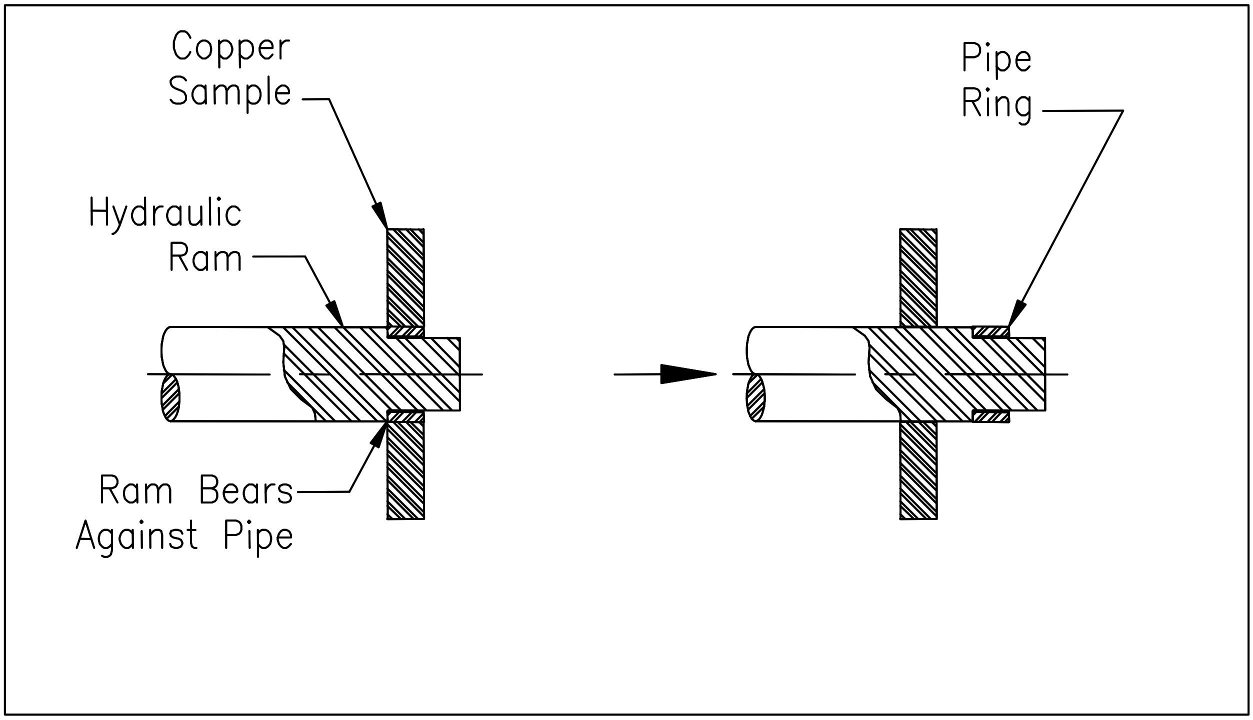

Figure 7: Hydraulic Ram Test of Cut Samples.

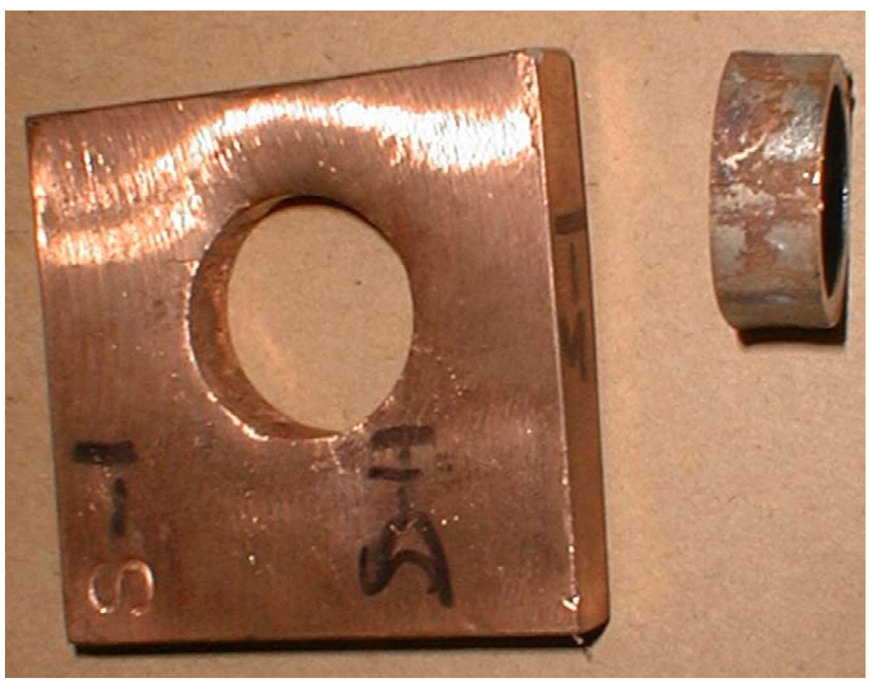

Figure 8: Hydraulic Ram Test, Sample with Monel Pipe.

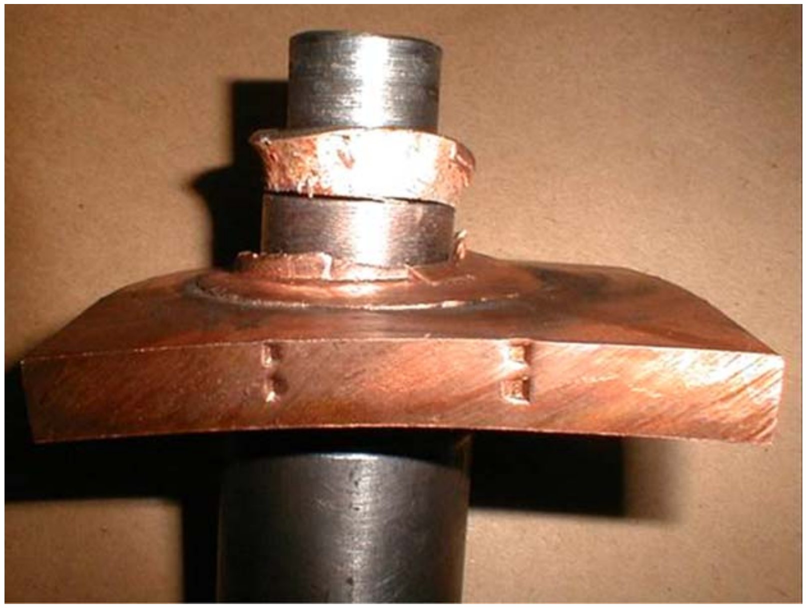

Figure 9: Hydraulic Ram Test, Sample with Copper-Nickel Pipe.

Production Castings

A sample layout for an EAF wall is shown in Figure 10, with a typical casting shown in Figure 11.

Cast copper blocks with copper-nickel pipe are currently installed and operating very well in the following locations:

- EAF wall panels
- Blast furnace staves
- EAF burner panels
- Smelting furnace upper walls, roofs, and critical slag bath areas
- Slag launders

Benefits

The many benefits of the UltraLife™ copper castings include the following:

- Greater layout flexibility with the pipe coil compared to drilled and plugged water passages
- Low pressure drop with the smooth curves
- Deep face pockets for excellent slag retention
- Leak proof design without welded plug
- Heat loads in excess of 150,000 BTU/ft^2/hr, without distortion
- Excellent heat transfer
- Low cost when priced on a per heat or per ton basis

Conclusions

No single cooling system is suitable for all applications (leak potential, cost, slag retention, heat load, etc.). For many situations, copper castings with an internal pipe coil have proven to be a very effective solution. UltraLife™ copper castings are in service in several EAF's, as well as smelting furnaces and blast furnaces. These innovative castings incorporate new technology for bonding the cast copper to the cast in pipe coil.

Continued testing of production castings points to the ability to consistently produce high quality castings with the copper-nickel pipe well bonded to the cast copper.

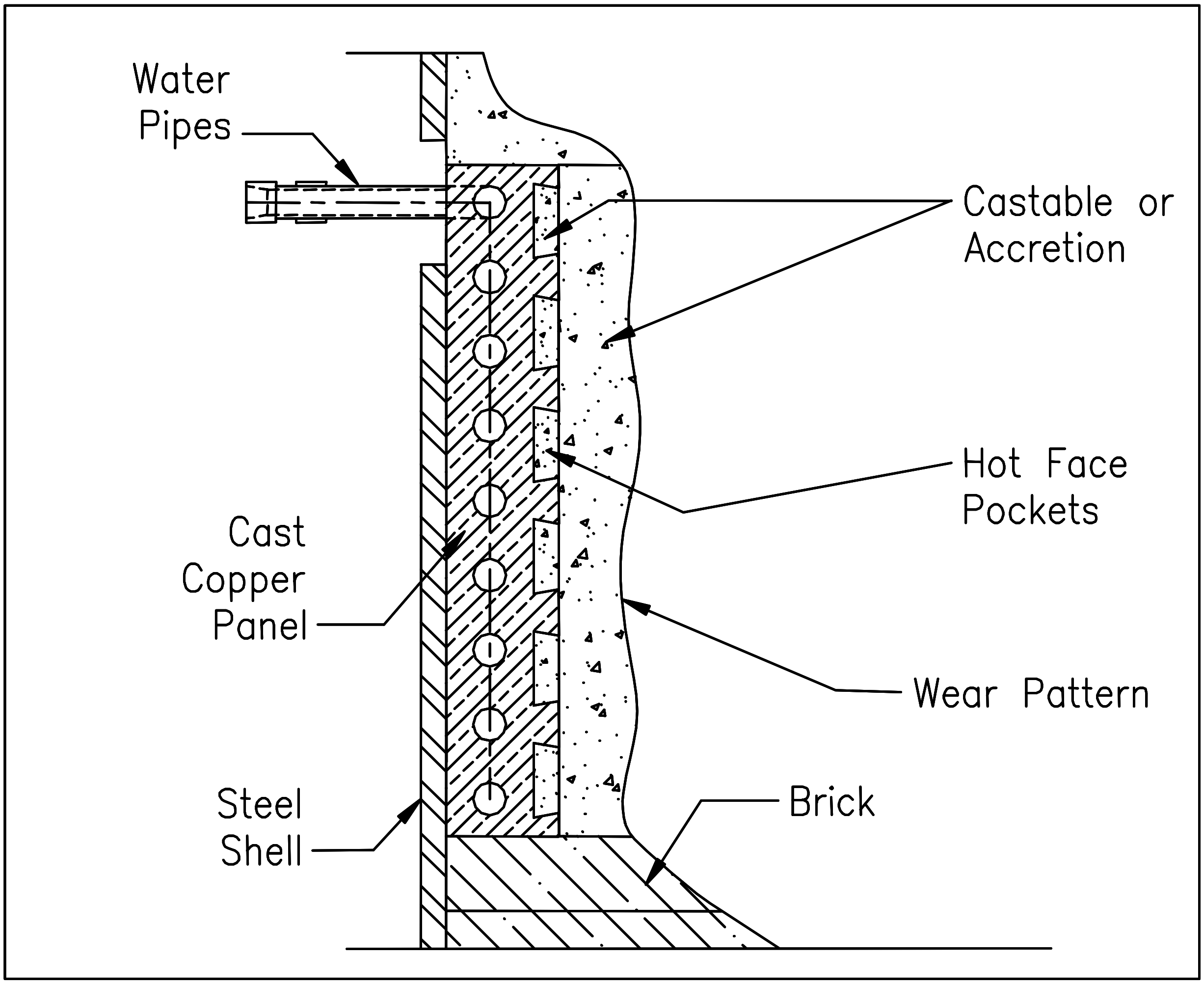

Figure 10: Furnace Arrangement for Cast Copper Cooler.

Figure 11: Sample Cast EAF Wall Panel (Courtesy Falcon Foundry).

References

1. A. MacRae, "Pipe Coil Selection for Cast Copper Cooling Blocks", Sulfide Smelting 2002, TMS Annual Meeting, Seattle, Washington, 17-21 February 2002.
2. A. MacRae, "New Technology for the Manufacture of Cast Copper Cooling Blocks", ISS 59th Electric Furnace Conference, Phoenix, Arizona, 11-14 November 2001.