IMPROVED CONTROL FOR ALUMINUM HOLDING FURNACES

Aluminum holding furnaces can offer a considerable challenge for combustion and control system design. The furnaces often require a significant gross heat input for bringing metal to temperature for tapping while requiring only minimal heat input for actually holding the metal at temperature. This can be a major concern in a melter/holder used for a casting process.

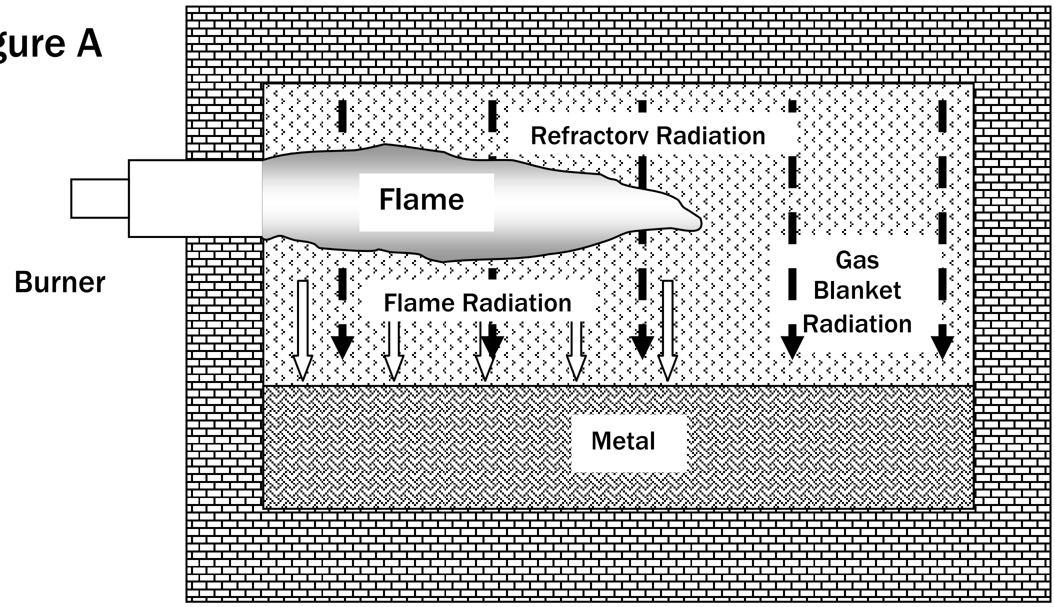
In an aluminum holding furnace, the goals are to hold the metal at the desired temperature, consume as little fuel as possible, avoid dross formation and keep the metal temperature uniform. Achieving all these goals can be difficult especially in furnaces that also have a melt cycle or holders that have long holding periods before casting. Often this process requires the holder to hold the metal at a reduced temperature until just before casting. Then the metal temperature is raised for processing. This reduces fuel consumption and the potential to form dross. In both cases the challenge is to have a system with an efficient heat cycle and great enough turndown for holding and still maintain uniformity.

An efficient operation uses all the surface area available for transferring heat to the metal bath. In a holder only application this would be the surface area of the bath. In a melter/holder the surface area would vary with the point of the cycle. During the melting phase considerable more surface area is available for heat transfer due to the exposed solid metal pieces. As the pieces melt and the metal level rises the scrap pile will be submerged and the heat transfer area is again reduced to the bath surface area. In designing a combustion system for furnace that functions primarily as a holder it is necessary to design for efficient operation in the flat bath condition.

Figure A shows the heat transfer mechanisms in a flat bath holder. In most holding applications the radiation heat transfer from the wall and roof refractories to the bath surface is the dominant source of heat to the metal. This can be in the area of 90-95% of the heat transferred. The other sources of radiated energy and convection although useful at times in the furnace cycle are not major contributors to the overall energy transferred during an efficient furnace cycle.

The combustion system must supply sufficient heat to raise the refractory temperature uniformly so that it radiates to the bath surface uniformly. To do this the burners must circulate gases evenly through out the furnace. Good circulation insures an even gas blanket and uniform radiation to the surface of the bath and thus equal heat transfer without areas of elevated temperature. This significantly reduces the potential for dross formation and subsequent metal loss.

Figure A



Care has to be given to burner selection. During the period that the burners are on high fire the radiation from the flame to the bath can be significant. The burner heat release pattern and location must be such as to avoid impingement of hot unburned gases on the bath or the formation of localized hot spots. These conditions can provide greater heat transfer to the metal but also increase dross formation and the potential for gas pick up in the metal. (Burner selection is a separate subject that is dependent on furnace design and operation.)

If the combustion and control system can provide a uniform radiating source than the condition of the bath surface dictates the heat transfer efficiency. A surface with minimum skim/dross will allow the greatest transfer of heat, uniformly.

Systems capable of high calorific inputs need to supply the turndown necessary to maintain the metal temperature during the holding or casting periods without additional excess air to eliminate temperature creep. This additional excess air increases fuel consumption as well as the potential for dross formation. Many of these systems use cascade control logic to achieve the high turn downs necessary while maintaining temperature uniformity and efficiency.

Figure B is a schematic showing a system with two forms of cascade control – cascade temperature control and cascade burner control.

Cascade Temperature Control

Heat transfer requires that there is a temperature difference between the source and the receiver. In a holder that means the refractory must be heated above the metal temperature in order for the transfer of heat to occur. Once the refractory temperature is elevated it does not cool rapidly. Therefore even when a combustion system is shut off there continues to be energy transferred to the metal from the refractory. This is often referred to as a “flywheel affect”. In a system that needs to heat up quickly (or has a melt cycle), the refractory temperature can be raised significantly to increase the heat transfer rate. As the metal comes to temperature, the burners cut back or go off. The refractory is still above the metal temperature so energy is still transferred to the metal causing the metal to exceed the desired set point. This can cause significant over heating of the bath surface increasing the potential for dross formation and gas pick up. In addition the fuel consumption of the furnace increases unnecessarily.

To avoid this “fly wheel” affect and the subsequent over heating a two loop temperature control system can be used.

Control **Loop 1** monitors the metal bath temperature and varies the 4-20ma output based on the difference between the metal temperature and the set point programmed in the control loop. If the metal is above set point, then the output is 4ma. If the bath temperature decreases below the set point, the output increases to a maximum of 20ma.

The output from **Loop 1** goes to **Loop 2** and is the set point for **Loop 2**.The process variable for **Loop 2** is the roof temperature. The output from control **Loop 2** drives the burner firing rate control element (example the air valve.)

The 4-20ma input from **Loop 1** is scaled by the **Loop 2** controller. A 4ma input would be a set point of 1300F (704C) and a 20ma input would be a set point of 2000F (1095C). Therefore the roof operating temperature will vary based on the metal temperature. If the metal temperature is low, the roof temperature would be driven up to increase temperature. As the metal comes closer to set point, the roof set point would be decreased. This would decrease the burner firing rate so that as the energy from the refractory is transferred to the metal there is no source to replenish the lost energy in the refractory. The refractory cools down as the metal approaches the set point. When the metal reaches the set point the refractory is at a lower temperature minimizing the “fly wheel affect”.

Successful application of cascade temperature control requires correct thermocouple placement. The bath temperature control thermocouple cannot be set to deep in the metal pool. If it is too deep to be affected by the increase in furnace temperature with in a reasonable time, then tuning the two loops becomes very difficult. A TC placement in the bath of 6-8” below the surface usually allows good performance.

Placement of the roof TC is also important. The roof control loop must operate faster than the bath control loop. If the roof TC is recessed to far into the refractory changes in the roof surface temperature will not be sensed fast enough. It is the temperature difference between the roof surface and bath surface which controls the heat transfer. Therefore the roof TC should be recessed approximately ½” (10mm) from the surface.

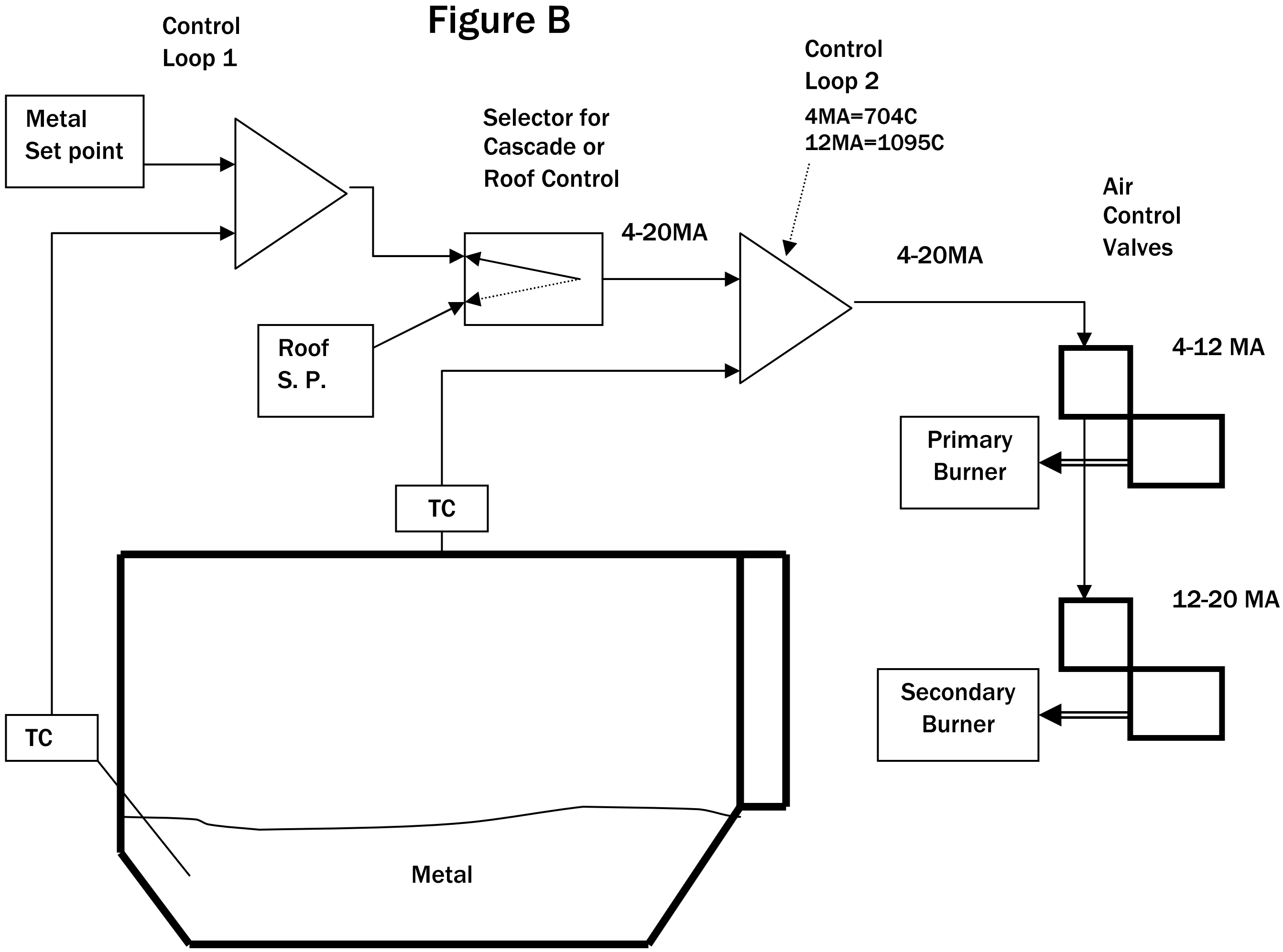
Burner Cascade

Figure B shows the output from control **Loop 2** going to the air control motors on Burner 1 and 2. The 4-20ma signal would drive both motors simultaneously with each of the motors being spanned for a different operating range. (This spanning could also be done in the controller using 2 output signals to the drive motors.)

The primary or holding burners would be set so a 4ma signal would drive the motor to low fire or the minimum input the burner can operate at. As the demand for heat increases, the 4ma signal would increase driving the burner firing rate up. At 12ma the burner would be at it's high fire or maximum input condition. As the controller output increases to 20ma this burner maintains the maximum input.

The secondary burner would be scaled so that from 4ma to 12ma the burner stays at minimum input (in many cases this is the off position). When the drive signal from control **Loop 2** increases above 12ma, the secondary burner firing rate increases. The maximum input being at 20ma. With a 20ma control signal both burners are at the maximum firing rate.

Figure B



Cascading the two burners and shutting the secondary burner down when the control system is below a 12ma signal increases the turndown of the burner system. The turndown can easily be increased from 7:1 to 14:1 and with proper burner selection 20:1 is not a problem. This means the system can provide efficient and timely heat up cycles while maintaining holding periods with minimum excess air and no over heating.

Using two burners and shutting one off during holding periods means the burner left firing must operate at a higher input. This increases the velocity and mixing action of the POC's from the burner. This provides much better circulation and refractory temperature uniformity.

Shutting one burner down and forcing the holding burner to a greater firing rate forces the heat down the furnace away from the burner wall. Using two burners for holding at low fire increases the heat release at the burner wall with little push down the furnace. This increases the potential for localized over heating at the burner wall and the potential for increased dross formation and possible refractory wear problems.

With proper burner selection and implementation of a cascade control system holders as well as melter/holders can operate efficiently and provide excellent control of the metal temperature.

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