Improving Aluminum Furnace Performance while Processing Uneven Loads with Adjustable Ratio Control

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In June of 1970, SECO/WARWICK under the previous name of Sunbeam Equipment Corporation received the original patent for the conventional ratio control system. This system was the hallmark of temperature control systems for the past thirty years. However, there have been problems encountered in the annealing or homogenizing of coiled material, specifically light aluminum sheet materials. Because of the requirements of the annealing cycle and the characteristics of the material in the coil form, the conventional annealing furnace with a standard controls package has been adequate at best within a multi-zoned furnace with different size coils. Generally, the heat processing cycle requires that the temperature of the aluminum be elevated to a temperature, between 700°F to 1000°F, and soaked at that temperature for a fixed period of time. It is important that the material not be heated higher than the target temperature as this could cause detrimental conditions to the metallurgy. Accordingly, it is the objective to heat the material to the target temperature as quickly as possible and maintain this temperature for the desired soak period.

The United States Patent and Trademark Office issued SECO/WARWICK Corporation patent US 6,609,906B1 on August 26, 2003 for this Adjustable Ratio Control System and Method. This advanced patent generally relates to heat processing of coiled aluminum sheet in a multi-zoned furnace with uneven loads. However, the system can be effectively applied to other applications. Most importantly, the system provides for accurate temperature control and uniformity when varying loading conditions exist.

Much of the aluminum provided today is in the form of large coils. While aluminum is essentially a good conductor of heat, it has been found that the coiled aluminum presents serious problems as far as conducting heat from the exterior to the interior portions of the coil. The adjacent layers of aluminum present obstacles to conduction of heat radially through the coil. In some instances, there will be small air spaces, which effectively insulate the adjacent layers of the coil and inhibit the heat transfer. Because the interior of the aluminum coil is more or less insulated from the exterior, it has been found to be very difficult to raise the temperature of the entire coil equally to the desired target temperature. If the heating is performed too rapidly, the interior of the coil could severely lag behind the exterior temperature of the coil.

In operation, the ratio temperature control program moves the active load setpoint, at the rate in the recipe step, toward the load setpoint as defined in the recipe steps. The active load setpoint is the temperature that all of the load thermocouples in each of the zones within the furnace are to reach. The control system calculates (using the formulas listed below) both an east and west air setpoint for each fan zone. When the zone air temperature is less then the zone air setpoint, there is a call for heat in that specific zone. If the zone air temperature is above the zone air setpoint, there is a call for cooling in that zone. When the zone is satisfied, no heat is applied.

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If the calculated zone air setpoint is greater then the recipe air limit setpoint, as is generally the case early in a typical cycle, when the load is cold, the air limit setpoint becomes the zone air setpoint. The calculated zone air setpoint uses the ratio value from the temperature control recipe to develop the maximum allowable air temperature to bring the zone load thermocouple to the zone load setpoint in the shortest period of time, while preventing load temperature overshoot.

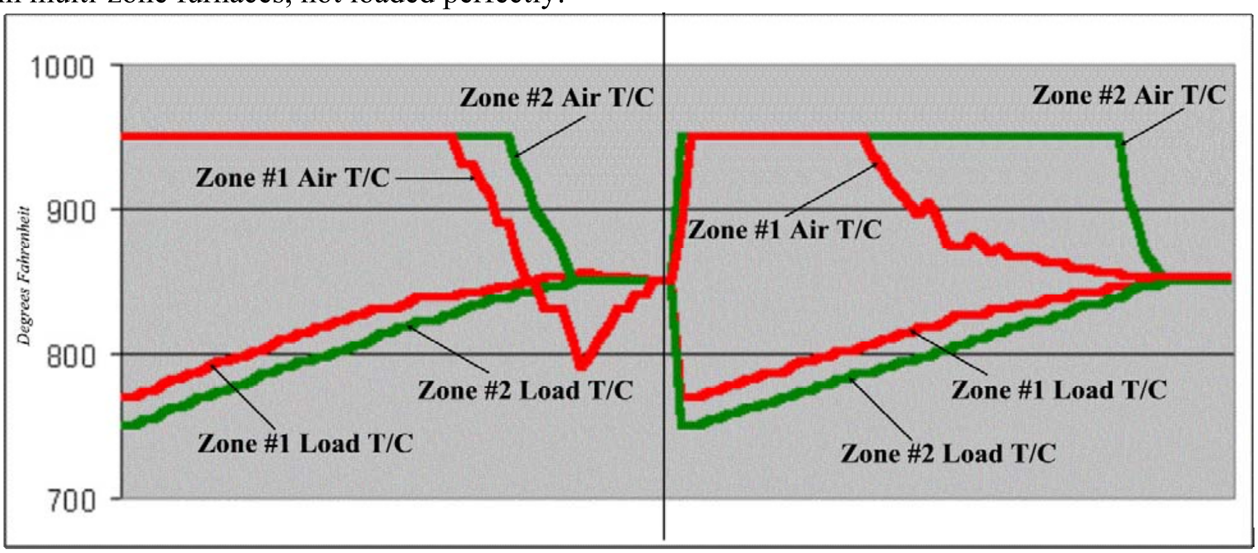
The formula for the zone Air setpoint is as follows:

Air setpoint = (Load SP – Load Temp) (ratio) + Load SP

The formula for the zone Air setpoint is as follows:

F1 = (Load SP – Load Temp)/(Load SP – Coldest Load Control Temp)
For an adjustable ratio of 0, F = 1
For an adjustable ratio of 1, F = F1
For an adjustable ratio of 2, F = (F1) (F1)
For an adjustable ratio of 4, F = (F1) (F1) (F1) (F1)
Air SP = (Load SP – Load Temp) (ratio) (F) + Load SP

The adjustable ratio control system provides improved temperature control and cycle reduction in multi-zone furnaces, not loaded perfectly:



Conventional Ratio **Adjustable Ratio**

Conventional Ratio
Zone Air SP = Work SP + Ratio (Work SP – Zone Work Temp)

Adjustable Ratio
Zone Air SP = Work SP + Ratio (F) (Work SP – Zone Work Temp)

Where

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F = 0.1 to 1 based on the difference between the coldest work temp, the work SP and the selected work temp and work SP.

With the adjustable ratio, the slowest zone will be entirely unaffected by this system. However, a zone that may be heating too fast and in danger of overheating, will be detected early. In this case, the ratio for that specific zone will be automatically reduced. This reduced ratio will lower the zone air set point, resulting in the zone approaching the work set point together with the slowest zone. This should allow all zones in a multi-zone furnace to reach work set point at the same time.

With this system and when there is no difference between the zone work temperatures, the value for F would be 1, thus allowing both zones to utilize the higher, or conventional ratio number. With conventional ratio, if a zone work temperature goes over the work set point, it may take an extended period of time to bring it back down. The resulting lower air temperature in this zone may depress adjacent zone air temperatures, thus delaying all zones reaching work set point.

This system may allow for higher ratios to be used, as the ratio is selected as the greatest number that would minimize the chances for work over heating, generally on the hottest load. Likewise, higher head temperatures may also be considered.

About SECO/WARWICK's Aluminum Furnace Group

SECO/WARWICK has been involved in the design development and manufacture of aluminum heat processing equipment for over 40 years. The Aluminum Group provides precision engineered equipment for annealing, log homogenizing, ingot heating, solution heat treating, stationary and tilting reverbs, central melt and holding furnaces. The Group sponsors the Aluminum Furnace Seminar twice a year in April and October which provides in-depth information on improving efficiencies and methods to minimize waste and conserve energy through a review of the fundamental principles involved in heat transfer, heating systems, protective atmospheres and process controls. For more information, please visit our website at www.secowarwick.com.

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