GPLUS No.:

Title: Glass Coating Enhancement

User Organization: Marble King
PO BOX 195
Paden City, WV 26159

UserContact: Beri Fox

ORNL R&D Staff: Craig Blue
(865) 574-4351
blueca@ornl.gov

Other Partners:

Relevance to OIT:

This project involves the infrared processing of glass and is relevant to industries involved in heat treating, coating or annealing of glass products.

Background:

Presently, glass marbles are being coated with Tetraisopropyl Titanate (TIPT) to enhance the marbles esthetics. The process incorporates heating of the substrates followed by room temperature aspiration of the TIPT onto the heated substrates. The Glass Technology Roadmap identifies the following needs, "increase yield/decrease rejection rate of product", "use of process heat", and "increase throughput and waste minimization". Heating is presently the rate-limiting step and is not fully characterized. In some instances the substrates crack upon heating.

Objective:

This goal of this project is to fully characterize the heating and coating process at Marble King. Once completed and implemented, this work will result in decreased energy usage through: optimization of heating, improved heating technology, and reduced scrap.

Experimental:

Currently marbles of various shapes and sizes are being heated, in a resistance furnace, to the coating temperature of 1050°F-1100°F. Upon reaching the coating temperature the marbles are sprayed with TIPT and dropped into a bucket to cool. Prior work at Marble King has shown that, although the boiling point of the TIPT is 450°F, it is necessary for the marbles to be at least 1000°F for the coating to be uniform.

Characterization of the heating process was carried out to identify the heating time and the uniformity of heating within the furnace for several different marble types. Further characterization was made on the cooling and tempering process. Once the characterization of the heating and cooling processes was complete, the elements of the process that could be improved upon were identified and tests were carried out to characterize the new methods.

Throughout all of the tests, the furnace and marble temperatures were measured using thermocouples attached to a data acquisition and storage device. This data was then used to typify the heating process. A similar method was used to typify the cooling characteristics; two thermocouples were placed at different locations within the cooling bucket and the time and temperature data was recorded.

Once the heating and cooling characterization was complete, it was determined that the heating process could be aided by using an infrared furnace to heat the marbles. The infrared furnace used was a 90kW, 24” x 24”, flatbed, drop-bottom furnace on site at Oak Ridge National Laboratory (ORNL). The furnace consists of a water-cooled reflector with 36- 100 W/linear inch lamps, 25 inches long.

Results:

Several tests were conducted to determine the heating rates of the different marbles in the resistance furnace currently being used at Marble King. shows a typical heating curve for marbles heated in the resistance furnace, a summary of the tests by marble type can be found in Table 1 below. Special note should be taken that the times listed for the resistance furnace include a preheat time of 1-1/2 to 2 minutes at about 150°F to prevent the marbles from cracking. It was not necessary to preheat the marbles in the infrared furnace because the output of the infrared furnace was controlled in order to prevent the marbles from cracking.

From the tests in the resistance furnace at Marble King it was learned that the heating rate was nearly independent of marble shape, size and color. This is in strong contrast to the results obtained from the tests using the infrared furnace where the black marbles tended to heat up more quickly due to a higher absorptivity. However, due to the nature of the controller on the infrared furnace, the heating rate could be constrained to prevent cracking and overheating.

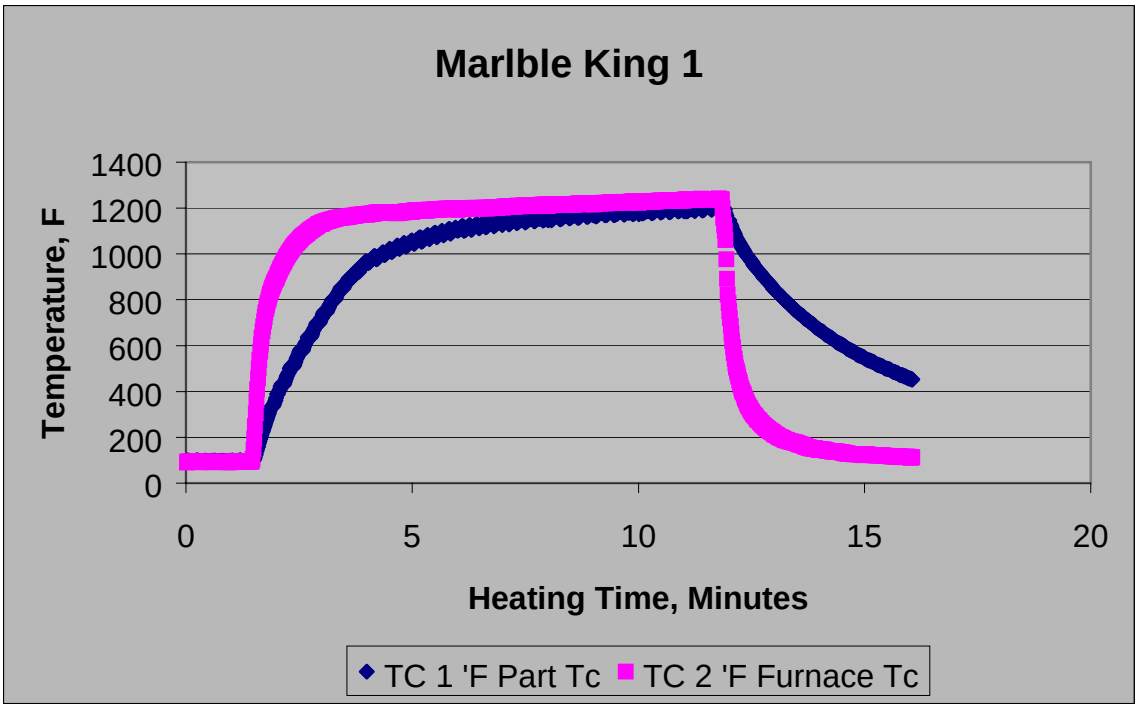

Figure 1 A typical heating curve for marbles processed in the resistance furnace at Marble King.

Table 1 Comparative summary of heating times for the different marbles using the resistance furnace at Marble King and the infrared flatbed furnace at ORNL.

Color			Clear				Black	
Size			1 inch		½ inch		1 inch	½ inch
Shape			Flat	Round	Flat	Round	Flat	Flat
Furnace Type	Resistance	Temp (°F)	1220	952	1137	1077	1152	1186
		Time (min.)	11.8	5.7	11.2	10.5	11.4	11.5
	Infrared	Temp. (°F)	1100	----	----	----	1100	----
		Time (min.)	6.4	----	----	----	5.6	

The data collected from the cooling tests show a 300°F gradient between the front and the back of the cooling bucket (Figure 2). It was determined that more even cooling and annealing of the marbles would be possible if some method for stirring the marbles or rotating the bucket were used as the marbles are dropped into the bucket.

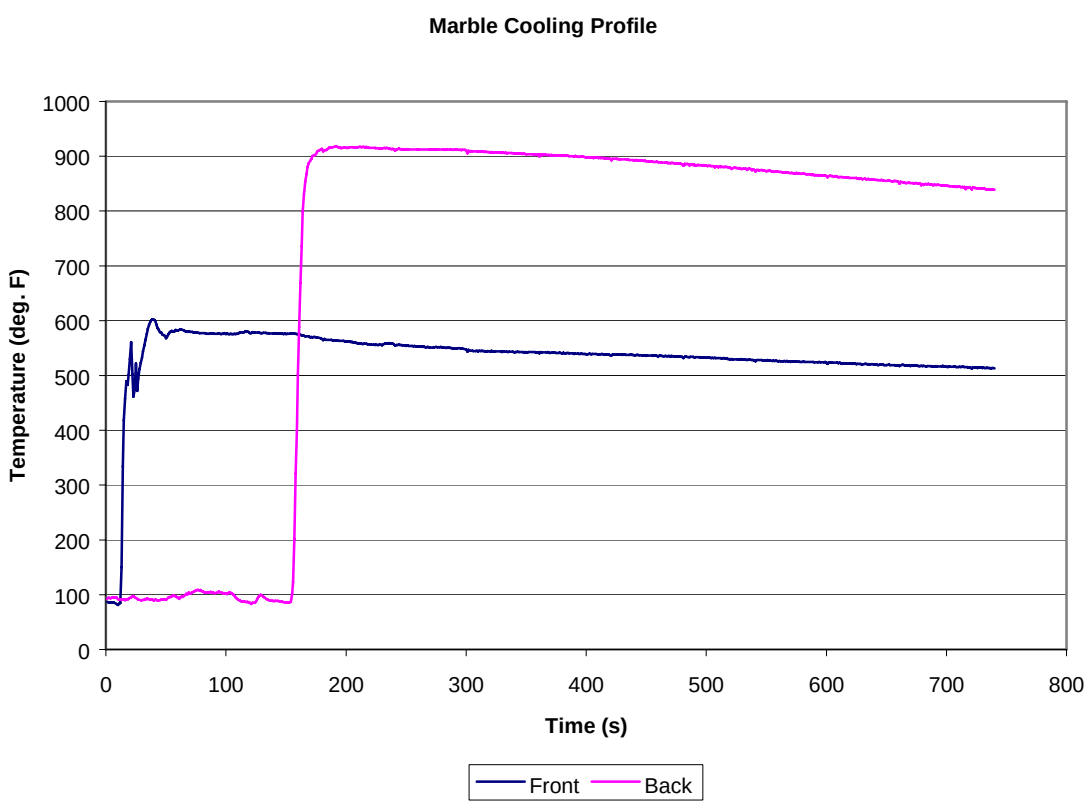

Figure 2 Cooling time and temperature data as marbles are dropped into the cooling bucket. It is important to note the difference in temperature between the front and the back of the bucket.

Conclusion:

Use of an infrared furnace to heat the marbles to the processing temperature decreased the cycle time by nearly half. Additionally, the thermal control established by the use of a direct heating method resulted has the potential to reduce scrap by preventing overheating and by insuring uniform batch-to-batch heating. Implementation of a rotational system on the cooling bucket is expected to result in a large reduction in the scrap that was the result of uneven cooling and poor annealing

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Future Work:

Future work is expected to include the possible implementation of an infrared furnace at Marble King, justified by the expected increase in productivity and the decreased energy usage. Future work will also include the implementation of a rotational system on the cooling bucket as well as an analysis of the scrap reduction involved with the installation of the rotational system.