Simplified Temperature Uniformity Surveys Utilizing Ceramic Technology for the Metals Industry

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Heat treaters have been searching for ways to simplify furnace temperature uniformity surveys. Using proven technology developed in the ceramics industry, this is now a reality. With emphasis today on the importance of meeting the requirements of AMS 2750D, CQI-9 and Nadcap, the heat-treating, brazing and sintering industries now have a tool to help them focus on the uniform and efficient delivery of heat to their products to ensure consistent and repeatable quality.

For many years the ceramics industry has known that predictable shrinkage can be obtained by various nonmetallic, inorganic materials when exposed to a known amount of thermal energy. This technology offers a simple, economical option for the measurement and recording of temperature (Fig. 1). Various types of ceramic temperature-measurement devices are in common usage throughout the ceramics industry.[1]

**Product Development for Heat Treating, Brazing and Sintering**
Starting from product mixes known to work in the ceramics industry, various blends of inorganic materials were developed and tested to determine the best fit for the rapid heating and cooling cycles utilized in the metals industry. Also necessary was the investigation of the various furnace atmospheres used in the heat-treating, brazing and sintering industries, including air, various hydrogen/nitrogen mixtures, endothermic and exothermic gas and even gases used for vacuum partial-pressure and high-gas-pressure quenching (up to 20 bar). Material selection also took into account the need to prevent contamination of the work or the furnace from an atmosphere with unwanted contaminates released from inorganic compounds. As a result, a number of blends of materials were investigated and an optimum mix selected to give the best performance over the wide range of temperatures necessary to meet the requirements of the metals industry. The ceramic-disc product developed is called a TempTab®.[2]

Once the blends were established, the size and shape of the measurement device was carefully chosen to provide ease of use and to maximize its ability to withstand the thermal shock of rapid heat-up and quench rates (Fig. 2).

Dry pressing was the forming method of choice due to the ability to control size and density of the finished piece. Once pressed, the product is further dried to remove processing water and then calcined.
to remove the binder used during forming, bound-chemical water and other volatiles, resulting in a product with no contaminant evolution on subsequent exposure to temperature. Each batch is then analyzed to develop a unique temperature look-up table (Fig. 3) to account for the shrinkage characteristics in the raw materials.

The ceramic-disc location within a load or furnace can be marked with an identifier simply by using a high-temperature marking pen or in many cases a Sharpie®. Once the heat-treating process is complete, the discs are collected and measured (in millimeters to two decimal places) using a digital micrometer and a gauge fixture (Fig 4).

The measurements are taken across the widest dimension of the disc and then converted to a TempTab temperature using the look-up table supplied with each batch. The accuracy of temperature can be measured within +/−10°F (5.5°C). Therefore, variations in temperature within the furnace can easily be detected and quantified. TempTab discs have been successfully tested in mesh-belt conveyor furnaces (Fig. 6). They have also been used for brazing steel, stainless steel, copper and even brass alloys in various atmospheres, including dissociated ammonia and various nitrogen/hydrogen atmospheres supplied from cylinders, tube trailers and cryogenic tanks.

These ceramic shapes have been tested in integral-quench furnaces, which were hardening, carburizing and carbonitriding gears and other types of critical components. They are used to provide an indication of the uniformity of temperature within a large batch load. Ceramic discs are well suited to the sintering of Brass, Copper and Stainless Steel, also used for brazing steel, stainless steel, copper and even brass alloys in various atmospheres, including dissociated ammonia and various nitrogen/hydrogen atmospheres supplied from cylinders, tube trailers and cryogenic tanks.

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placed on the belt alongside the product as it was going through the furnace (Fig. 8). The dwell time in the furnace was approximately 40 minutes with the parts being exposed to maximum temperature for approximately 10 minutes. Depending on belt width, either two or three discs were placed on the belt – left side, right side and center, if necessary. Once through the process, the discs were measured and the look-up table used to determine the maximum (peak) temperature they were exposed to as a function of location.

As expected in a well-run operation, the temperature uniformity of many of the furnaces was relatively close, within ±10°F (5.5°C). These tests revealed, however, that several furnaces had large temperature differences across the belt, in one case as much as 122°F (50°C). Finding this large difference told the process engineer he needed to immediately work with his maintenance group to find and correct the source of the temperature variation, and he alerted the quality engineer to conduct more extensive testing of product being produced from those specific furnaces.

Running discs at the beginning of every shift provided a record of the thermal energy being applied to the product, and this was used as a diagnostic tool to locate problems. The use of this product can alert personnel to a problem with temperature or assist when trying to solve problems with higher than normal reject rates.

**Case Study 2 – Brazing of Stainless Steel**

Product-contamination tests were conducted on small stainless steel components run on graphite boards through mesh-belt conveyor furnaces in which the operating dew point of the dissociated-ammonia atmosphere was in the -50 to -60°F (-45 to -50°C) range. In addition to determining the peak temperature achieved during the brazing operation, part contamination was carefully evaluated using X-ray photoelectron spectroscopy (XPS). This analysis method revealed that the TempTab discs did not cause any type of part surface contamination to occur.

**Case Study 3 – Annealing of Stainless Steel**

Ceramic discs were tested in a commercial heat-treat facility in a vacuum furnace dedicated to bright annealing of stainless steel automotive parts. The discs were run along with survey thermocouples attached to a data logger at several temperatures, and the resulting data showed good correlation against thermocouple readings. The discs were wired in place in and around the parts in a stack of five wire trays used to hold the parts to be annealed. The batch furnace was brought to temperature and the parts were loaded into the vacuum chamber. Once evacuated, the parts were exposed to temperatures of 1740°F (950°C) for three hours.
The temperature was quickly lowered using a 2-bar nitrogen quench. Temperature differences were identical from both testing methods, and a 30°F differential was found from one location to another.

Case Study 4 – Hardening of Tool Steels
Tests were run in two identical single-chamber batch vacuum furnaces processing M-series (M2, M3 Type 1 & 2, M7, M42), T-series (T-1, T-15) and specialty tool steels (ASP 23, ASP 30, CPM M4, REX 23, REX 76) at temperatures between 2050°F (1120°C) and 2315°F (1270°C) to check disc integrity as a function of pro-
cess recipe, load configuration, ramp rate, partial-pressure settings, austenitizing temperature and quench severity (5- and 6-bar nitrogen). The discs were unaffected by changes in any of the process variables. The results from these tests proved that running a temperature uniformity survey before its scheduled date was unnecessary, and a good correlation was achieved with the two load thermocouples routinely run with each workload.

Case Study 5 – Sintering of Powder Metal
A major producer of automotive powder-metal engine components ran tests to check the side-to-side temperature uniformity as well as peak temperature values in multiple mesh-belt conveyor furnaces having both open-chamber and muffle-type designs. The impact of delubrication and changes in furnace-atmosphere dew point as a function of location within the furnace were evaluated. The discs were unaffected, and comparison to standard temperature uniformity surveys showed excellent correlation.

Conclusion
The importance of temperature control in the heat-treatment, brazing and sintering industry cannot be overstated. Furnace temperature uniformity surveys have and always will be necessary, but they have never been as simple as now. TempTab® discs offer the first truly simple and affordable way to monitor thermal processing on a daily basis. Early detection of problems allows more time for thought as to the best path for corrective action and promotes preventative maintenance.

Although these discs are not a complete replacement for temperature uniformity surveys, they are very capable of providing a record of the temperature history within a furnace without interrupting production schedules and without incurring additional cost. IH

References
1. The Edward Orton Jr. Ceramic Foundation (www.ortonceramic.com)
2. TempTab® ceramic discs (www.temptab.com)

For more information: Contact Jim Litzinger, director of business development for The Edward Orton Jr., Ceramic Foundation, 6991 Old 3C Highway, Westerville, OH 43082; tel: 614-895-2663; fax: 614-895-5610; e-mail: info@temptab.com; web: www.temptab.com

Additional related information may be found by searching for these (and other) key words/terms via BNP Media SEARCH at www.industrialheating.com: temperature uniformity survey, AMS 2750D, Nadcap, annealing, hardening