Utilizing Modern Technology to Optimize Shell Drying

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ABSTRACT

Shell drying is an important aspect of the investment casting process. Over or under drying can result in various issues related to casting quality. In the past, shell dryness was difficult, if not impossible to measure, which resulted in casting quality variations.

Building on a newly created method for measuring shell dryness, it is now possible to measure temperature and relative humidity of the shell during the dipping and drying process using wireless technology. This provides the opportunity to monitor shell dryness in real time and as necessary, modify the process to achieve optimal shell dryness.

This paper will provide a case study on how this technology was used to improve casting quality at FS Precision Tech.

INTRODUCTION

The 2012 ICI paper titled, "A NEW METHOD FOR MEASURING DRYNESS DURING THE SHELL BUILDING PROCESS,"[i] introduced an innovative method of measuring mold dryness during the shell building process. Using a strategically located sensor, the environmental conditions of the mold can be measured in the area around the sensor. The collected data allows the user to quantify the level of dryness achieved during the shell building process.

TECHNOLOGY OVERVIEW

Figure 1: Photo of Sensor and Protective Cap

The original design consisted of a relative humidity and temperature sensor, a cable and a data logger. The data logger was encased in a waterproof box with waterproof connections. The sensor, enclosed in a cap, was protected from the slurry by a waterproof, breathable fabric membrane that allowed the vapor to cross the barrier while preventing moisture from penetrating. The sensor cap, measuring 3/8" in diameter and 1" long, was placed in the mold location where the temperature and relative humidity was to be measured. The photos below are just a few examples of where the sensor can be located.

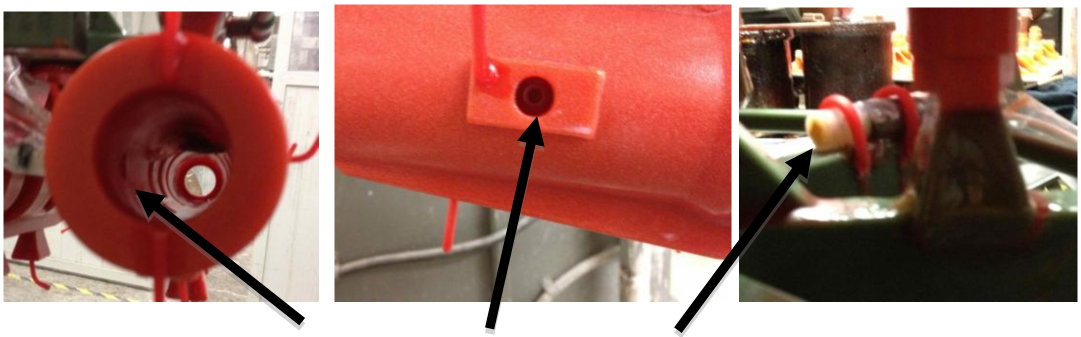

Figure 2: Sensor Location Examples

The data logger measured and logged the environmental conditions of the sensor location over the course of the shell building and drying process.

The chart below shows an example of the data gathered using this technology. In this example, two sensors were placed on the same mold but in different locations.

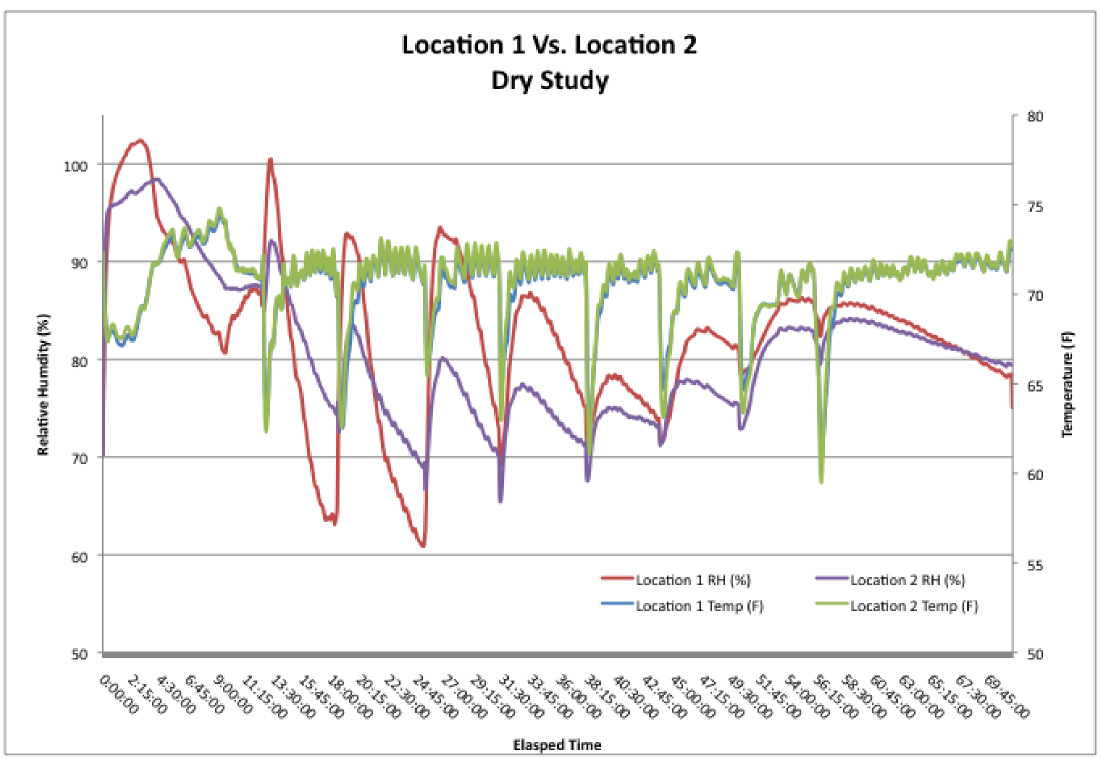

Figure 3: Dry Study with 2 Sensors on Same Mold

It is interesting to note that the mold temperature between the two sensors is very similar, even though the relative humidity varies between the two. As discussed in the 2012 paper, historically temperature has been one method utilized to measure shell dryness. However, Figure 3 shows that temperature alone may not provide enough information to determine mold dryness.

One of the limitations of the initial prototype was that the data wasn't accessible during the shell building process. Understanding that drying conditions can vary based on temperature or relative humidity of the room, or the amount of air-flow the mold encounters, the true value of this technology is the ability to monitor the drying conditions of the mold real-time. This would allow the shell room engineer or supervisor to modify the drying conditions during the process, rather than waiting until the end to review the data. It is this realization that led to the development of the wireless version of this data logger.

Building on this earlier technology, the updated data logger uses Microchip Wireless Protocol (MiWi™) for communication with a PC dongle. The data is stored by the data logger and can then be sent wirelessly to a PC located within 400 ft of the mold for viewing of the real time data. The data can be shared with another computer on the same network utilizing Remote Desktop.

The data logger is powered by an enclosed 5300 mAh Lithium Ion battery that can be charged from the USB port on the side of unit via a computer or wall charger. A separate circuit monitors the state of the battery and displays the battery life to the user interface. The data logger can also be connected to a computer via the USB port to transfer the data to the computer.

Figure 4: Photos of EMS-1000™ & PC Dongle

The data logger functionality can be programmed from the user interface including specifying logging intervals, clearing the memory, uploading the data and stop/starting the data logger. While the unit is collecting data, the user interface provides the readings of the temperature and relative humidity for each sensor.

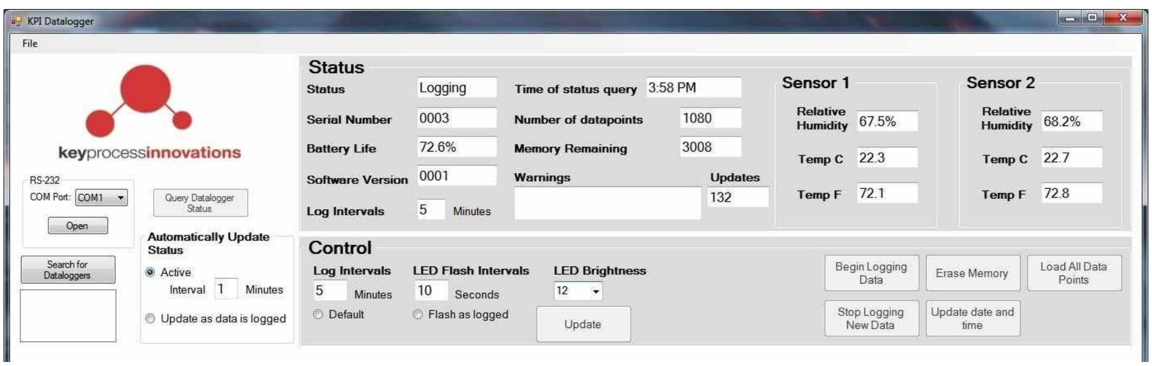

Figure 5: EMS-1000™ User Interface

This technology was utilized at FS Precision Tech as a part of their process improvement initiative that they began in late 2012.

CASE STUDY

FS Precision Tech, Co, LLC Overview

FS Precision manufactures precision investment castings for automotive, aerospace, and commercial applications. We produce titanium, zirconium, stainless steel, and cobalt, alloy investment castings from our facility in Los Angeles, California. Our castings range from as little as an ounce to one hundred pounds – for applications as diverse as commercial hand tools to aircraft weapons components.

We are the world leaders in titanium turbocharger castings. Years of development have brought nearly 100% of that market to our business and inspired the development of our proprietary titanium alloy, FS-2S; an alloy that boasts 20% greater tensile strength than cast Ti-6Al-4V, and fatigue lives equivalent to wrought titanium alloys.

FSPT was first introduced to Key Process Innovation's technology late in 2012. At the time, FSPT initiated a process improvement program to reduce process variability and improve casting quality. Since that time, we have utilized this technology for a number of different applications, including:

1. *Troubleshooting variations in our casting quality.* Through the use of this technology, we have been able to identify variations in drying conditions between our two dry tunnels in order to improve casting quality.
2. *Establishing drying conditions for hard to dry parts.* In the past, we would estimate how long to dry the parts and hope for good results, but, utilizing this technology allows us to monitor the environmental conditions of the mold in order to minimize drying time while optimizing shell quality.

We have two shell rooms, one for the robot and one for the manual line. Dependent on number and type of molds in the shell room, parts can be dipped by the robot or by hand. In the past, we didn't make any changes to way the molds were dried if they were moved to a different drying tunnel. However, as we looked at the drying curves between the two rooms, it is evident there are distinct differences. We ran this test two separate times and both times, it yielded similar results. It may be worth pointing out that the spikes in temperature in the Robot Room temperature were due to the elevated temperature of the fluid bed.

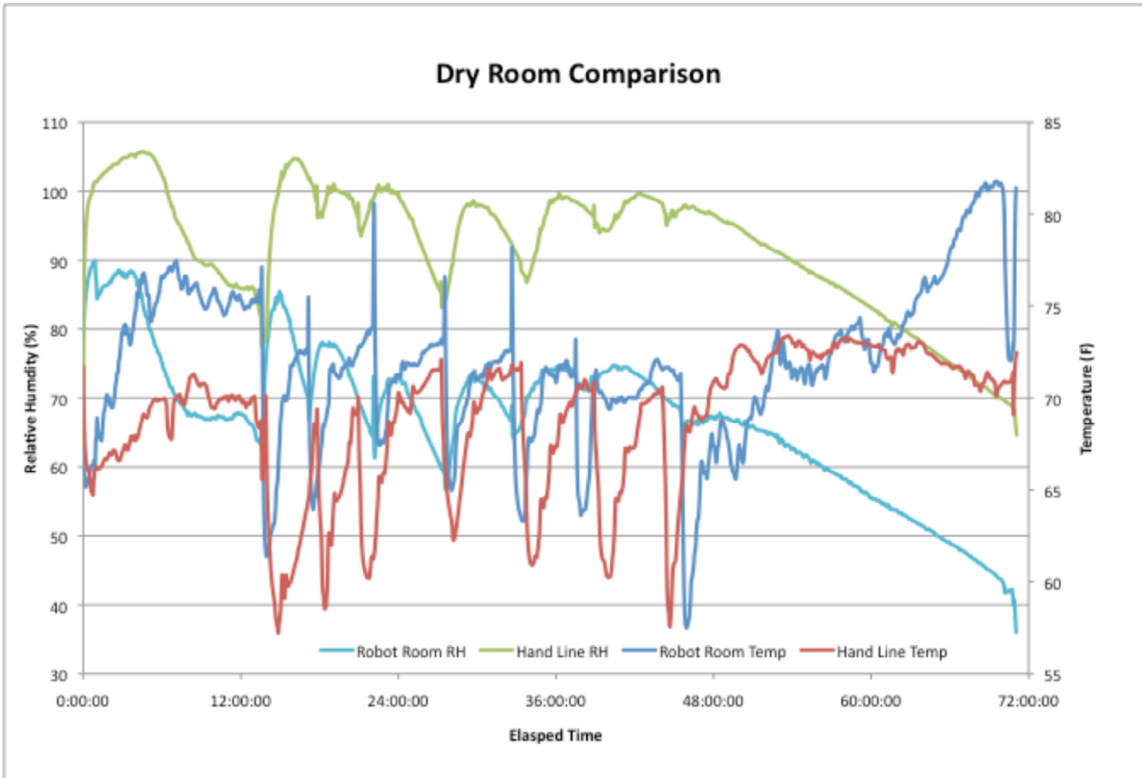

Figure 6: Comparison of Drying Curves between Robot & Hand Lines

At the same time that the shell dryness testing was conducted, we also measured temperature, relative humidity and airflow of the two drying rooms and this information explained the differences we were seeing in the shell drying profiles. The following chart shows the differences in the environmental conditions between the two rooms. While the temperature is fairly consistent, there are differences in the relative humidity and airflow between the two rooms. In this case, it would appear that the reduced airflow in the hand line dry tunnel is the cause of the longer dry times.

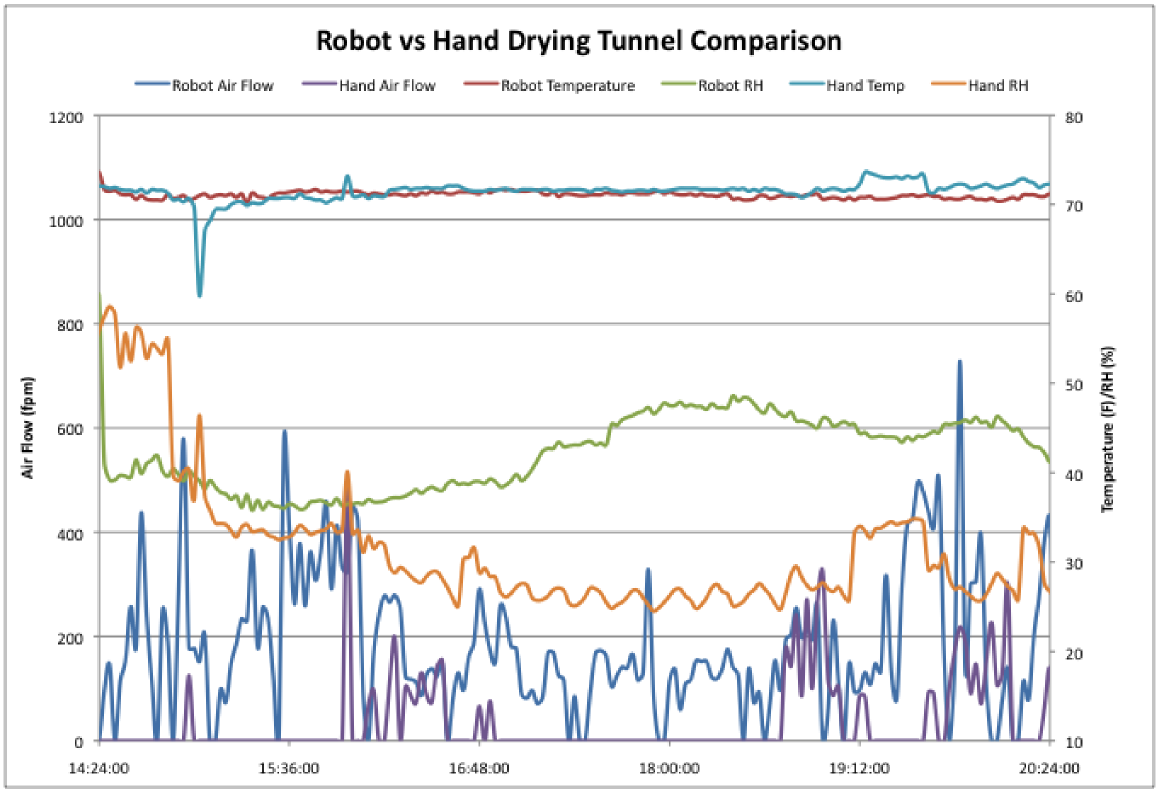

Figure 7: Comparison of Environmental Conditions between Robot & Hand Lines

Now that we understand the differences in the drying conditions, we have established different drying times for those parts that are moved between the two rooms. We also will be using this technology when the Santa Ana winds shift in the upcoming months as this has historically impacted the shell room environment, and in turn, the integrity of our shells.

The other area where we have seen value in this technology is in the development of the shell process for new or hard to dry parts. For example, we have one part that has a very deep channel in a hard to reach area. This part has historically been difficult for us to shell and has resulted in a lot of rework in the finishing department.

Our shell room supervisor created a manifold to use in order to dry the parts more efficiently, however, we didn't have a method to establish the optimal dry time between coats. The dry time between coats was arbitrarily selected to be minimum of 6 hours.

But, we had so much variability it was difficult to ensure that the shells reached the same level of dryness for every lot.

We first decided to monitor the drying of the mold without making any changes to the process. In this example, we placed two sensors in the mold: one facing inside of the "box" and the second facing out of the box.

Figure 8: Location of Sensors for Dry Test

The chart below shows the environmental differences between the inside of the box and outside. Again it is interesting to note that while the temperatures are fairly close to each other, there are large differences in the relative humidity between the two locations on the mold.

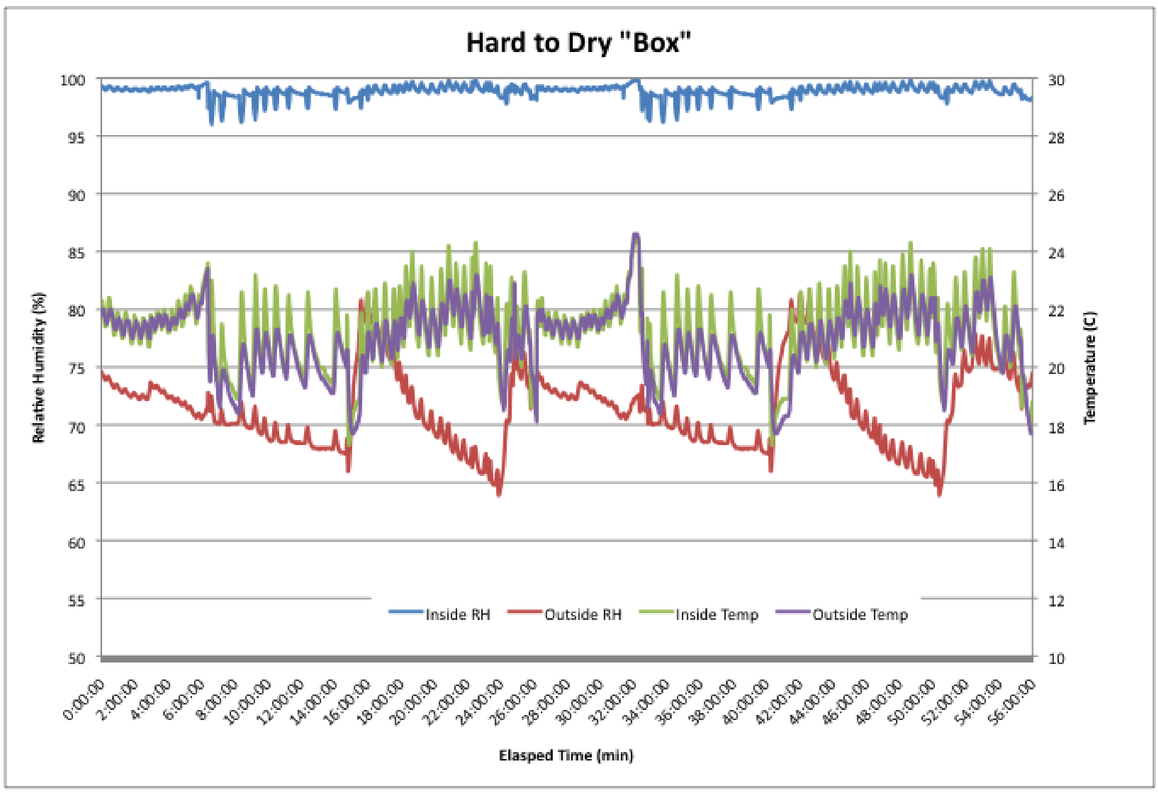

Figure 9: Initial Dry Study for "Box"

When the sensor was removed from the shell, it was evident that the inside of the shell wasn't dry: it was chalky and didn't have any strength. A photo of the two sensors after shelling is shown.

Figure 10: Sensor location after shelling

Using the wireless version of the EMS-1000™ allowed our shell room supervisor to monitor the drying of the mold and decide at what point the next coat should be applied. For this part, we have determined that it is critical to ensure the inside is dry prior to applying the 3rd dip. By monitoring the dryness of the mold, we were able to identify that approximately 8 hours dry time is sufficient prior to applying this coat. As we continue to work with this "box", we will be able to monitor the dryness of the mold and ensure it matches the dry curves of the successful lots.

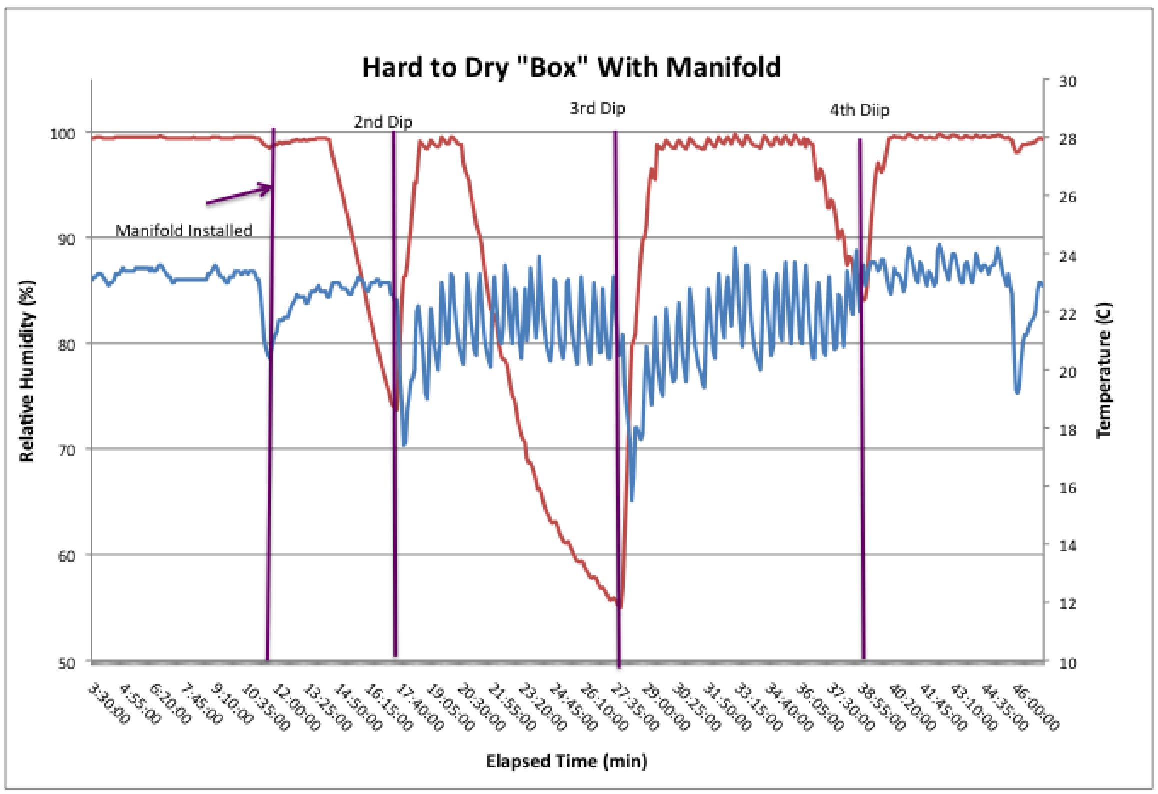

Figure 11: Dry Study with Manifold Installed

We do acknowledge that more work will need to be done to correlate our results with environmental conditions of our mold. However, with the ability to monitor the data real-time, we will be able to achieve accurate, repeatable drying curves that will assist in the development of a robust shell building process.

CONCLUSION

The ability to monitor the environmental conditions of the hard to dry areas of a mold during the shell building process provides the investment casting foundry with a tool that can further optimize their process and reduce variability. We believe the use of this technology will be a great tool as we continue to fine-tune our shell building process.

References:

[i] Julie Markee, 'A New Method For Measuring Dryness During The Shell Building Process,' 59th Annual Technical Conference on Investment Casting, 2012, paper 7