Basics of Pyrometry, Industry Specifications and Temperature Uniformity Surveys

Pyrometry

In its simplest sense, pyrometry is the measurement of temperatures. Practically speaking, in the business of heat treatment, the term also refers to the equipment, standards, and specifications that make it possible to measure high temperatures accurately.

Take a standard run-of-the-mill thermometer, for example – the kind you might have on your front porch. Most people don't give this device a second thought, because it can't be adjusted, and it doesn't need to be very accurate. After all, does it really matter whether it's 60° or 65° outside?

But sometimes, measurement accuracy is more important – for example, in a meat thermometer. You rely on that device to ensure that your food is cooked enough to kill off harmful bacteria. If your thermometer is inaccurate, you or your family could become very ill.

In heat treatment, the need for accuracy even more critical. If the temperature readings for your furnace are inaccurate, those aircraft parts you're heat treating could literally put lives at risk.

To make matters even more complicated, you must have blind faith in the instruments that measure such extreme temperatures. If your porch thermometer reads 70° but it's snowing, you know that something's wrong. If your meat thermometer reads 165° but the chicken is still pink, you know it's not safe to eat. But if your furnace reads 1900° and it's actually 1875°, how can you even know that there's a problem?

And even if you *do* somehow realize that something's not right, how do you determine where the problem is? Measuring temperatures in industrial applications isn't as simple as sticking a thermometer in a piece of chicken – rather, it takes an entire system of devices all working together to give a glimpse of what's happening inside a furnace (See Fig. 1). Any one of the parts could be to blame for an inaccurate measurement.

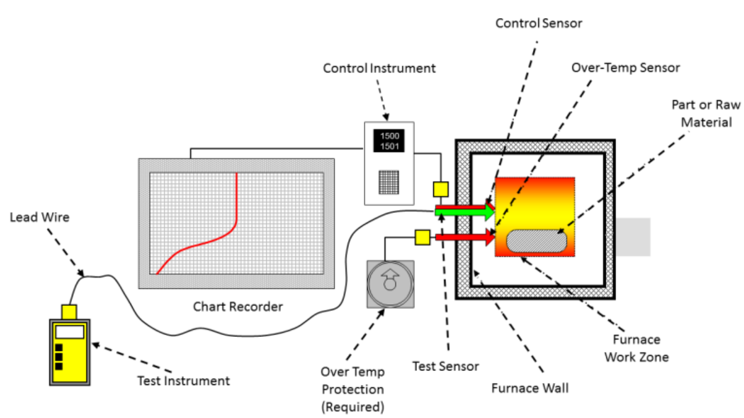

Figure 1 - Typical Measurement and Control System

AMS 2750

To address these complications, industry leaders have developed a number of systems and guidelines that help lead to consistency and quality.   One of the most important such programs is the National Aerospace and Defense Contractors Accreditation Program (NADCAP). NADCAP certification is essential to any business that wants to do heat treating work for the aerospace industry.

To ensure consistency of temperature measurement in heat treating processes, NADCAP relies on a document known as AMS 2750 (AMS = Aerospace Materials Specification). It's important to note that although NADCAP and AMS are both based in the aerospace sector, the certification and specification apply to the overall heat treatment industry and are not limited to aerospace alone. AMS 2570 covers all aspects of pyrometry in heat treatment, including:

- Controllers (calibrations, specifications and readability requirements)
- Thermocouples (calibrations, usage, types)
- Recording instruments (calibrations, accuracy)
- Calibration requirements for thermocouples and equipment
- Accuracy requirements and tolerances for acceptance
- Calibration procedures
- Temperature survey procedures
- Frequency of activities

Temperature Uniformity Surveys

One of the key components to AMS 2750 is the Temperature Uniformity Survey (TUS). A TUS verifies the classification of your furnace and its qualified working zone, and this in turn determines your required ongoing testing schedule in order to maintain conformity with AMS 2750.

Furnace Classification

Furnace Class	Temperature Uniformity Range (Degrees F) (1)	Temperature Uniformity Range (Degrees C) (1)
1	±5	±3
2	±10	±6
3	±15	±8
4	±20	±10
5	±25	±14
6	±50	±28

(1) Uniformity range requirement is established by the specification for the material being processed.

Figure 2 - Furnace Classifications

Furnace classification is a key piece of information that the TUS will use to determine required frequency of testing activities. Furnace class is determined by the temperature uniformity range within the qualified working zone – put simply, in the area of furnace that you will be using, how close are you staying to your desired temperature? The temperature uniformity range is described as a plus/minus degrees value, as shown in Figure 2. So, for example, if a furnace is meant to run at 1900°F, and it ranges between 1887° and 1913°, it would qualify as Class 3. A higher-rated furnace classification means that the furnace is able to stay closer to its target temperature without variation.

Instrumentation Type

In addition to classification, AMS 2750 also uses Instrumentation Type to determine a furnace's mandatory testing schedule. Instrumentation type can be look at as the number of sensors used for control/recording in a furnace. All of these sensors, controls, and recording systems have strict accuracy requirements and calibration intervals. The five instrumentation types (A-E) are defined clearly within the specification (see figure 3 for a sample).

3.3.1.1 Instrumentation Type A:

3.3.1.1.1 Each control zone shall have at least one control sensor connected to a control instrument that displays and controls temperature.

3.3.1.1.2 The temperature indicated by the contr… a recording instrument.

3.3.1.1.3 At least two additional recording sensor… represent the coldest and hottest tempe… temperature uniformity survey. It is reco… configurations can prevent the location … locations, but these sensors shall be lo…

3.3.1.1.3.1 These recording locations may chang… requirements.

3.3.1.1.4 At least one recording load sensor shall be located in each control zone.

3.3.1.1.5 Each control zone shall have over-temperature protection. The sensor representing the hottest location per 3.3.1.1.3 may also be utilized as the over-temperature protection sensor.

3.3.1.4 Instrumentation Type D:

3.3.1.4.1 Each control zone shall have at least one control sensor attached to a control instrument that displays and controls temperature.

3.3.1.4.2 The temperature indicated by the control sensor in each control zone shall be recorded by a recording instrument.

3.3.1.4.3 Each control zone shall have over-temperature protection.

Figure 3 - Instrumentation Type Descriptions

Testing Intervals

Put together, furnace classification and instrument type clearly determine the testing schedule necessary for your furnace in order to maintain certification. So, for example (See Fig. 4) a Class 2 Furnace with Instrumentation Type B is required to undergo a TUS on a monthly basis, whereas a Class 5 Furnace with Instrumentation Type B only requires a quarterly TUS.

Furnace Class	Temperature Uniformity °F	Temperature Uniformity °C	Minimum Instrument Type	Initial TUS Interval	Number of Successful Consecutive TUS (1)	Extended Periodic TUS Interval
1	±5	±3	D	Monthly	8	Bimonthly
			B, C	Monthly	4	Quarterly
			A	Monthly	2	Semiannually
2	±10	±6	D	Monthly	8	Bimonthly
			B, C	Monthly	4	Quarterly
			A	Monthly	2	Semiannually
3	±15	±8	D	Quarterly	4	Semiannually
			B, C	Quarterly	3	Semiannually
			A	Quarterly	2	Annually
4	±20	±10	D	Quarterly	4	Semiannually
			B, C	Quarterly	3	Semiannually
			A	Quarterly	2	Annually
5	±25	±14	D	Quarterly	4	Semiannually
			B, C	Quarterly	3	Semiannually
			A	Quarterly	2	Annually
6	±50	±28	E	Annually	Not Applicable	Annually
Refrigeration units and quench tanks do not require TUS						

Figure 4 - TUS Interval Chart

However, AMS 2750 rewards TUS success. If a furnace completes a designated number of TUSs successfully, the interval between testing can be increased. In our above example, if the Class 2 Furnace with Instrumentation Type B were to undergo four consecutive successful TUSs, its required testing would stretch from monthly to quarterly. Having to perform fewer TUSs is a huge benefit, leading to:

- Lower cost of labor/materials,
- Increased production/reduced down time, and
- Decreased time spent on documentation of the process.

It is also important to note that AMS 2570E provides different timelines based on what is being treated in the furnace. Figure 5 deals specifically with parts, while a furnace treating raw materials would be subject to another chart, and would have a less rigorous TUS interval to maintain.

TUS Logistics

A TUS requires time and organization since there are many pre-requisites prior to performing the TUS. Even though a survey may only take two hours to run, it takes planning and coordination to get all the pieces in place. All the while, management and production are probably waiting for that valuable furnace time. To minimize this downtime, work to streamline the activities that surround the TUS in order to create an efficient process:

- Organize paperwork.
- Ensure quick and easy access to maintenance logs.
- Have a prefabricated TUS rack wired in advance.
- Communicate dates for calibration of equipment.
- Develop a quick reporting technique for easy review and signoff.
- Ensure that the survey device is calibrated and certified (3 months per AMS 2750E).

All these preparations put together can shave off hours off the process. When multiplied by a number of furnaces, the financial benefits are obvious.

When the time comes to actually perform the TUS, there is a great deal to consider. Items such as thermocouple wire requirements, instrument calibration and more are covered in great detail in AMS 2750E, but it is critical to know and understand your equipment (e.g., thermocouple type, noble or base metal, primary or secondary use), so that you can make use of the guidelines included in the specification (see Fig. 5, next page).

Sensor	Sensor Type [1]	Use	Calibration [3] [4] Period	Calibration Against	Maximum Permitted Error [2] [12]
Reference Standard [7]	Types R and S noble metal	Primary standard calibration[8]	5 years	NIST[5]/ Reference standard	None
Primary Standard [8]	Types R and S noble metal	Secondary standard calibration[9]	3 years	Reference standard[7]	±1.0 °F (±0.6 °C) or ±0.1%
Secondary Standard [9]	Base or Types R and S noble metal	Sensor calibration[10]	Before first use. Recalibration: 2 years - Types R & S 1 year - Base metal [11]	Primary standard[8]	Base metal: ±2 °F (±1.1 °C) or ±0.4% Noble metal: ±1.5 °F (±1.0 °C) or ±0.25%
	Type B noble metal		2 years - Type B		±1.0 °F (±0.6 °C) or ±0.5%, Type B
Temperature Uniformity Survey	Base or Types B, R, and S noble metal	Temperature uniformity surveys	Before first use. Recalibration: [6]	Primary or secondary standard[10]	±4 °F (±2.2 °C) or ±0.75%

Figure 5 - Sensor Calibration Chart

Thermocouples

Thermocouples in particular can present a challenge. By their very nature, they have associated calibration errors that must be corrected to determine a true temperature. Many areas in AMS2750 cover these correction factors, which are used to adjust the readings of thermocouples. It is absolutely mandatory to use these corrections when performing TUSs. While they can be entered after the survey, it strongly recommended to capture this information beforehand. This will enable the technician to immediately identify any potential issues with the survey, allowing actions to be taken immediately. It is important that the individuals that are performing activities understand how to use these correction factors and how to document the results for future reference, such as would be required during a NADCAP audit.

Conclusion

Understanding the TUS process as it applies to AMS 2750E will allow you to be proactive regarding your requirements and responsibilities as a reliable heat treater. If you are familiar with your equipment and the specification, you can prepare for efficient transitions, minimize downtime, and streamline the process of TUS testing. And if you take the time to document the process for future surveys, you can save time and money in the long run by enabling yourself to identify problems before they are too late to prevent.