SATs, Alternate SATs, wait, what?!

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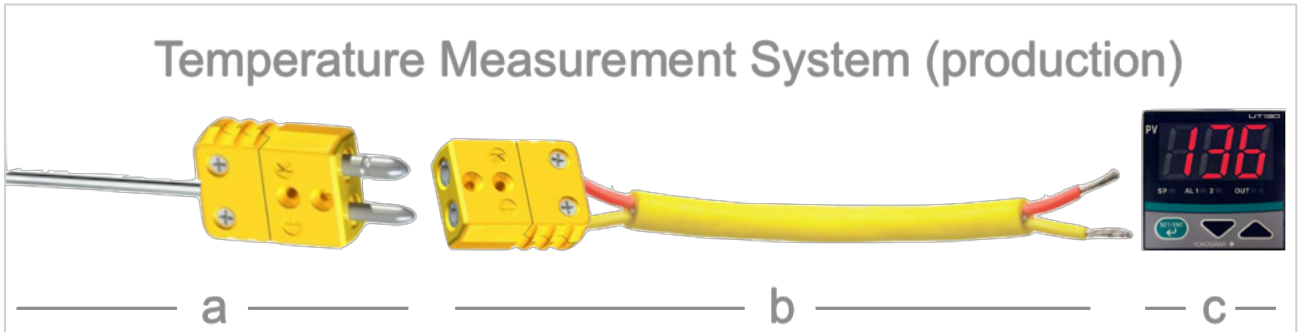
In September of 2005 the aerospace heat treat community was introduced to an alternative method of meeting system accuracy (SAT) requirements in AMS2750D. At that time, the method was not called the "Alternate SAT Process" and it was not abundantly clear what the requirements were. With the release of AMS2750E in July of 2012 there was promise to provide added guidance for suppliers to help them better understand the requirements and successfully document the "Alternate SAT Process".

However, the heat treat task group continues to report a significantly high number of non-conformances (NCRs) resulting from suppliers failing to meet what was then the new and improved requirement. Has the standard failed to effectively communicate the requirements for suppliers to be successful? Or is there a general lack of knowledge among suppliers to understand the requirements and the underlying intent? Let's dive in and let you be the judge…

Before we can fully understand the "*Alternate* SAT Process" it's important to first understand what a *traditional* system accuracy test (SAT) is and what its purpose is.

SAT

Figure-1 below shows a typical **Temperature Measurement System** used in production. The system is made up of three components: (a) sensor, (b) lead-wire and (c) control or recording instrument:

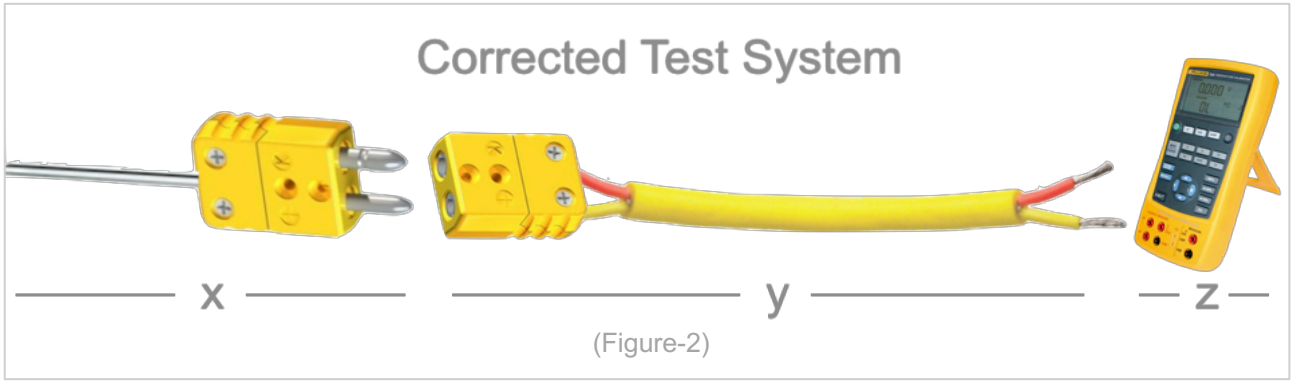


(Figure-1)

A quick glance at AMS2750E (Tables 1 & 3) tell us that both (a) *sensors* and (c) *instruments* must be calibrated at predefined frequencies based on their use. Although AMS2750E does not require calibration of (b), the *leadwire* connecting the sensor to the instrument, it is expected that the sensor (mV) signal reach the instrument unchanged.

In a perfect world these three components would remain within calibration tolerances over their usage life. Unfortunately heat and time negatively affect these components and their ability to maintain their calibration, giving purpose to the system accuracy test. The purpose of the system accuracy test is to ensure that the entire temperature measurement system continues to function accurately according to the tolerances defined in AMS2750E (Tables 6/7). But what exactly does the system accuracy test involve?

A system accuracy test is an assessment of the sum of the combined errors of all three components shown in Figure-1 above. This assessment is made by comparing the temperature reading obtained in Figure-1 against what is referred to as '*True Test Temperature*', obtained from a **Corrected Test System** (see Figure-2 below). A typical Corrected Test System is made of up the three components: (x) test sensor, (y) lead-wire and (z) field test instrument.



(Figure-2)

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Test sensors (x) and test instruments (z) come with calibration reports that list their known error at various temperatures. As part of the SAT these known errors are mathematically added to the test system's temperature reading in order to calculate '*True Test Temperature*'.

In order for the SAT to pass, the temperature measurement system reading (determined in Figure-1) must not differ from '*True Test Temperature*' by more than the maximum allowable SAT difference defined in AMS2750E (Tables 6/7).

OK so there you have it…a summary of the *traditional* SAT, yea!

Alternate SAT

OK so what is an alternate SAT and why do we have them? The goal of the alternate SAT is the same as that of the traditional SAT: *to ensure the entire temperature measurement system continues to function accurately according to the tolerances defined in AMS2750E (Tables 6/7)*.

OK so why an entirely different *type* of test? Well, there are temperature measurement systems whose sensor requires replacement *before* the traditional SAT test frequency has had time to kick in. In this scenario the traditional SAT is ineffective at ensuring the temperature measurement system stays accurate throughout the life of the sensor. This is where the Alternate SAT method comes into play.

Is alternate SAT method optional? Yes and no. In order to use the alternate SAT method, the temperature measurement system must first qualify. Qualifying requires that the sensor of the system be replaced at an interval more frequent than the applicable *traditional* SAT test frequency listed in AMS2750E (Tables 6/7). *Ref: AMS2750E: 3.4.6*

How is the alternate SAT performed? There are two options given in AMS2750E for performing the alternate SAT. Both options involve two simple steps, and in both cases Step 1 is always performed.

Step 1 (calibrate instrument): When the instrument for the system is calibrated it must be performed by connecting the field test instrument at the point where the sensor normally plugs into the system. By calibrating the instrument in this manner, the error of the lead-wire (and connectors) are included in the instrument calibration. In other words, you have just assessed 2 of the 3 system errors. *Ref: AMS2750E:*

The only remaining error in the measurement system to be assessed is that of the sensor.

There are two acceptable methods for making this assessment.

Step 2-A or Step 2-B

Step 2-A (add sensor error):
Establish calibration (error) limits for the sensor which, when added to the two system errors assessed in Step 1, do not exceed SAT tolerances defined in AMS2750E (Tables 6/7).

Ref: AMS2750E: 3.4.6.1.1

The following page illustrates an example using this widely accepted method.

Step 2-B (apply sensor correction to instrument):
During production runs apply the sensor correction factors (either manually or electronically) to the control or recording instrument. Doing this cancels out the error of the sensor in the system by mathematically making the sensor error 0°C/F.

Ref: AMS2750E: 3.4.6.1.2

NOTE: This method is rarely used because most instruments today don't allow (or make impractical) electronic entry of sensor corrections factors across the entire furnace operating range. Manually applying correction factors is highly susceptible to human error.

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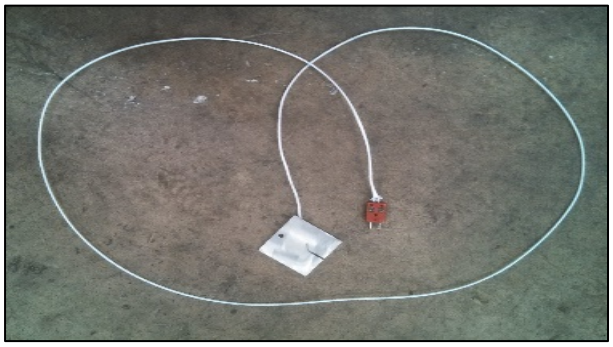
Example: A vacuum furnace that uses an expendable load sensor/thermocouple (single-use). The qualified operating temperature range is 900°F → 2100°F.

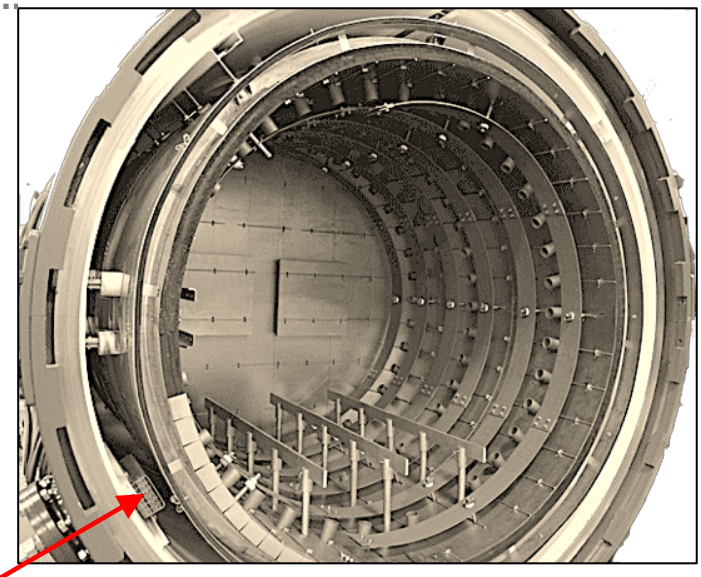


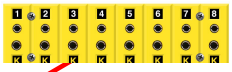
Step-1 (calibrate the instrument):

Instrument calibration on control and recording instruments is to be performed periodically (quarterly in this example) from the point at which the sensor plugs in at these temperatures:

900°F 1500°F 2100°F

The 'as-found' & 'as-left' calibration errors (not the corrections) at each of the above calibration test points are documented on the calibration report as shown:





previous CAL	
(as-left)	
+1ºF	
+1ºF	
+1ºF	

current CAL	
(as-found)	(as-left)
+2ºF	+0ºF
+2ºF	+0ºF
+2ºF	+0ºF

IMPORTANT:

Users of the Alternate SAT process are reminded that Nadcap Auditor Advisory (HT 13-003) requires users to have a written procedure which guarantees that the subsequent error for the system "instrument/lead-wire/connector" does not affect any SAT results calculated or calibration limits applied between two consecutive routine calibrations.

This means at each routine calibration, the user must assess changes in the instrument/lead wire calibration that could have affected the Alternate SAT values calculated for the **previous CAL results**, this is in addition to assessing the total system error calculated in the **current CAL results**.

Failure to take previous CAL results into consideration can result in an NCR.

If previous CAL error differs from the current CAL error (as-found), then an Alternate-SAT must be performed using:

- current CAL error (as-found).

Additionally: If the current CAL error changes (from as-found to as-left) an Alternate-SAT must be performed using:

- current CAL error (as-left)

previous CAL

(as-left)
+1ºF
+1ºF
+1ºF

current CAL

(as-found)	(as-left)
+2ºF	+0ºF
+2ºF	+0ºF
+2ºF	+0ºF

Step 2-A (add in the sensor error):

Mathematically add the current CAL error assessed in Step 1 to the applicable sensor error found on your sensor calibration certificate (sensor certificate show here).

Be mindful to not confuse sensor *error* with sensor *correction factor*, as they are the inverse of one another.

This calculation provides us with the sum/total error of the **Temperature Measurement System**.

With this information an alternate SAT report can be generated to document all the values and results obtained in Steps 1 and 2A. In this report the sum/total error is checked to ensure that the maximum allowable error (as defined in Tables 6/7 of AMS2750E) has not been exceeded.

If the sum/total error has not been exceeded, then the alternate SAT passes. Otherwise the alternate SAT will have failed.

CALIBRATION REPORT
No. 13-0374

Thermocouple Calibration Certificate

CUSTOMER:

P.O. NO.:
ITEM NO.: K20-2-301-047, 1020'
T/C TYPE: "K" QTY: 20'
S/N: 26915

CALIBRATED IN ACCORDANCE WITH:
ANSI Z540-1-1994, ISO 10012-1-1992
BAC 5621K, DPS 1.700P, AMS 2750E
AMS-H-6875B ,BPS 4416C-1, ASTM E220-07a
ASTM E230/E230M-12 & CKI QI 22.1
X WITHIN SPECS (BAC 5621K)

*	CALIBRATION POINT	* READING	* CORRECTION FACTOR	* TOL. *
INSIDE	100 F	100.4 F	-0.4 F	± 2.0° F
	200 F	200.8 F	-0.8 F	± 2.0° F
	400 F	401.1 F	-1.1 F	± 2.0° F
	600 F	599.8 F	0.2 F	± 2.0° F
	800 F	800.5 F	-0.5 F	± 2.0° F
	1000 F	1001.2 F	-1.2 F	± 2.0° F
	1200 F	1201.9 F	-1.9 F	± 4.8° F
	1400 F	1402.5 F	-2.5 F	± 5.6° F
	1600 F	1603.3 F	-3.3 F	± 6.4° F
	1800 F	1804.1 F	-4.1 F	± 7.2° F
	2000 F	2004.3 F	-4.3 F	± 8.0° F
	2200 F	2203.0 F	-3.0 F	± 8.8° F
OUTSIDE	100 F	100.4 F	-0.4 F	± 2.0° F
	200 F	200.7 F	-0.7 F	± 2.0° F
	400 F	400.9 F	-0.9 F	± 2.0° F
	600 F	599.6 F	0.4 F	± 2.0° F
	800 F	800.2 F	-0.2 F	± 2.0° F
	1000 F	1000.8 F	-0.8 F	± 2.0° F
	1200 F	1201.5 F	-1.5 F	± 4.8° F
	1400 F	1402.2 F	-2.2 F	± 5.6° F
	1600 F	1602.8 F	-2.8 F	± 6.4° F
	1800 F	1803.3 F	-3.3 F	± 7.2° F
	2000 F	2003.5 F	-3.5 F	± 8.0° F
	2200 F	2202.3 F	-2.3 F	± 8.8° F

*** CALIBRATION EQUIPMENT ***

	TYPE	S/N	CAL DATE	DUE DATE
SECONDARY POTENTIOMETER	HART SCIENTIFIC T/C SCANNER	A07859/A08248	9/30/2013	12/30/2013
REFERENCE THERMOCOUPLE	ANSI TYPE "S"	24546	5/29/2013	11/29/2013

The calibration equipment used for this test is traceable to NIST through the following standards:

TYPE	S/N	CERT NO.	CAL DATE	DUE DATE
HEWLETT PACKARD 3458A	2823A24116	1-4814258965-1	11/30/2012	11/30/2013
ANSI TYPE "S" THERMOCOUPLE	26615	283607	4/24/2013	4/24/2014

AMB. TEMI 72°F HUMIDITY: 40% RH TEST DATE: 11/7/2013

CALIBRATED BY: _____ TECHNICIAN ISSUE DATE: 2/25/2014

REVIEWED BY: _____ QUALITY ASSURANCE

Triggering Events

- any change in Sensor correction-factors/errors
- any change in CAL results of control/recording instrument

OK so there you have it…a summary of the *alternate* SAT, if only there was a way to make this simple…

So back to the original question:
Has the standard failed to effectively communicate the requirements for suppliers to be successful? Or is there a general lack of knowledge among suppliers to understand the requirements and the underlying intent?

Perhaps both have contributed to the high number of NCRs that continue to be associated with alternate SATs. One thing we can say for certain is the alternate SAT process is not labor-intensive.

The challenges lie in establishing a system that can reliably schedule, track, calculate, document, and determine pass/fail status. A system that can carry out these tasks day-in and day-out with minimal human involvement will greatly reduce vulnerability to NCRs. There is such a system today that automates 99% of the alternate SAT processes to free up resources for other value-added activities.

Alternate SATs…automated

C3 Data's *Compliance Management Software* tracks calibration data for all instruments and all sensors/thermocouples in real-time. This allows the C3 system to automate the entire alternate SAT reporting process. The user simply tells C3 system which furnace channels he/she wants the alternate SAT to be performed on and assigns a sensor/spool to each. C3 Data then fully automates compliance, including automatic report generation for all alternate SATs.

Automated report generation for *traditional* SATs is also available with minimal user effort.

To learn more about how C3's compliance management system can help streamline your compliance processes while eliminating NCRs, visit us on the web C3data.com or reach out to us directly.

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