

## **Optimizing Procedures For Temperature Uniformity Surveying For Vacuum Furnaces**

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# Optimizing Procedures For Temperature Uniformity Surveying For Vacuum Furnaces

A Temperature Uniformity Survey ( TUS ) for a vacuum furnace to satisfy AMS 2750D must be performed using established procedures and methods that fully meet the requirements of the specification and allows for consistent and more accurate results of actual furnace capabilities.

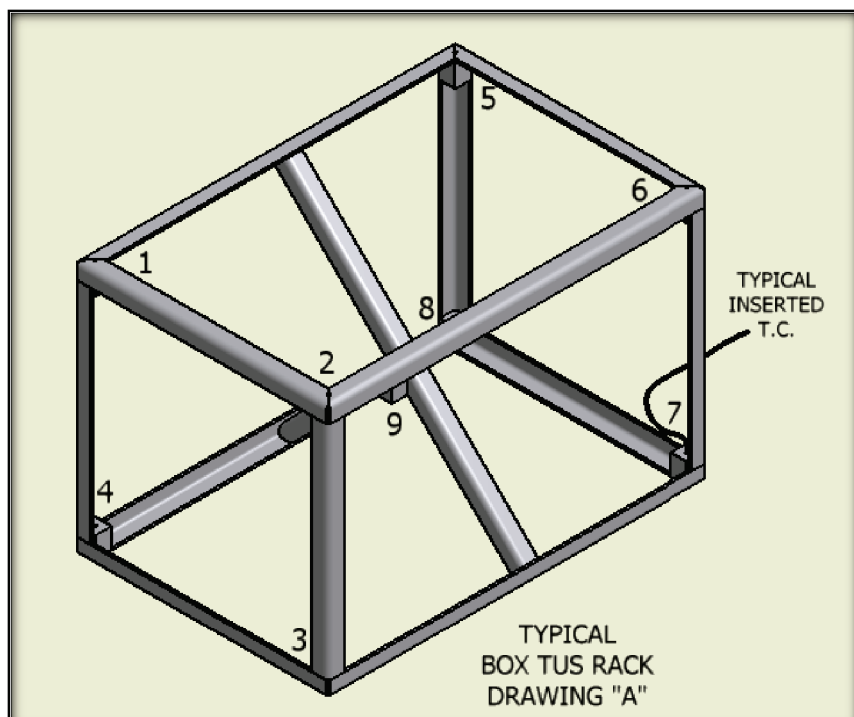
Solar Atmospheres and Solar Manufacturing, with their extensive vacuum furnace experience and processing knowledge, have combined to create a standard procedure for TUS for all newly manufactured and current in-production vacuum furnaces. This procedure considers the many critical aspects of AMS 2750D that must be fully satisfied to produce acceptable processing results and the following outline could be applied to any vacuum furnace user to satisfy their TUS requirements.

## A) THERMOCOUPLE SUPPORT STRUCTURE

AMS 2750D allows for the use of racks specifically designed to accomplish the TUS. A thermocouple heat sink attached to the rack is allowed for placement of the thermocouple provided that the cross-section of the heat sink does not exceed .50" or is not thicker than the thinnest material being processed. The key to any rack structure is to be able to correctly place and rigidly support the T/Cs at the true dimensions of the furnace work zone.

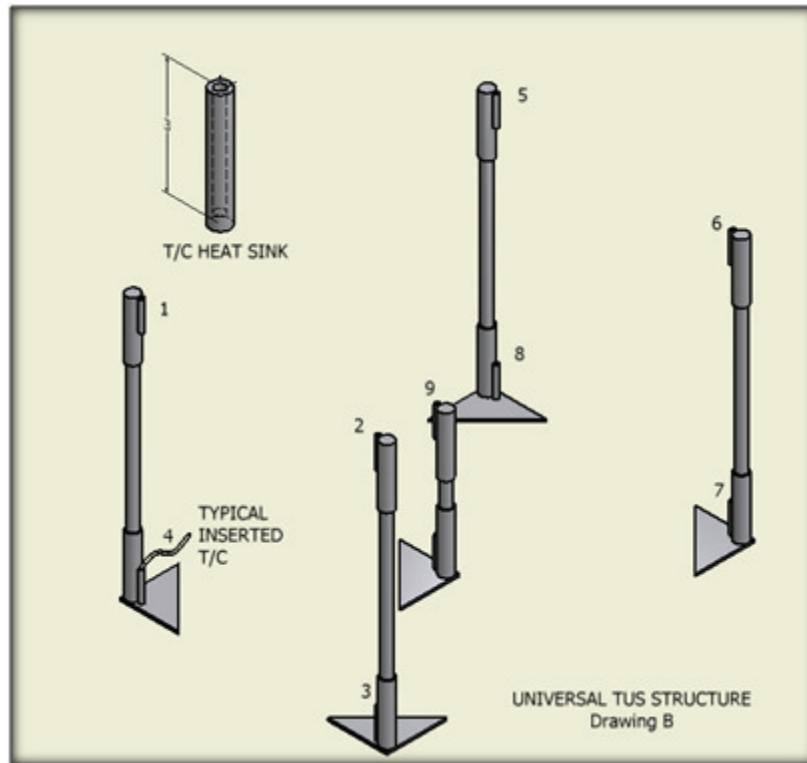
Racks can be specifically designed as they apply to the expected use of the vacuum furnace. Also, baskets can be stacked to represent a full load configuration with the T/C heat sinks positioned on the on the inner eight corners of the baskets with a ninth T/C positioned in the center position of the load.

Solar has designed several T/C racks similar to that shown in Drawing A. This typically is a box configuration fabricated using RA330 angle members with heat sink blocks located at the corners and center position. This structure will satisfy many commercial applications but has certain limitations when conforming to AMS 2750D and is not universal when having multiple sized furnaces all requiring TUS. Also, these types of racks require considerable storage space when not in use.





The newest, most acceptable and universal TCU support structure that has been designed, consists of individual corner pipe members that sit vertical with a bottom support structure ( Drawing B ). The vertical height of each member can be adjusted with different center lengths to accommodate various size furnace hot zones. Each structure can be accurately positioned to the outer extremes of the Hot Zone to locate the eight corner T/Cs. An additional center structure is provided to properly locate the center T/C. All main pipe corner vertical structures will have top and bottom T/C heat sinks welded to the inner surface. Each heat sink shall be 1/2" Diameter by 3" long with a hole drilled on center to accept the T/C. This type of support structure configuration should be used to meet the most critical aerospace applications.



#### B) PRE-SURVEY FURNACE PREPARATION

In order to insure that the furnace is functioning properly under all dynamic thermal conditions for the TUS, a pre-survey preparation should be considered. Based on the temperature range to be surveyed, one or more temperature set points shall be selected for initiating an Autotune of the furnace PID controls. As an example, if the initial TUS temperatures are 900<sup>0</sup>F, 1500<sup>0</sup>F, and 2100<sup>0</sup>F, the ranges are therefore 900<sup>0</sup>F-1500<sup>0</sup>F and 1500<sup>0</sup>F-2100<sup>0</sup>F and a single set point Autotune at 1500<sup>0</sup>F would be acceptable.

Following an initial mechanical zeroing of the power meters, the empty furnace should be heated to 1500<sup>0</sup>F and all zone power meters balanced ( average volt/amps ) using the power supply trim adjustments. The initial power trim settings shall be set to 90%. The Autotune feature of the controlling instrumentation is then initiated. The Autotune feature allows for either a "Slow" or "Fast" tune

capability. The "Slow" tune feature should be selected as it calculates conservative tuning constants with the objective of minimizing overshoot critical to any TUS test.

#### C) TEST T/C CONSIDERATIONS

The following criteria shall be used in preparation of the T/C's to be used for the TUS test.

- 1) Sensors shall be type "K" thermocouples, Refrasil insulated or Inconel-sheathed type ( minimum 3/8" O.D.) and calibrated in accordance with AMS 2750D section 3.1.
- 2) All T/C's must be new and cut to the same length. In considering the proper length, it is essential that adequate length be provided for any T/C shrinkage during the actual testing which could result in failure or accidental movement from the desired fixed position. An additional length factor of 10% should be considered.
- 3) Each T//C shall have a tight, twisted end junction measuring approximately 1/2" long with the other end properly affixed to the T/C plug connector.
- 4) All test T/C's shall be brought into the hot zone as a bundle assembly that has been properly wrapped with Kaowool insulation as they feed through the Graphite felt insulation. The wrapping is essential to prevent any possibilities of Graphite infusion or electrical shunting. All excess T/C wire shall be distributed within the hot zone and not stuffed into the cold wall area.
- 5) After the T/C's have been placed into the various heat sinks located on the support structures, it is imperative that all excess length of the various T/C's remain within the hot zone and not outside on the cold wall side. It is important that no thermocouple come in contact with the heating elements.
- 6) The T/C heat sinks on the support structures that hold the sensors, should be facing inward from the heating elements.
- 7) The control and over-temperature T/C's should be extended into the hot zone a minimum of 2" beyond the heating elements.
- 8) Jack panels must have spare plugs inserted to prevent metallic buildup on contact surfaces.

#### D) FURNACE INSTRUMENTATION

A typical furnace shall be equipped with a controlling sensor attached to a controlling instrument which controls and displays the furnace temperature. In addition, the furnace must have an over-temperature sensor/instrument that turns off the control power should the temperature exceed the setting of the control instrument. Both the control temperature and over-temperature sensors are recorded on separate calibrated instruments to conform to AMS 2750D.

#### E) FURNACE CLASS

The furnace to be surveyed may be any one of four classes as defined in AMS 2750D, table 8. The class defines the expected + or – uniformity factor. Classes are as follows:

- 1) Class 1 = +/- 5°F,
- 2) Class 2 = +/- 10°F,
- 3) Class 3 = +/- 15°F,
- 4) Class 4 = +/- 20°F,
- 5) Class 5 = +/- 25°F

#### F) Survey Frequency

The survey frequency on any furnace is dependent on the furnace class. The following frequency of TUS shall be required:

Class 1 & 2: An initial survey is performed prior to production followed by three monthly periodic surveys for a total of four as the initial frequency. Subsequent surveys may then be reduced to quarterly provided prior surveys are all acceptable.

Class 3 – 5: An initial survey is performed prior to production followed by three quarterly periodic surveys for a total of four at the initial frequency. The frequency may then be reduced to semi-annually provided all prior surveys are acceptable.

#### G) FURNACE WORKING ZONE

The working zone of the furnace shall be defined as the nominal hot zone dimensions specified in the overall furnace general specifications. For horizontal furnaces this is usually Width x Height x Length and for vertical furnaces, Diameter x Height. These parameters form the working dimensions of the hot zone to be surveyed. The universal structure described above will be used to place the T/C's in their respective corner and center locations.

#### H) STANDARD SURVEY TEMPERATURES FOR MOST VACUUM FURNACES

The initial TUS temperatures shall be 900°F, 1500°F, and 2100°F. This defines the ranges as 900°F – 1500°F, and 1500°F – 2100°F for a total of two ranges. However, some furnaces may have an additional range between 300°F and 900°F required for certain steel tempering, age hardening of PH steels, and solution heat treating of certain nickel based alloys.

The periodic survey temperatures for the above shall be 900°F and/or 1500°F with the 900°F representing the 300°F – 900°F range and the 1500°F representing the 1500°F – 2100°F range.

Once a year, each furnace shall be surveyed at all validated temperatures.

I) NON STANDARD FURNACE TEMPERATURES

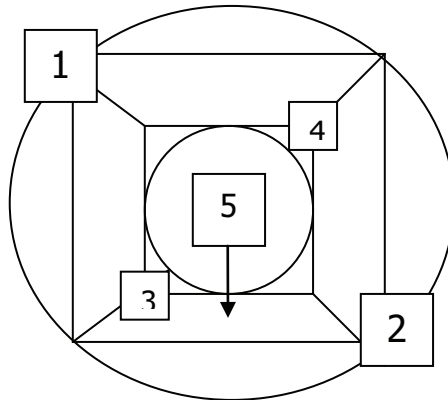
Aerospace work shall not be run outside of the standard uniformity survey temperatures without first performing an appropriate survey. The survey may be performed with an actual load of the subject materials. However, if the risk of failure is too great, the survey should be performed with the above described universal TUS rack. Once performed, the TUS shall be repeated as required by AMS2750D.

Non-aerospace work may be run outside the standard uniformity temperatures whenever considered acceptable by the Quality Department. If not, an appropriate survey shall be performed and repeated per the above temperature range requirements.

J) QUANTITY/LOCATION OF T/CS

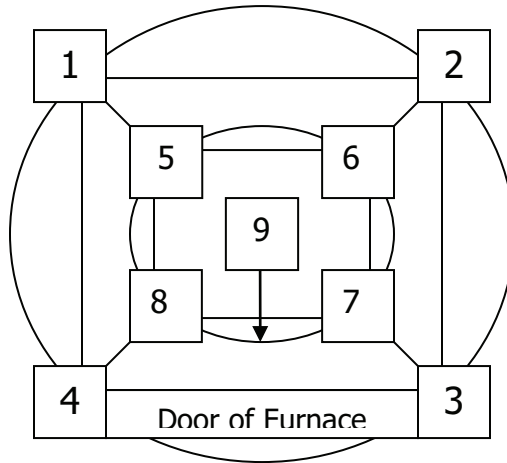
1) Furnaces under 3 Cubic feet

For furnaces with a work zone of less than 3 Cubic feet, 5 T/C's shall be used. Placement of the T/C's will be top left and bottom right corners, bottom left and top right back corners, and center location. These locations shall be documented in the TUS report and TUs certification.



2) Furnaces Between 3 and 225 Cubic Feet

For horizontal furnaces between 3 and 225 Cubic feet of work zone, 9 T/C's shall be used for the uniformity survey. Placement of the T/C's shall be at the four front and back corners and one in the center location of the hot zone.



For vertical furnaces, nine T/C's shall be placed at 120° positions at the bottom, center and top levels of the hot zone located at the outside extremes of the work zone. Also, one additional T/C shall be located at the center position of the work zone.

For larger furnaces such as car bottom furnaces with multiple work zones, TUS must be accomplished as defined in AMS 2750D for these furnaces. This outline has been basically written for batch type vacuum furnaces.

#### K) US SURVEY PROCEDURE

- 1) Install the T/Cs onto the support structure inserted in the heat sinks and position the corner structures at the proper end and center locations. As stated above, make sure that all excess T/C wire stays within the hot zone area and that the hot zone exit point for the T/Cs is properly wrapped.
- 2) Plug the T/Cs into the jack panel inside the chamber making sure to install blank plugs for the unused slots.
- 3) Make sure that the Control T/C is extending at least 2" beyond the heating elements.
- 4) Ramp the furnace to the lowest survey temperature using a rate no lower than that used in typical processing cycles and stabilize the furnace.
- 5) After stabilization, balance the zones using the Ammeters and Voltmeters. Adjust the trim pots to bring the nine T/Cs within the required specification. Do not set any trim pot below 80%.
- 6) If there continues to be an imbalance from back to front, trim accordingly, and restart the entire test.
- 7) After all is stabilized at this first temperature, start a 30 minute data collection period during which no T/C shall deviate more than the high or low uniformity limits allowed by the Class being tested.
- 8) Ramp to the next temperature and hold for the 30 minute soak period. Do not adjust any trim pots at this and subsequent temperatures.
- 9) Continue onto the next required temperature if required and repeat as above.

10) The test will fail if any of the following occurs:

- a) A temperature reading during any soak period exceeds the allowable + or – tolerance.
- b) Any of the T/Cs fails
- c) A trim pot is adjusted at two different temperatures.

L) TUS RESULTS

DATA: Data collected by the TUS instrument shall be processed through the Eurotherm Chessell Temperature Uniformity Excel Utility or equivalent. This software uses only encrypted data from the Eurotherm Chessell Review software and incorporates the requirements of AMS 2750D and calculates the results, producing the final report. All data entered shall be recorded to the tenth digit of the nearest whole number. After a departure from set-point has been determined, the number may be rounded to the nearest whole number for reporting purposes. If the tenth digit is five it shall be rounded to the next even whole number.

CORRECTION FACTOR (CF) : Thermocouple correction factors shall be applied to correct the data. If thermocouples are made from spool material, the front and back data shall be averaged to determine the CF to be used. If the TUS temperature is performed between points of the thermocouple calibration report, the closest correction factor shall be used. If TUS temperature is performed midway between points of the thermocouple calibration report, the correction factor shall be interpolated. Interpolation shall be performed by determining the average CF of the points above and below the target point, then determining the midway point between the two averaged results.

ROUNDING: Numbers used to determine TUS results shall be recorded to the tenth digit. If calibration results in a 100<sup>th</sup> digit, the 100<sup>th</sup> shall be rounded to the nearest tenth digit.

ACCEPTABLE RESULTS: After a survey is completed, the high and low corrected T/C readings shall be determined with the offshoot of any channels higher than the soak temperature included in the “high” calculation. The uniformity tolerance (+or-) shall than be documented on the TUS certification.

OFFSET: Offset used to bring the range within the desired tolerance shall be entered into the controlling instrument and documented on the Controller Offset Report. Offset on the controlling instrument will be over and above any offset used during instrument calibration.

TUS REPORT: A TUS report shall be generated using the Eurotherm Chessell TUS software utility. ( See Attached Sample ). The software utility uses the encrypted data applying correction factors, documenting any overshoot, and provides the report to meet the requirements of AMS2750D.



CERTIFICATION : Once determined that the furnace meets uniformity requirements, a certification report shall be made available and posted for that furnace. The uniformity tolerance shall be identified for each range of use and all future work orders processed through that furnace shall not require more stringent uniformity tolerances.

UNACCEPTABLE RESULTS:

- 1) SENSOR FAILURE – As it is well known, sensors sometimes fail to work as desired. In addition, jack panels inside the furnace are prone to minor contamination that could affect the T/C readings. Sensor or jack panel failure shall be cause for re-processing a survey procedure if the amount of failed sensors exceeds the limitations as outlined in AMS2750D.
- 2) DRIFT/EQUIPMENT FAILURE: If results of the uniformity survey fall outside of the standard uniformity tolerance for a given furnace and the cause determined to be an actual drift in furnace uniformity, the furnace shall not be used for any further aerospace processing until the drift problem has been corrected and a subsequent TUS is completed to the satisfaction of the quality manager.

M) SAMPLE TEST REPORT

See below

Written By : William R. Jones – CEO – Solar Atmospheres Inc.

Real J. Fradette – Senior Technical Consultant – Solar Atmospheres Inc.

# Vacuum Heat Treat Furnace

## Temperature Uniformity Survey Report

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### Furnace Information

Furnace Identification:	Solar SF-98	Temperature Range:	538°C-1218°C
Furnace Categorization:		Temperature Tolerance:	±6°C
Class:	2		
Instrumentation Type:	C		
Work Zone Dimension:	3ft x 3ft x 4ft	Work Zone Volume:	36 Cubic Ft
Controlling Specifications:	AMS 2750D	<input checked="" type="checkbox"/>	Heating Method: Electric

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### Schedule

Date Tested:	07/23/2009	Next Due Date:	07/23/2010
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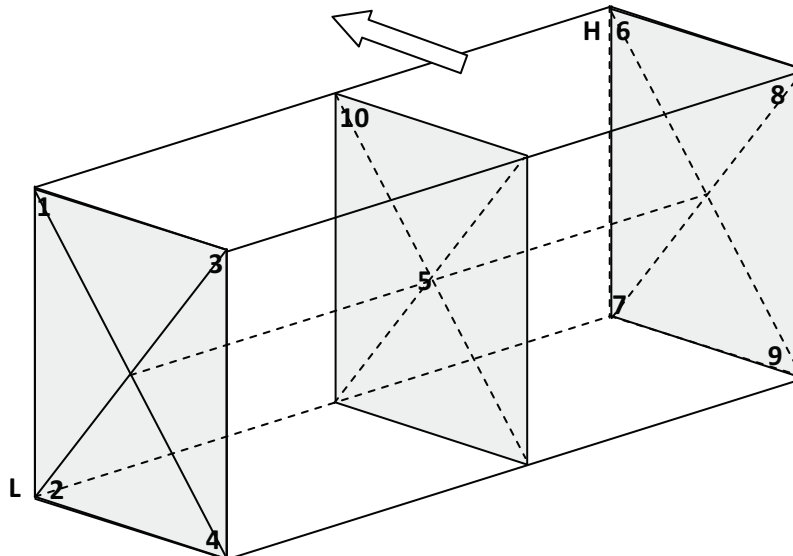
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### TUS Test Load Data

Test T/C Wire Type:	“K” Refrasil	Test T/C Identification:	KK-VBGVBG-20
Test Instrument Used:	Eurotherm 6180 Rec.	Temperature Set Points:	538°C 760°C 982°C 1218°C
Time in Furnace:	6:30 AM to 2:00 PM	Time Stabilized:	30 Minutes Each Setpoint

Correction Factors Applied to the Test Instrument Prior to the TUS.  
 Test Instrument C/F: -1 °C On DCP 552 all Temperatures

Thermocouple C/F: 538°C = -.6 °C	760°C = -1 °C
982 °C = 0 °C	1218 °C = -3.3 °C



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Temperature Uniformity Survey

Furnace Solar SF-98

07/23/2009

538°C

Date	Time	T/C 1	T/C 2	T/C3	T/C4	T/C 5	T/C 6	T/C 7	T/C 8	T/C 9	T/C10
07/23/09	8:10AM	530.0	532.7	532.4	528.3	532.4	528.1	531.8	532.6	528.8	538.8
07/23/09	8:12AM	532.4	533.5	533.7	530.0	533.5	529.8	533.3	533.6	530.6	539.0
07/23/09	8:14AM	533.8	534.3	534.8	531.4	534.5	531.3	534.6	534.9	532.2	539.2
07/23/09	8:16AM	534.9	534.8	535.6	532.6	535.1	532.5	535.6	535.9	533.5	539.2
07/23/09	8:18AM	535.7	535.3	536.4	533.6	535.9	533.6	536.5	536.6	534.5	539.2
07/23/09	8:20AM	536.5	535.8	537.1	534.5	536.3	534.5	537.3	537.1	535.5	539.2
07/23/09	8:22AM	537.2	536.0	537.6	535.3	536.7	535.3	538.0	537.6	536.4	539.3
07/23/09	8:24AM	537.8	536.4	538.2	535.9	537.2	536.0	538.6	538.1	537.1	539.3
07/23/09	8:26AM	538.3	536.7	538.7	536.6	537.6	536.7	539.1	538.6	537.8	539.4
07/23/09	8:28AM	538.6	536.8	538.9	537.0	537.5	537.1	539.4	538.7	538.2	539.3
07/23/09	8:30AM	539.0	537.0	539.2	537.4	537.8	537.5	539.8	539.0	538.6	539.3
07/23/09	8:32AM	539.3	537.1	539.5	537.7	538.1	537.9	540.1	539.3	539.0	539.3
07/23/09	8:34AM	539.4	537.1	539.7	538.0	538.1	538.2	540.3	539.4	539.3	539.2
07/23/09	8:36AM	539.7	537.3	539.9	538.3	538.3	538.5	540.6	539.6	539.6	539.3
07/23/09	8:38AM	540.0	537.8	540.3	538.8	538.6	539.0	541.1	540.1	540.2	539.5
07/23/09	8:40AM	540.2	537.8	540.4	539.0	538.6	539.2	541.2	540.2	540.3	539.5
07/23/09	8:42AM	540.2	537.8	540.4	539.0	538.8	539.3	541.2	540.1	540.4	539.4
07/23/09	8:44AM	540.3	537.8	540.5	539.2	538.8	539.5	541.3	540.2	540.6	539.4
07/23/09	8:46AM	540.4	537.9	540.6	539.3	536.6	539.6	541.4	540.2	540.6	539.4
07/23/09	8:48AM	540.4	537.8	540.6	539.3	538.7	539.6	541.4	540.3	540.7	539.4
07/23/09	8:50AM	540.4	537.8	540.6	539.3	538.7	539.7	541.4	540.3	540.7	539.3
07/23/09	8:52AM	540.4	537.7	540.6	539.4	538.9	539.8	541.5	540.3	540.8	539.3
07/23/09	8:54AM	540.5	538.0	540.8	539.5	538.9	539.9	541.6	540.5	540.9	539.3
07/23/09	8:56AM	540.6	537.9	540.7	539.6	538.9	539.9	541.6	540.4	540.9	539.4
07/23/09	8:58AM	540.5	537.9	540.9	539.8	538.8	539.9	541.4	540.4	541.0	539.4
07/23/09	9:00AM	540.6	537.9	540.8	539.6	538.9	539.9	541.7	540.5	541.0	539.6
07/23/09	9:02AM	540.9	538.2	541.2	539.9	539.2	539.9	542.0	540.7	541.3	539.7
07/23/09	9:04AM	540.7	538.1	541.0	539.8	539.1	540.1	541.7	540.8	541.1	539.4
07/23/09	9:06AM	540.6	538.0	540.8	539.7	539.0	540.1	541.6	540.4	541.0	539.4
07/23/09	9:08AM	540.8	537.8	540.7	539.5	538.9	540.0	541.3	540.1	541.0	539.3
07/23/09	9:10AM	540.8	537.6	540.6	539.4	538.7	540.0	541.0	539.9	540.7	539.1

Note: Above temperature values have test thermocouple and test instrument correction factors applied.

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Temperature Uniformity Survey

Furnace Solar SF-98

07/23/2009

760°C

Date	Time	T/C 1	T/C 2	T/C3	T/C4	T/C 5	T/C 6	T/C 7	T/C 8	T/C 9	T/C10
07/23/09	9:43AM	742.7	745.8	744.4	736.7	740.2	737.9	740.4	744.0	734.4	756.3
07/23/09	9:45AM	747.7	750.4	749.9	742.8	745.8	743.1	746.6	749.0	744.7	758.1
07/23/09	9:47AM	750.8	753.9	752.1	747.9	749.7	747.4	750.4	752.2	748.8	759.9
07/23/09	9:49AM	753.1	754.3	754.2	748.7	751.1	750.0	752.8	754.1	751.6	758.3
07/23/09	9:51AM	754.8	755.5	756.8	752.2	754.0	752.4	755.2	755.8	753.9	758.5
07/23/09	9:53AM	756.2	756.2	757.2	753.8	755.9	754.0	756.1	757.9	755.5	758.6
07/23/09	9:55AM	757.3	756.8	758.3	755.3	756.0	755.5	758.0	758.0	757.0	759.6
07/23/09	9:57AM	759.0	757.1	759.1	756.3	756.5	756.5	758.9	758.6	757.9	759.7
07/23/09	9:59AM	758.7	757.5	759.7	757.2	757.1	757.3	759.7	759.3	758.7	759.8
07/23/09	10:01AM	759.2	757.7	760.2	757.7	757.5	758.1	760.3	759.7	759.4	759.7
07/23/09	10:03AM	759.7	757.9	760.6	758.5	757.8	758.7	760.8	760.0	760.0	759.8
07/23/09	10:05AM	760.1	758.0	760.1	758.8	758.0	759.0	761.1	760.2	760.3	759.8
07/23/09	10:07AM	760.1	758.0	761.0	759.0	758.2	759.2	761.3	760.4	760.5	759.7
07/23/09	10:09AM	760.1	758.1	761.2	759.2	758.3	759.4	761.4	760.5	760.7	759.8
07/23/09	10:11AM	760.1	758.0	761.1	759.3	758.2	759.4	761.4	760.4	760.7	759.5
07/23/09	10:13AM	759.9	757.9	761.0	759.3	758.3	759.6	761.4	760.3	760.7	759.6
07/23/09	10:15AM	759.8	757.8	761.1	759.3	758.4	759.7	761.3	760.2	760.7	759.5
07/23/09	10:17AM	759.8	757.8	761.1	759.3	758.3	759.8	761.3	760.2	760.7	759.6
07/23/09	10:19AM	759.8	757.8	761.1	759.4	758.4	759.9	761.2	760.2	760.7	759.7
07/23/09	10:21AM	759.8	757.8	761.2	759.4	758.5	760.0	761.2	760.1	760.8	759.7
07/23/09	10:23AM	759.9	757.9	761.3	759.5	758.5	760.1	761.3	760.3	760.8	759.7
07/23/09	10:25AM	760.0	758.0	761.4	759.5	758.6	760.1	761.5	760.3	760.9	759.8
07/23/09	10:27AM	760.2	758.1	761.4	759.8	758.5	760.1	761.5	760.4	760.9	759.8
07/23/09	10:29AM	760.3	758.2	761.5	759.7	758.5	760.1	761.6	760.5	761.0	759.8
07/23/09	10:31AM	760.4	758.2	761.5	759.7	758.7	760.2	761.9	760.6	761.1	759.8
07/23/09	10:33AM	760.6	758.3	761.6	760.9	758.7	760.2	762.0	760.8	761.3	760.0
07/23/09	10:35AM	760.7	758.4	761.7	760.0	758.6	760.3	762.1	761.1	761.3	760.0
07/23/09	10:37AM	760.8	758.5	761.8	760.0	758.9	760.3	762.2	761.0	761.4	760.0
07/23/09	10:39AM	760.8	758.5	761.8	760.1	758.8	760.4	762.3	761.1	761.5	760.2

Note: Above temperature values have test thermocouple and test instrument correction factors applied

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Temperature Uniformity Survey

Furnace Solar SF-98

07/23/2009

982 °C

Date	Time	T/C 1	T/C 2	T/C3	T/C4	T/C 5	T/C 6	T/C 7	T/C 8	T/C 9	T/C10
07/23/09	11:03AM	966.1	967.1	969.3	962.2	970.2	962.2	969.3	971.5	978.0	985.1
07/23/09	11:05AM	977.5	978.1	978.7	973.0	977.4	972.7	977.0	977.8	978.0	985.6
07/23/09	11:07AM	980.2	979.9	981.2	976.5	979.3	976.4	980.2	980.4	978.6	985.9
07/23/09	11:09AM	982.4	981.4	983.4	979.4	980.9	979.2	982.8	982.5	981.1	986.2
07/23/09	11:11AM	983.8	982.1	984.7	981.1	981.7	981.0	984.2	983.5	982.7	986.3
07/23/09	11:13AM	984.6	982.5	985.2	982.0	981.9	981.9	985.1	984.1	983.6	986.1
07/23/09	11:15AM	985.1	982.7	985.8	982.7	982.3	982.7	985.7	984.7	984.3	986.1
07/23/09	11:17AM	984.1	981.8	985.1	982.4	981.6	982.5	985.4	984.2	984.0	985.3
07/23/09	11:19AM	984.4	982.1	985.6	982.9	982.0	983.0	985.7	984.5	984.4	985.6
07/23/09	11:21AM	984.8	982.1	985.6	982.9	981.9	983.0	985.7	984.4	984.3	985.4
07/23/09	11:23AM	984.7	981.9	985.5	982.9	982.0	982.0	985.8	984.8	984.4	985.5
07/23/09	11:25AM	984.6	981.8	985.5	983.0	982.0	983.0	985.8	984.4	984.4	985.5
07/23/09	11:27AM	984.5	981.8	985.6	983.1	981.8	983.1	985.8	984.6	984.4	985.4
07/23/09	11:29AM	984.5	981.8	985.6	983.1	981.9	983.2	985.9	984.4	984.5	985.5
07/23/09	11:31AM	984.4	981.7	985.6	983.1	982.0	983.1	985.8	984.5	984.4	985.4
07/23/09	11:33AM	984.2	981.5	985.4	983.0	981.9	983.1	985.8	984.4	984.4	985.4
07/23/09	11:35AM	984.1	981.4	985.4	983.0	981.9	983.2	985.7	984.3	984.4	985.4
07/23/09	11:37AM	984.0	981.5	985.4	983.0	981.9	983.2	985.5	984.1	984.3	985.4
07/23/09	11:39AM	983.9	981.3	985.4	982.9	981.9	983.3	985.4	984.0	984.2	985.4
07/23/09	11:41AM	983.8	981.3	985.3	982.9	981.9	983.3	985.3	984.0	984.2	985.4
07/23/09	11:43AM	983.8	981.3	985.4	982.9	981.9	983.4	985.3	983.9	984.2	985.5
07/23/09	11:45AM	983.8	981.3	985.4	983.0	982.0	983.4	985.3	984.1	984.2	985.5
07/23/09	11:47AM	983.9	981.4	985.5	982.9	981.9	983.4	985.4	984.0	984.3	985.6
07/23/09	11:49AM	984.0	981.4	985.6	983.0	982.0	983.4	985.5	984.0	984.3	985.5
07/23/09	11:51AM	984.1	981.6	985.6	983.1	982.1	983.4	985.7	984.2	984.4	985.6
07/23/09	11:53AM	984.3	981.6	985.7	983.1	982.1	983.5	985.8	984.3	984.6	985.5
07/23/09	11:55AM	984.6	981.8	985.8	983.3	982.2	983.5	986.0	984.6	984.7	985.8
07/23/09	11:57AM	984.7	981.9	985.9	983.4	982.3	983.6	986.2	984.7	984.8	985.9

Note: Above temperature values have test thermocouple and test instrument correction factors applied.



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Temperature Uniformity Survey

Furnace Solar SF-98

07/23/2009

1218 °C

Date	Time	T/C 1	T/C 2	T/C3	T/C4	T/C 5	T/C 6	T/C 7	T/C 8	T/C 9	T/C10
07/23/09	12:21PM	1199.4	1197.2	1200.9	1193.5	1197.2	1191.8	1198.9	1198.0	1196.1	1209.2
07/23/09	12:23PM	1210.5	1208.7	1211.5	1205.8	1207.6	1205.1	1208.7	1209.3	1208.0	1206.3
07/23/09	12:25PM	1212.6	1210.5	1214.0	1209.3	1209.7	1209.4	1214.0	1212.6	1212.0	1217.0
07/23/09	12:27PM	1214.6	1211.6	1216.0	1212.4	1211.1	1212.6	1216.3	1215.0	1214.1	1217.0
07/23/09	12:29PM	1215.0	1212.0	1216.3	1213.0	1211.1	1213.2	1216.8	1215.1	1214.3	1217.0
07/23/09	12:31PM	1215.0	1211.6	1216.3	1213.2	1211.2	1213.4	1217.1	1215.2	1214.5	1216.5
07/23/09	12:33PM	1215.0	1211.5	1216.3	1213.3	1211.4	1213.5	1217.3	1215.1	1214.3	1216.3
07/23/09	12:35PM	1215.0	1211.3	1216.2	1213.3	1211.6	1213.4	1217.5	1215.0	1214.4	1216.3
07/23/09	12:37PM	1214.6	1211.3	1216.4	1213.3	1211.8	1213.4	1217.6	1215.0	1214.4	1216.1
07/23/09	12:39PM	1214.6	1211.2	1216.1	1213.2	1212.0	1213.4	1217.6	1215.0	1214.3	1216.0
07/23/09	12:41PM	1214.6	1211.6	1216.1	1213.2	1212.3	1213.6	1217.8	1215.1	1215.0	1218.0
07/23/09	12:43PM	1216.5	1212.2	1218.0	1215.0	1212.5	1215.0	1218.0	1216.6	1216.1	1218.0
07/23/09	12:45PM	1216.7	1213.4	1218.0	1215.0	1212.7	1215.0	1218.1	1217.0	1216.3	1217.9
07/23/09	12:47PM	1216.8	1213.8	1218.3	1215.3	1213.3	1215.1	1218.2	1217.1	1216.4	1217.9
07/23/09	12:49PM	1217.1	1214.0	1218.4	1215.4	1213.4	1215.1	1218.3	1217.4	1216.6	1218.0
07/23/09	12:51PM	1217.2	1214.0	1218.4	1215.4	1213.3	1215.2	1218.5	1217.5	1216.7	1218.0
07/23/09	12:53PM	1217.3	1214.0	1218.5	1215.5	1213.5	1215.2	1218.7	1217.6	1216.9	1218.0
07/23/09	12:55PM	1217.3	1214.0	1218.5	1215.6	1213.5	1215.3	1218.7	1217.6	1216.8	1218.0
07/23/09	12:57PM	1217.4	1213.9	1218.6	1215.6	1213.4	1215.2	1218.8	1217.8	1216.9	1218.0
07/23/09	12:59PM	1217.4	1214.0	1218.6	1215.6	1213.6	1215.2	1218.8	1217.9	1216.8	1218.0
07/23/09	1:01PM	1217.4	1214.0	1218.9	1215.7	1213.6	1215.2	1218.9	1218.0	1217.0	1218.1
07/23/09	1:03PM	1217.4	1214.1	1219.0	1215.7	1213.6	1215.2	1219.0	1217.9	1217.0	1218.2
07/23/09	1:05PM	1217.5	1214.0	1218.7	1215.7	1213.6	1215.3	1218.9	1217.9	1217.1	1218.2
07/23/09	1:07PM	1217.4	1214.1	1218.9	1215.7	1213.6	1215.2	1218.9	1217.9	1217.1	1218.2
07/23/09	1:09PM	1217.5	1214.0	1218.7	1215.6	1213.6	1215.3	1218.9	1218.0	1217.1	1218.2
07/23/09	1:11PM	1217.5	1214.0	1218.7	1215.7	1213.6	1215.2	1218.8	1217.9	1217.0	1218.2
07/23/09	1:13PM	1217.4	1214.0	1218.9	1215.9	1213.6	1215.2	1218.8	1218.0	1217.0	1218.1
07/23/09	1:15PM	1217.4	1214.0	1218.7	1215.6	1213.6	1215.2	1218.7	1217.8	1217.0	1218.2
07/23/09	1:17PM	1217.3	1214.0	1218.7	1215.6	1213.4	1215.2	1218.7	1217.9	1217.0	1218.1
07/23/09	1:19PM	1217.3	1214.0	1218.6	1215.5	1213.5	1215.2	1218.6	1217.6	1216.9	1218.1

Note: Above temperature values have test thermocouple and test instrument correction factors applied.

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**Furnace SF-98 TUS Summary**

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Channel	1	2	3	4	5	6	7	8	9	10
High:	540.9	538.2	541.2	539.7	539.1	540.1	539.6	542.0	541.3	539.7
Low:	540.0	537.6	540.4	539.0	538.6	539.2	539.3	541.2	540.3	539.1
Avg:	540.5	537.9	540.8	539.4	538.9	539.7	539.5	541.6	540.7	539.4

**Furnace Uniformity @ 538°C**

Time Period: 8:40 through 9:10 7/23/09

Furnace uniformity resulting from the TUS: +3.3/ -0.4° C.

Overshoot 0°C

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Channel	1	2	3	4	5	6	7	8	9	10
High:	760.8	758.5	761.8	760.1	758.8	760.4	762.3	761.1	761.5	760.2
Low:	759.8	758.1	761.4	759.2	758.2	761.4	761.4	760.5	760.7	759.5
Avg:	759.5	758.3	761.6	759.7	759.5	761.9	761.9	760.8	761.1	759.9

**Furnace Uniformity @ 760°C**

Time Period: 10:09 through 10:39, 7/23/09

Furnace uniformity resulting from the TUS: +1.3 / -1.8C.

Overshoot 0°C

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Channel	1	2	3	4	5	6	7	8	9	10
High:	984.7	981.9	985.9	983.4	982.3	983.6	986.2	984.7	984.8	985.9
Low:	983.9	981.3	985.3	982.9	981.8	983.1	985.4	983.9	984.2	985.4
Avg:	983.3	981.6	985.6	983.2	982.1	983.4	985.8	984.3	984.6	985.7

**Furnace Uniformity @ 982°C**

Time Period: 11:27 through 11:57, 7/23/09

Furnace uniformity resulting from the TUS: +4.2 / -0.7° C.

Overshoot 0°C



Chan	1	2	3	4	5	6	7	8	9	
High:	1218.5	1214.1	1218.9	1215.9	1213.6	1215.3	1218.0	1218.0	1217.1	1218.2
Low:	1217.1	1213.9	1218.4	1215.4	1213.4	1215.1	1217.3	1217.3	1216.6	1218.0
Avg:	1217.3	1214.0	1218.7	1215.7	1213.5	1215.2	1217.7	1217.7	1216.9	1218.1

**Furnace Uniformity @ 1218°C**

Time Period: 12:49 through 1:19, 7/23/09

Furnace uniformity resulting from the TUS: +.9/ -4.1° C.

Overshoot 0°C

**Report Summary**

Are the TUS test results acceptable per applicable specification requirements?  
A "No" response requires explanatory comment in the notes section.

Yes

No

Notes:

1) Furnace TUS test results were within the required  $\pm 6^\circ\text{C}$  tolerance. No adjustments were necessary.

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Signature of Technician and Date

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Quality Assurance Acceptance and Date