

The Thermal Performance of the Isotech Saturn Furnace

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Introduction

The production of isothermal volumes of known temperature is the essence of both fixed point and comparison calibrations. The uncertainty of comparison calibrations is made up from:

1. The uncertainty of the isothermal volume.
2. The uncertainty of the measurement of its temperature.

The uncertainty of the isothermal volume is dependent on its stability and uniformity. The Saturn furnace is manufactured by Isothermal Technology and this article describes the tests made on the furnace to determine the uncertainty of its isothermal volume and how the uncertainty varies dependent on the calibration procedure used.

The Saturn

The Saturn was developed from the concept that the best way to calibrate thermocouples (T/Cs) was to have all the junctions touching one other. The only way to achieve this is to have them arranged like spokes in a wheel with the junctions at the centre, Fig. 1.

Fig. 1

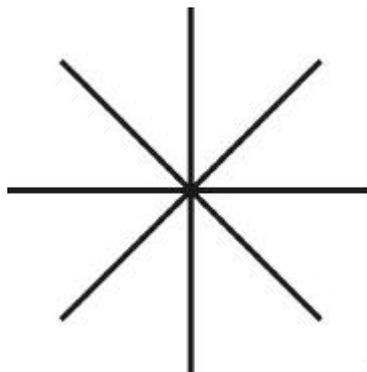
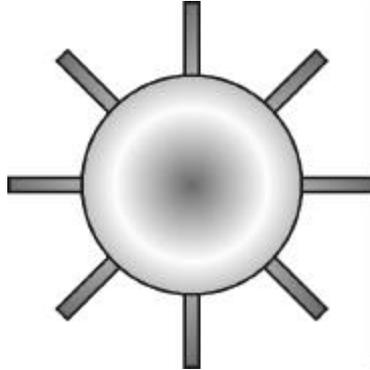


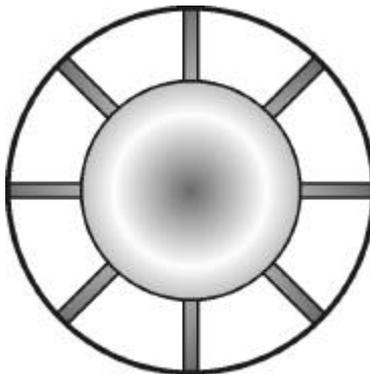
Fig. 2 shows the design of the Saturn's isothermal volume. This consists of a ceramic ball into which are moulded up to 16 ceramic tubes.

Fig. 2

Isotech term this 'the spider'. Spiders can be made to the customer's requirements including having a tube which passes through the ball so that T/Cs with multiple junctions along their length -as used in the semiconductor industry- can be calibrated.

The spider has the advantages of enabling good thermal transfer between the heat source and the T/Cs. This could not be achieved if the T/Cs are bundled in order to get their junctions together, and unlike most tube furnaces it also enables short T/Cs to be calibrated.

The spider is mounted inside a spherical ceramic shell which houses the heaters Fig.3. The Saturn has a temperature range of 100°C to 1300°C and requires only 3kW of power so normally no special supply circuits are needed.

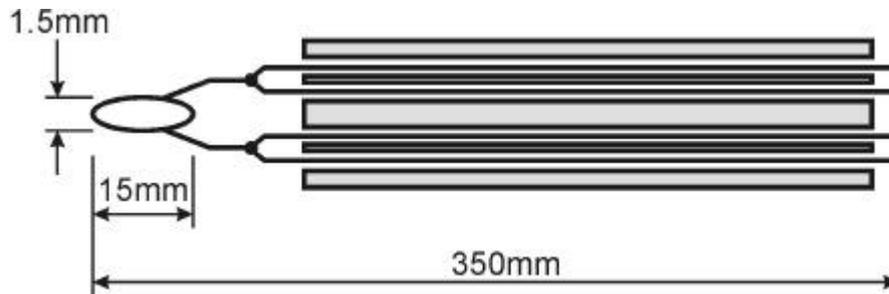
Fig. 3

The Saturn that was tested had an 8 legged spider, 4 x 8mm I.D. and 4 x 6mm I.D. The ball had the option of a Platinum foil covering which improves the temperature distribution in the isothermal volume and helps reduce electrical interference which can occur in poorly constructed T/Cs at high temperatures.

Test Method

The Saturn was thermally surveyed using type R T/Cs and Platinum resistance thermometers (PRTs) up to 850°C, and then only the T/Cs up to 1300°C. Although the Saturn is not meant to be used with PRTs the ones used were constructed so they were suitable for the tests Fig. 4. They were used because they gave a more accurate result than could be obtained with T/Cs. The PRT's construction consisted of special high temperature resistance elements, made by Thermal Developments International, mounted on 4 Platinum wires which were supported by a 5 bore ceramic tube, and there was no sheathing. This meant that the probes had a short isothermal depth of immersion and a fast time response.

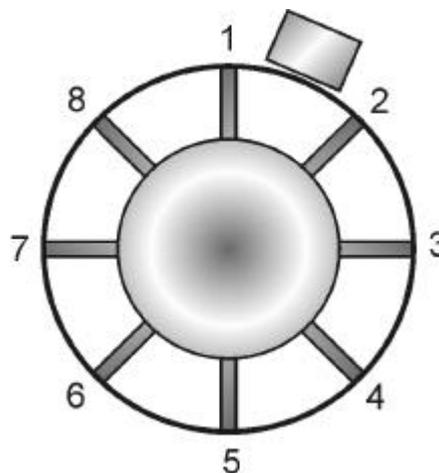
Fig. 4



The type R T/Cs had exposed junctions and were each housed in 4mm diameter 2 bore ceramic tube. They were referenced using an Isotech Zeref 136/6 and their outputs were measured using a Solartron 7075 digital multimeter.

The spider in the Saturn had its pockets numbered as shown in Fig. 5 with the even numbered pockets having a 6mm I.D and the odd numbered pockets having a 8mm I.D.

Fig. 5



Stability

The worst case absolute temperature stability (any one thermometer) of the Saturn was measured over its whole working temperature range and found to be $\pm 0.1^{\circ}\text{C}$ for 10mins and $\pm 0.2^{\circ}\text{C}$ for 60mins.

Pocket Differences

Table 1 shows the worst case pocket differences with Pocket 7 being the reference pocket against which the temperatures in the other pockets were compared. All the thermometers were at the ends of the pockets tested.

Table 1

Temperature $^{\circ}\text{C}$	Pocket Number That is Different From 7	Pocket Difference Using T/Cs $^{\circ}\text{C}$	Pocket Difference Using PRTs $^{\circ}\text{C}$
104.2	1	0.0	-0.048
104.2	3	0.0	-0.078
104.2	5	0.0	-0.015
354.1	1	0.0	+0.044
354.1	3	-0.1	-0.130
354.1	5	-0.1	+0.026
602.7	1	0.0	-0.103
602.7	3	-0.2	-0.200
602.7	5	-0.2	-0.068
851.5	1	-0.1	-0.253
851.5	3	-0.3	-0.233
851.5	5	-0.1	-0.119
1099.6	1	+0.1	N/A
1099.6	3	-0.4	N/A
1099.6	5	-0.2	N/A
1249.0	1	+0.2	N/A
1249.0	3	+0.4	N/A
1249.0	5	+0.2	N/A

Pocket Variations

Table 2 shows the worst case variation of temperature in any one pocket.

Table 2

Temperature °C	Temperature Difference From the Pocket Bottom			
	Distance From Pocket Bottom cm's			
	0	1	2	3
100	0	0.05	0.2	0.4
350	0	0.04	0.1	0.3
600	0	0.03	0.2	0.3
850	0	0.1	0.2	0.4
1100	0	0.1	0.1	0.1
1250	0	0.1	0.2	0.2

Uncertainty of the Saturn's Isothermal Volume

As stated above the uncertainty of an isothermal volume is made up of how stable and uniform it is. Table 3 shows a simple worst case assessment for the Saturn.

Table 3

Temperature °C	a Stability (60mins) ±°C	b Pocket Diff. ± °C	c Pocket Var. (3cm) ±°C	$\sqrt{0a^2+b^2+c^2}$ ±°C
100	0.2	0.078	0.4	0.45
350	0.2	0.130	0.3	0.38
600	0.2	0.200	0.3	0.41
850	0.2	0.3	0.4	0.54
1100	0.2	0.4	0.1	0.46
1250	0.2	0.4	0.2	0.49

An example of when this assessment would apply would be if a T/C was calibrated 3 cm's from the bottom of the worst pocket with the measurements being taken over 60 minutes.

Table 4 shows a typical case where the measurements are taken over 10 minutes, 2 standards are used to measure the mean temperature across the Saturn and the bottom 2cms of the pocket give a typical figure for the pocket variation.

Table 4

Temperature °C	a Stability (10mins) ±°C	b Pocket Diff. ± °C	c Pocket Var. (2cm) ±°C	$\sqrt{a^2+b^2+c^2}$ ±°C
100	0.1	0.039	0.2	0.23
350	0.1	0.065	0.1	0.16
600	0.1	0.100	0.2	0.24
850	0.1	0.15	0.2	0.27
1100	0.1	0.2	0.1	0.24
1250	0.1	0.2	0.2	0.30

Table 5 shows the best case where a standard and the unit under test (UUT) are in the same pocket, the measurements take 10 minutes, the minimum pocket differences are used and the 1cm pocket variations are used as the best estimate for this procedure.

Table 5

Temperature °C	a Stability (10mins) ±°C	b Pocket Diff. ± °C	c Pocket Var. (1cm) ±°C	$\sqrt{a^2+b^2+c^2}$ ±°C
100	0.1	0.015	0.05	0.11
350	0.1	0.026	0.04	0.11
600	0.1	0.068	0.03	0.13
850	0.1	0.119	0.1	0.18
1100	0.1	0.1	0.1	0.17
1250	0.1	0.2	0.1	0.24

Conclusions

The uncertainty of the Saturn's isothermal volume has been assessed for a Platinum covered 8 tubed spider and at worst it is about ±0.5°C and at best it is about ±0.2°C across the range 100°C to 1300°C, dependent on the calibration procedure used.