LM2500 & LM5000 T5.4 Exhaust Gas Thermocouples: Vibration Testing and Thermal Cycling

Scope

This document summarizes Conax Technologies' (CT) product qualification testing for GE aeroderivative turbines LM2500 & LM5000 T5.4 exhaust gas thermocouples used for land-based power generation applications.

Product Type Details

The CT LM2500 & LM5000 T5.4 exhaust gas sensors are engineered from state-of-the-art materials that are fully interchangeable with OEM products.

LM2500 & LM5000 T5.4 exhaust gas sensor		
Design Parameter Type	**Description**	**Specification**
Thermocouple Type	Type K	+/- 0.4% accuracy, special limits of error per ASTM E230
No. of Junctions & Type	2 & Ungrounded	Dual staggered junction
Material – Thermocouple Sheath	Hastelloy® X	UNS Number N06002

Note: GE Reference Part number: L44830P01

Purpose

Three LM2500 & LM5000 T5.4 exhaust gas sensors were subjected to 12g vibration dwell of sensor resonance and Thermal cycling up to 1700 ºF. Observed and recorded sensor performance.

Test Conditions

1. Three LM2500 & LM5000 T5.4 exhaust gas sensors are built as per CT assembly procedures with rigorous in-process inspection and quality control procedures
2. Below table 1, illustrate different acceptance tests conducted before sensors are subjected to vibration testing at 12g and high temperature thermal cycling up to 1700 ºF

Acceptance Testing		
Test Type	**MIMS Only***	**Sensors***
Calibration	X	-
Insulation Resistance	X	X
Polarity	X	X
Continuity	X	X
Water Immersion	-	X
Loop Resistance	-	X
HiPot Test (Dielectric)	-	X

* - X represent type of testing conducted

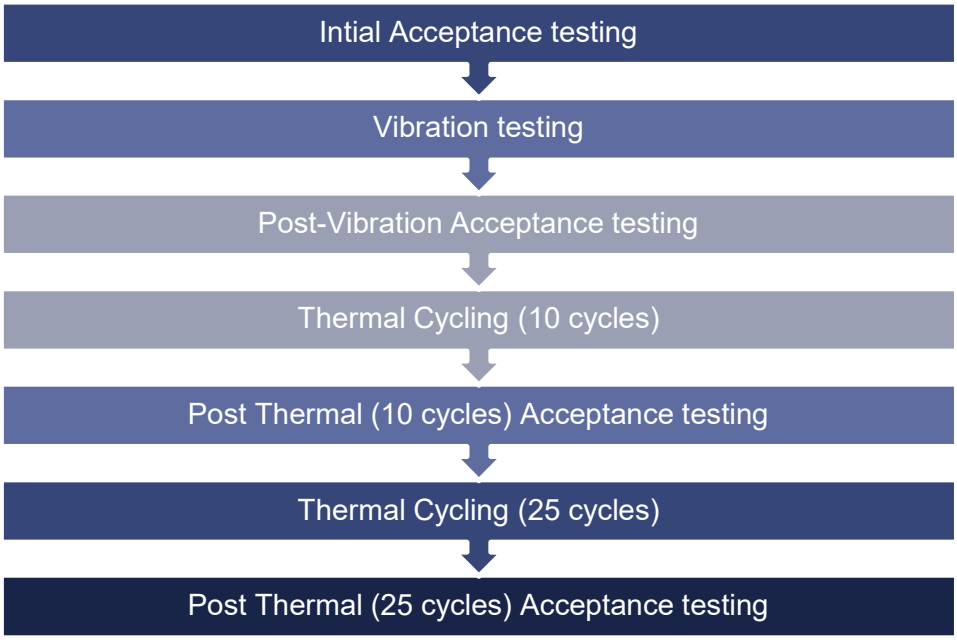
Table 1

Unless otherwise specified, tests were conducted at room ambient conditions of temperature, pressure, and humidity.

Temperature: 0 - 95ºF
Pressure: 14.7±2 PSIA
Humidity: 10 - 90%

Test Methods

- Three sensors are subject to sequence of tests, starting from acceptance testing (as stated in above section), then vibration testing and thermal cycling.
- Below schematic illustrates testing sequence



Vibration Test Methods

- Figure 1 illustrates Sensor vibration test set-up.
- A one (1) mA current was imposed through each sensor under test and the continuity of each sensor monitored throughout duration of vibration testing
- Each Sensor were subjected to a resonant search in the X, Y & Z-axis between 10 Hz and 1500 Hz at 1g for 30 minutes.
- The amplitude of the resonances was measured at each axis and determined to be greater than two (2) times the input amplitude, thus a resonance dwell was performed on the sensor on each axis one at a time.

Figure 1

- Each sensor is exposed to a 12g resonance dwell for 10 million cycles at each of the resonance's show in table 2 for X, Y and Z.
- Upon completion of the post vibration testing, Sensors are subjected to acceptance testing.

Vibration testing – Resonance (Hz)			
Sensor	X-axis	Y-axis	Z-axis
1	260.5	365.9	1419.5
2	546.3	914.4	754.6
3	619.3	996.8	1423.5

Table 2

Thermal cycling Test Method

- 1450 °F to 1700 °F temperature range represents typical pattern of LM2500 & LM5000 T48 sensors
- Each sensor is subjected to ten (10) cycles between 1450 ±25°F to 1700 ±25°F thermal cycling
- Each Sensor is mounted to an aluminum fixture which was then mounted to a pneumatic slide as shown in Figure 2.
- Sensor is controlled using an automated computer-controlled furnace cycle program.
- Sensor is inserted in the furnace using slide mechanism and allowed to achieve a temperature of 1700 ±25°F. Then, Sensor is slid out of the furnace until it reached a cool down temperature of 1450 ±25°F. This process constituted one (1) cycle.
- The process was repeated for a total of ten (10) cycles and This is considered as thermal cycling cycle # 1
- Once completion of thermal cycling cycle# 1, all three sensors are tested for acceptance testing.
- Then, all three sensors were subjected to an additional 25 thermal cycles as stated above and this is considered as thermal cycling cycle # 2
- Once again, after completion of thermal cycling cycle# 2, all three sensors are tested for acceptance testing.

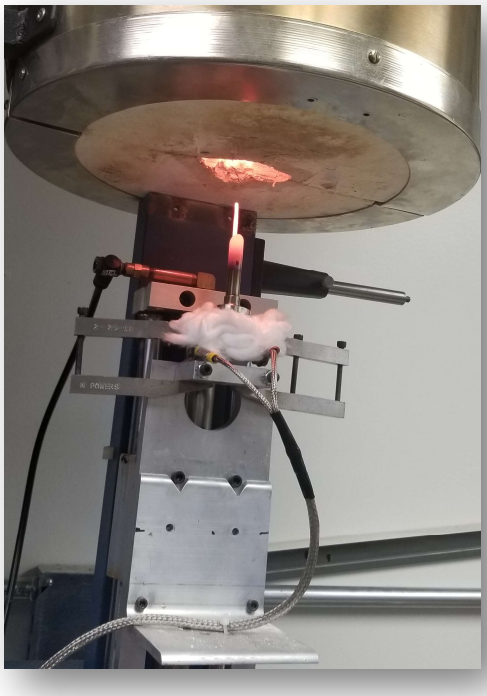


Figure 2

Test Results

Initial Acceptance test				
Test Type	Test Criteria	Sensor 1	Sensor 2	Sensor 3
Insulation Resistance	Minimum acceptable IR: $1x10^9\Omega$ 500 VDC for 30 seconds minimum	Pass	Pass	Pass
Polarity	Pass or Fail: Output Voltage response to temperature	Pass	Pass	Pass
Continuity	Pass or Fail: Verified as part of polarity test	Pass	Pass	Pass
Water Immersion	Min. Acceptable IR : $1x10^8\ \Omega$ Pre-heat→Water immersion for 30 minutes→ IR test	Pass	Pass	Pass
Loop Resistance	Acceptable resistance range: 0.44 – 0.83 Ω Sensor stud to stud	Pass 0.58 Ω	Pass 0.80 Ω	Pass 0.68 Ω
HiPot Test (Dielectric)	Max allowable leakage: 5 mA 300 VDC for 60 seconds	Pass 0.01 mA	Pass 0.01 mA	Pass 0.01 mA

Table 3

Post-Vibration Acceptance test				
Test Type	Test Criteria	Sensor 1	Sensor 2	Sensor 3
Insulation Resistance	Minimum acceptable IR: $1x10^9\Omega$ 500 VDC for 30 seconds minimum	Pass	Pass	Pass
Polarity	Pass or Fail: Output Voltage response to temperature	Pass	Pass	Pass
Continuity	Pass or Fail: Verified as part of polarity test	Pass	Pass	Pass
Water Immersion	Min. Acceptable IR : $1x10^8\ \Omega$ Pre-heat→Water immersion for 30 minutes→ IR test	Pass	Pass	Pass
Loop Resistance	Acceptable resistance range: 0.44 – 0.83 Ω Sensor stud to stud	Pass 0.54 Ω	Pass 0.78 Ω	Pass 0.69 Ω
HiPot Test (Dielectric)	Max allowable leakage: 5 mA 300 VDC for 60 seconds	Pass 0.01 mA	Pass 0.01 mA	Pass 0.01 mA

Table 4

Post Thermal (10 cycles) Acceptance testing				
Test Type	Test Criteria	Sensor 1	Sensor 2	Sensor 3
Insulation Resistance	Minimum acceptable IR: $1x10^9\Omega$ 500 VDC for 30 seconds minimum	Pass	Pass	Pass
Polarity	Pass or Fail: Output Voltage response to temperature	Pass	Pass	Pass
Continuity	Pass or Fail: Verified as part of polarity test	Pass	Pass	Pass
Water Immersion	Min. Acceptable IR : $1x10^8\ \Omega$ Pre-heat→Water immersion for 30 minutes→ IR test	Pass	Pass	Pass
Loop Resistance	Acceptable resistance range: 0.44 – 0.83 Ω Sensor stud to stud	Pass 0.55 Ω	Pass 0.72 Ω	Pass 0.67 Ω
HiPot Test (Dielectric)	Max allowable leakage: 5 mA 300 VDC for 60 seconds	Pass 0.01 mA	Pass 0.01 mA	Pass 0.01 mA

Table 5

Post Thermal (25 cycles) Acceptance testing				
Test Type	Test Criteria	Sensor 1	Sensor 2	Sensor 3
Insulation Resistance	Minimum acceptable IR: $1x10^9\Omega$ 500 VDC for 30 seconds minimum	Pass	Pass	Pass
Polarity	Pass or Fail: Output Voltage response to temperature	Pass	Pass	Pass
Continuity	Pass or Fail: Verified as part of polarity test	Pass	Pass	Pass
Water Immersion	Min. Acceptable IR : $1x10^8\ \Omega$ Pre-heat→Water immersion for 30 minutes→ IR test	Pass	Pass	Pass
Loop Resistance	Acceptable resistance range: 0.44 – 0.83 Ω Sensor stud to stud	Pass 0.53 Ω	Pass .82 Ω	Pass 0.67 Ω
HiPot Test (Dielectric)	Max allowable leakage: 5 mA 300 VDC for 60 seconds	Pass 0.01 mA	Pass 0.01 mA	Pass 0.01 mA

Table 6

Sensor tests that were conducted beyond the product's recommended operating parameters and do not modify product performance range. All the tests were performed to consider a specific set of vibration and thermal cycling conditions using Conax proprietary processes. Conax Technologies makes no warranties regarding these selected Laboratory and testing conditions or the results attained there from. Laboratory tests cannot represent actual operating conditions.

Reference document

1. ASTM E112, Test Methods for Determining the Average Grain Size.
2. ASTM E585-99, Standard Specification for Sheathed Base-Metal Thermocouple Materials.
3. ASTM E608-00, Standard Specification for Metal Sheathed Base-Metal Thermocouples.
4. ASTM E230-98, Standard Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples.
5. ASTM E220-96, Standard Method for Calibration of Thermocouples by Comparison.
6. ASTM E839-89, Standard Methods of Testing Sheathed Thermocouples and Sheathed Thermocouples Material.