◈ 11.1 INSPECTIONS AND TESTING : For the assurance of the quality of Sensor different type of testing is done which are (i) Type Test & (ii) Routine Test.

(i) TYPE TESTS : Tests carried out to prove conformity with the requirements of the specification are called as type test. These are intended to prove the general qualities and design of a given sample of sensor.

(ii) ROUTINE TESTS :- Tests carried out on each sensor as per sampling plan.

The major tests for the assurance of the quality are as follows :

(A). APPEARANCE AND STRUCTURE CHECK : Visual inspection is made to confirm that the thermocouple assembly is in conformity with the specification, drawing and constituent materials. Visual checkings are conducted on the finish of joints, junctions, welds, name/tag plates and other parts to confirm that there is no error, flaw dirt or irregularity on the surface finish. If necessary, dye penetration check, hydrostatic pressure test and X-ray inspection can be made on welded and joint parts.

(B). DIMENSIONAL CHECK : Unless otherwise specified, dimensional check is made in accordance with the following tables using Vernier Caliper, Straight Measure and Gauges.

Non MI Unit : mm		MI Unit : mm	
Nominal Length	Tolerance	Nominal Length	Tolerance
Below 1,000	±3.0	Below 250	±3.0
1,000 ~ 2,000	±5.0	250 ~ 1,000	±5.0
Over 2,000	±7.0	Over 1,000	±1.0%

(C). INSULATION RESISTANCE TEST :- Insulation Resistance Test is conducted using a Super megohmeter applying steep temperature gradient on sensor assembly immersed in a boiling water bath so as to accelerate condensation of moisture that might be entrapped in the assembly. This enables the measurement of insulation resistance of the assembly very precisely between terminal and sheath.

Sensor	Voltage	Insulation Resistance
Non MI	at room Temperature DC 500V	More than 100MΩ
MI Dia-2.0 and below	at room Temperature DC 100V	More than 100MΩ
MI Dia-3.0 and above	at room Temperature DC 500V	More than 100MΩ
RTD	at room temperature DC 250V	More than 100MΩ
T/C	at 560°C DC 500 V	More than 5MΩ

(D). EMF CALIBRATION TEST :- These tests can be made either by comparison method with standard thermocouples /RTD or absolute method using fixed point standards on every unit or batch at the pre-set three temperature points depending on the types of sensor.

(E). PRESSURE TEST (FOR SEALED ELEMENTS ONLY):- The element shall be tested in a hydraulic test chamber containing water and ice in equilibrium and connected electrically to an appropriate indicator. The pressure of the fluid in the chamber shall be raised to 35kgf/cm^2 and shall be maintained for 15 minutes.

The resistance or EMF of the element shall not vary significantly from that appropriate to the equilibrium temperature corresponding to the pressure applied and when subsequently removed from the chamber, the element shall pass insulation resistance test and accuracy test.

(F). IDENTIFICATION TEST ON THE THERMOCOUPLE TYPE AND POLARITY

Either by dipping thermocouple assembly into the above boiling water bath or applying hot air-blow/flame heat on the beaded Thermocouple at its hot or cold end to have it generate EMF, which allows to indicate specific type of thermocouple through Temperature vs. EMF Table. A high resolution D.C. circuit testing instrument is used to identify the type of thermocouple and polarity of the thermocouple leg and terminal.

(G). OTHERS :- Loop Resistance test, voltage withstand test, X-ray test, vibration test, pressure test, Helium leak test, etc. can also conducted upon request.

◈ 11.2 CALIBRATION

Calibration may be defined, in general, as the process for determination, by measurement or comparison with a standard, of the correct value of each scale reading on a meter or other measuring instrument; or determination of the settings of a control device that correspond to particular values of voltage, current, frequency, pressure, flow or some other output.

In performing a calibration of an instrument, the following steps are necessary:

- Examine the construction of the instrument, identify and list all the possible inputs.
- Decide, as best as one can, which of the inputs will be significant in the application for the instrument which is to be calibrated.
- Procure apparatus that will allow all significant inputs to vary over the ranges considered necessary.
- By holding some inputs constant, varying others, and recording the output, that develops static input- output relations.

11.2.1 CALIBRATION METHOD : - Two types of methods are used for calibration of temperature sensors, one with fixed point cell and another by comparison method.

11.2.1 (a) COMPARISON METHOD: - In this method highly accurate PRT, T/C or any other standard (if required) is taken, both standard and UUC (unit under calibration) are kept at the same thermal environment

After stabilization of the calibration bath readings of standard and UUC are taken and by comparison of standard and UUC, deviation is found.

11.2.1 (b) FIXED POINT CELL : - For the very highest accuracy, comparison calibration is replaced by primary or fixed point calibration, fixed points cells are designed to realize the liquid-solid equilibrium temperatures of certain high purity metal elements, for calibration of thermometers at the ITS-90 fixed points.

11.2.2 UNCERTAINTY: - Uncertainty is defined as the estimate characterizing the range of values within which the true value of measurand lies (measurand is defined as the quantity which is subject to measurement) or in other words uncertainty is the estimate of how close you are to the true value.

◈ 11.3 TEMPERATURE CALIBRATION

provides a means of quantifying uncertainties in temperature measurement in optimize sensor and/or system accuracies.

In Temperature calibration 3 basic things are required viz:

1. Temperature sensor
2. Measuring instruments and
3. Temperature source

11.3.1. TEMPERATURE SENSOR :- For lower temperature calibration Platinum resistance detector is used in the form of SPRT and RTD, these are very stable and accurate. For higher Temperature calibration Noble metal Thermocouple is used like R, S type thermocouple. These sensors must have good Accuracy and repeatability. The detail of these temperature sensors is described in chapter 3rd and 4th of this handbook.

11.3.2. MEASURING INSTRUMENTS: - These instruments measures the output of the sensors, they must have high resolution and good accuracy.

11.3.3. TEMPERATURE SOURCE: - There are two types of sources used for calibration they are (1) secondary source and (2) primary source. Fix point cell is a primary source while stirred liquid bath, dry block bath, fluidized bath etc are secondary sources. These entire sources must have good stability and homogeneity.

11.3.3 .1 SECONDARY TEMPERATURE SOURCES

11.3.3.1(a) DRY BLOCK BATHS: - Dry block calibrators provide the most convenient, portable facilities for checking temperature sensors and they usually achieve reasonably rapid heating and cooling.

The units consist of a specially designed heated block within which is located an insert having well for the probe. The block temperature is controlled electronically to the desired temperature. The whole assembly is housed in a freestanding case. Although the block temperature is accurately controlled, any indication provided should be used for guidance only. As with any comparison technique, a certified sensor and indicator should be used to measure the block temperature and used as a reference for the test probe.

Black body furnace is also a dry bath, but used in non contact calibration. The black body furnace has been designed to provide stable and accurate temperature to enable professionals to calibrate non contact radiation pyrometer by comparison method.

11.3.3.1 (b)STIRRED LIQUID BATHS: - The comparison calibration accuracy can be considerably greater than that which can be achieved in any metal block bath. It also has a larger calibration area, that allows more probes to be calibrated and a greater immersion depth which provide a superior thermal environment for probe immersion since air gaps exists between the probe and the medium. Thermal coupling is therefore much better than the alternatives described and as a result of stirring heat distribution is very even throughout the liquid.

Water is used for temperature from 0° to 80°C and oil for temperature upto 300°C, various molten salts and sand baths are used temperatures in excess of 300°C.

Negative temperature bath or ice bath is mainly used for RTD calibration which provides negative temperature for low temperature calibration application. In this device a compressor & CFC gas is used for cooling purpose. Methanol is used as a medium for temperatures below 0°C.

11.3.3.1(c) FLUIDIZED CALIBRATION BATH: - These baths has a very wide operating range, large immersion depth and high accuracy work capability.

The bath contains a dry powder that is motivated into a fluid like state by flow of air. The bath is sealed which eliminates powder contamination of the laboratory. The continuous flow of the powder gives excellent temperature uniformity.

11.3.3.2 PRIMARY TEMPERATURE SOURCES

11.3.3.2.1 FIXED POINT CELL: -

Fixed points are the most accurate devices available for defining a temperature scale. Fixed-point devices utilize totally pure materials enclosed in a sealed, inert environment; they are usually fragile and need to be handled with care. They work in conjunction with apparatus, which surrounds them and provides the operational conditions required for melting and freezing to obtain the reference temperature. The housing, incorporate isothermal blocks with wells into which the probes are placed. Since physical laws define fixed-point temperatures, comparison of the test probe to a reference probe is not required.

ITS 90 fixed points include:

Boiling point of Nitrogen	-195.798°C
Mercury triple point	-38.8344°C
Triple point of water	000.01°C
Melting point of Gallium	029.7646°C
Freezing point of Indium	156.5985°C
Freezing point of Tin	231.928°C
Freezing point of Lead	327.462°C
Freezing point of Zinc Freezing point of Antimony	419.527 630.63°C
Freezing point of Aluminum	660.323°C
Freezing point of Silver	961.78°C

◈ 11.4 COMMON SOURCES OF ERRORS DURING CALIBRATION

11.4.1 RTD ERRORS:

11.4.1 (a) IMMERSION ERROR: - With the calibration of PRT stem conduction is likely to be the main sources of error.

Immersion or stem conduction errors are caused by the flow of heat along the thermometer sheath. If the thermometer is immersed into a hot body the flow of heat will be from the body along the thermometer sheath into the ambient surroundings. Conversely if the thermometer is placed into a body cooler than the surroundings then heat will flow along the sheath into the cool body. The temperature profile along the stem can lead to errors.

11.4.1 (b) LEAD RESISTANCE: - Two wire devices are best avoided whenever possible. The extension wire becomes part of the thermometer and as the lead length becomes greater so does the lead resistance error.

Three wires devices can be used to largely overcome errors introduced by the extension wires. Such devices can easily be connected to electrical circuits such that the lead wire resistance cancels each other. However slight errors remain due to variations in the resistance of the individual wires.

Four-wire connection offers further improvements but industrial instruments do not always have input connections designed for four wire connection, although laboratory instruments commonly do.

11.4.1. (c) THERMAL LAG: - Errors due to thermal lag are those caused by the delay in the thermometer to respond to a change in temperature. For a thermometer which is in a close fitting pocket of a metal block bath (which exhibits good temperature stability) it would be usual for the thermometer to reach its final value within a few minutes. A simple observation is the best means to confirm this for new or unknown sensors.

11.4.1 (d) THERMAL CAPACITY: - When a thermometer is placed into a metal block baths, heat will always flow into the thermometer, or from it. This loading of the block may cause the block to change its temperature, although the temperature controller of the block will compensate to some extent.

11.4.1. (e) SELF HEATING: - Measuring the resistance of a PRT requires an electrical current to be passed through the sensing resistor. The resultant power dissipated in the sensor (I^2R) is often warned against. In practice, for industrial probes with modern instrumentation, it is unlikely to cause significant error.

11.4.1 (f) DC ERROR: - Small DC voltage may be generated in PRTs due to thermoelectric effects caused by the joining of dissimilar metals in the construction of the PRT.

11.4.2 THERMOCOUPLE ERRORS: -

11.4.2 (a) HOMOGENEITY (WIRE UNIFORMITY): - With thermocouples the main error lies not with stem conduction but with errors arising from inhomogeneity of the thermocouples wires. Therefore for reliable and consistent results the wires must be homogenous, i.e. the wire must have uniform properties, throughout.

11.4.2 (b) LEAD RESISTANCE:- This is generally less of a problem with thermocouples than PRTs particularly with modern instrumentation. Manufacturers of the thermocouple instruments may specify a maximum loop resistance.

11.4.2 (c) THERMAL LAG : - For thermocouple built into large sheaths or thermowells, this effect needs to be as considered for PRTs. For thermocouple constructed from fine wires the thermal lag tends not to be significant, indeed such a sensor may be selected for its fast response properties.

11.4.2 (d) THERMAL CAPACITY: - As with thermal lag this may be an issue for larger assemblies but not for fine wires thermocouples.

11.4.2 (e) COLD JUNCTION COMPENSATION (CJC) ERROR: - For simple instruments the CJC is built into the device, e.g a hand held digital thermometer. This will typically consist of a temperature sensing device that measures the temperature of the junction of the thermocouple wire and the instrument. In industrial application where many junctions need to be referenced, it is common to use an external thermocouple referencing equipment. For precision use in a laboratory, the CJC might be achieved at the ice point which could be a well-prepared ice flask, or, more conveniently the zero reference bath, which automatically provides a high accuracy 0°C reference.

With an external reference junction wire matching errors can be introduced. This is an error caused by the difference between the wires used for the cold junction and the wire of the measuring junction.

For highest accuracy work, in the laboratory, the thermocouple can be made so that the actual thermocouple wire runs continuously from the measuring junction to the cold junction.