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Online Calibration Techniques For Core Thermocouples

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Abstract

ANSI type-K thermocouples are being used for continuous monitoring of sodium temperature in fast reactors. These thermocouples are capable of withstanding high neutron dosage as well as γ radiation. The thermocouples are susceptible to de-calibration after prolonged exposure to such harsh environment. The surface of the thermocouples also becomes radioactive, making it difficult to take them, out for calibration in a lab. Hence, it is essential to have some automatic means of calibrating them to ensure the measurements made by these thermocouples are within the accuracy limits. The performance and characteristics of the thermocouples is known early enough before effecting plant's measurement process using Cross-calibration technique online and in-situ. Cross-calibration technique has evolved as one of the best online techniques and can be easily implemented in the plant computer uses different sensors determining the same process parameter for calibration. We have found few outliers or misbehaving thermocouples that are exposed to radiation environment.

Keywords: Thermocouple, cross-calibration, outlier, deviation.

Introduction
The Fast Breeder Test Reactor (FBTR) is a 40MWt, loop type, sodium cooled fast breeder reactor. Below figure1 is showing the schematic view of how the heat is transferred. Two primary loops and secondary loops represented in the schematic

diagram are responsible for making the heat produced by the reactor get removed. Heat transfer happens from primary to the secondary loop with once-through stream generated modules and then to the steam water circuit containing of a turbine generator and a 100% dump condenser.

Sodium streams from the lowest of the Reactor Vessel and chills each Fuel Sub Assembly and exits through the highest through primary loop. Action of Na temperature at the outlet of each Fuel Sub Assembly is critical to verify that the each FSA is sufficiently chilled off. For this reason, In-Core Thermocouples (ICT) square measure gave and their yields square measure observed with the aid of a plant computer. These ICTs take a critical part in making certain assurance of the reactor. The vicinity of every nucleon and gamma flux inside the reactor's center blessing a cruel setting for these thermocouples that get to be radioactive inferable from their introduction to corpuscular radiation. Further, presence of Na stores on sensors surface can make it troublesome to handle. Subsequently, these ICTs, once put in inside reactor, aren't being taken out from field for logged off institutionalization. To preclude the radiation hurt, adjacent to the In-center thermocouples outlet thermocouples likewise are been graduated amid this work.

To ensure the safety of the plant it is required to calibrate these temperature sensors periodically. Hence a suitable technique is needed to calibrate these thermocouples online. Cross-calibration is one such technique in which, the sensor/instrument not being taken out, removed or isolated from the process for performing calibration

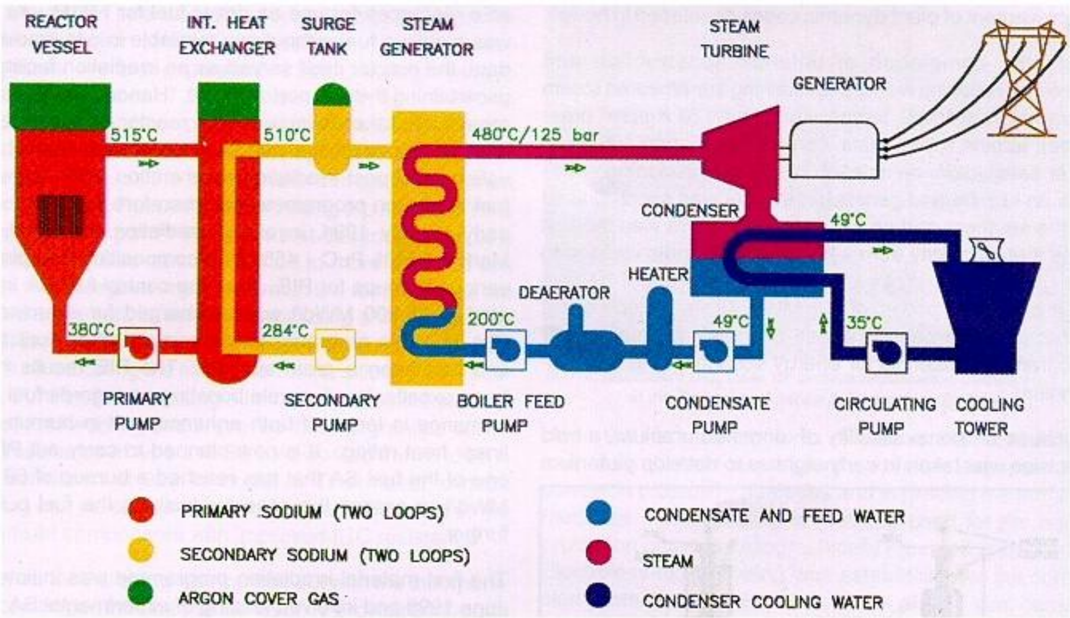

Figure 1: Source: 25 years FBTR published by Scientific Information and Resource Division, IGCAR, Kalpakkam**.**

Literature Survey

Out of 84 fuel subassembly positions in FBTR, sodium outlet temperature of all the sub assembly positions are monitored with 2 number of insulated Mgo ungrounded K type thermocouples of diameter 1mm, attached in thermowells[4]. The central fuel sub assembly has four redundant thermocouples mounted on central canal plug. For fast response these four thermocouples are immersed in sodium directly Type K thermocouples are hard in nature, can withstand to nuclear radiation with its inbuilt immunity. So, these are preferably chosen to measure the sodium temperature. Their linearity is an additional benefit for using them in nuclear power plants.

The core thermocouples work in highly damaging environment. Ref 1 reports the effect of high temperature (> 600 °C) , and fast flux irradiation exceeding 2 x 10^{22} nvt, which is measure of flux and time. γ-radiation of the order of 1x 10^{8} is also reported. Naturally prolonged exposure to harsh environment will have the tendency to affect the temperature-emf relationship of the thermocouple. FBTR has reported a number of problems with core thermocouples. Frequent failure of 1mm thermocouples without thermo-wells necessitated their replacement with 2 mm thermocouples in the early 00s[1]. The processing of thermocouples by isolation amplifiers resulted in normal-mode pick-up which necessitated design of special isolation amplifiers with 6-pole filter reduced the error due to noise pick-up, as ported by Sridhar & Kalyan Rao in [2]. Recently, during the 23rd power campaign in Jan, 2015, a few thermocouples have shown error of the order of 5 ˚C at temperatures above 400 ˚C, which seems to be originating from the thermocouples themselves. In addition, it was also seen that for some fuel sub-assemblies, the difference in reading between X and Y thermocouples is unacceptably high (of the order of 7 °C), even though they are very close to each other, kept in the same thermowell and are exposed to the same sodium stream.

The best way to check the healthiness of a thermocouple, which has already been installed in the field, is to remove it from its location, and use a dry-block or wet-block thermocouple calibrator. If the thermocouple is healthy, then it may be put back; otherwise it is to be replaced by a spare calibrated thermocouple.

However, the core thermocouples of FBTR can only be removed for safe disposal and not for lab calibration; hence, there is a need to ascertain their healthiness. The cross-calibration technique [2] is one such technique. One such attempt of cross-calibration of sore thermocouple signals was reported by Saha and Sridhar [3]. The technique was used for the complete measurement channel which includes the core thermocouple, the isolation amplifier and the analog input card. Though the maximum outlier determined thus was found to be 1.2°C which was within acceptable limits, subsequent high power operation revealed high errors necessitating recalibration. Further, it was decided to exclude the isolation amplifier and the analog input card from the analysis, as they have the tendency to mask the errors in the thermocouples. Hence, it was decided to directly measure the thermocouple output in the mV range and analyze for any outlier. This process describes the cross-calibration techniques applied only at the sensor level.

In addition to measurement of mV signals from core thermocouples, measurement of loop-resistance of thermocouples is also a useful technique to ascertain the healthiness of core thermocouples.

There are many techniques for calibrating and finding the response time of temperature sensors online. It includes techniques like Cross-calibration, Johnson noise technique, LCSR, Measurement of self-heating index. Cross-calibration technique is chosen in the proposed work [5].

Proposed Work

The cross calibration technique can be applied to for in-situ calibration of devices like RTDs and Thermocouples, when there are enough redundant sensors that measure the same process parameter.

The cross-calibration technique for temperature devices should be carried out at isothermal condition, i.e., when the sodium temperature seen by all the concerned thermocouples is ideally the same. This means that the reactor must be in shutdown condition and the residual power in the fuel sub-assemblies be in mW range.

In addition, during this process, it is essential that the cold junction box temperatures are also constant.

Isothermal condition at FBTR:

In FBTR, when the reactor is not operating, the sodium is kept at 180 °C. This is called cold shut-down. In this condition, the entire primary and secondary loops of FBTR are under the same temperature. In FBTR, three isothermal conditions are possible, namely, 180, 250, and 400 °C.

Thermocouple Data Acquisition

Generally the data for the cross-calibration is collected either from data acquisition system or from plant computer. To collect data from DA system, sensors are being accessed from plant control room. There is a lot of scope to acquire noise in the sensor output in this process.

To get rid of this instrumentation noise we have collected data directly from the relay room, i.e., data is collected directly from the sensor so that the calibration drift of the thermocouple is calculated accurately.

Procedure for Cross-calibration:

Figure3 shows the procedure for cross-calibration using dedicated plant computer (data acquisition system) for acquiring data. There is a chance of including instrumentation noise when data is collected from plant computer. Therefore, in proposed work the data is directly acquired from relay room, i.e., directly from the plant thermocouple (fig 2). This helps in finding the misbehaving or faulty thermocouple.

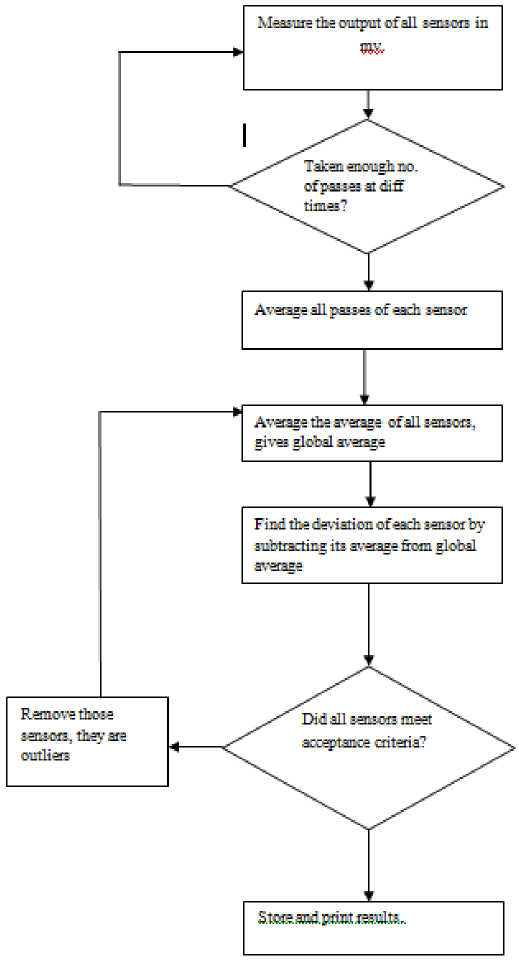

Figure 2: Represents data acquisition and procedure of cross-calibration of proposed method

Pseudo code

1. Take the mv measurement of all thermocouples those undergone cross calibration test directly from the relay room. TNA001x, TNA001y, TNA002x, TNA002y …… TNA054y.
2. Take the multiple numbers of passes at different time, for example at t1, t2, t3, t4.
3. Average the all passes of each thermocouple.
   For TNA001x,
   Avg1= t1+t2+t3+t4/4
   For TNA001y
   Avg2= t1+t2+t3+t4/4
   .
   .
   .
   For TNA0054y

Avg108 = t1+t2+t3+t4;

4. Average the average of all thermocouples to obtain the global average.
   Global Average:
   GAvg = Avg1 + Avg2 + Avg3 + ………… Avg108/108;
5. Subtract the global average from each average of thermocouple to obtain the deviation.
   Dev1 = Avg1 - GAvg;
   Dev2 = Avg2 - GAvg;
   .
   .
   .
   Dev108 = Avg108- GAvg;
   Declare the thermocouple as outlier if it doesn't meet the acceptance criteria**.**

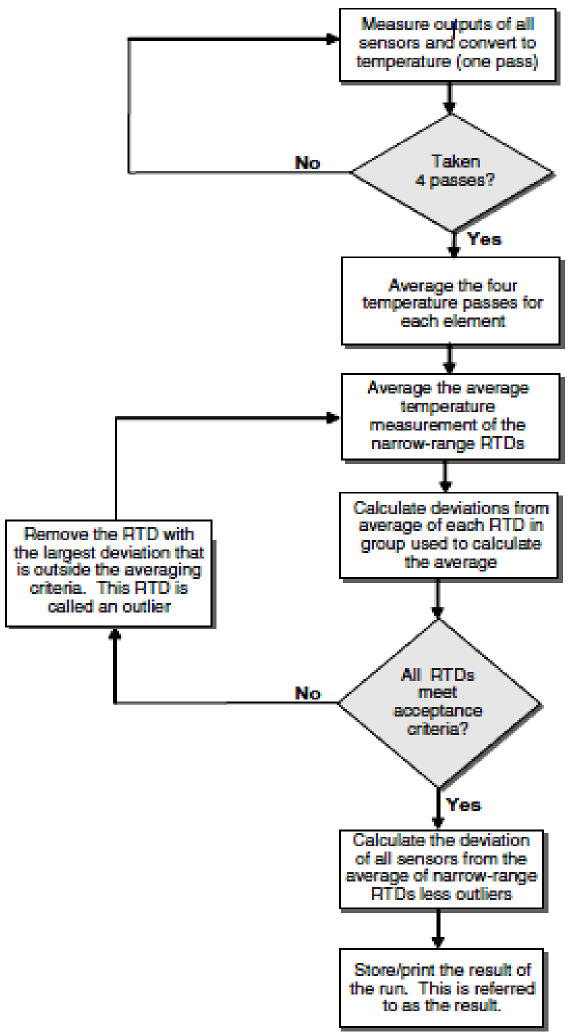

Figure 3: Source: Representation of cross-calibration technique using a dedicated data acquisition system [2]

Cross calibration as an on-line calibration technique:
The cross-calibration is an excellent online technique, which can be performed by the plant computer on demand. The demand should be made by the maintenance engineer when the plant is at the desired isothermal state. Best results of cross-calibration can be obtained within one hour, and can help the maintenance engineer to decide on the outliers. However, it may be note that the technique can be applied only for overall measurement, not just the sensors, in case a plant computer is used.

Results and Discussion

In the cross calibration of thermocouples (only the sensors), an acceptance value ± 1°C was fixed at a temperature of 180 °C. The cross-calibration did not yield any outliers, meaning that the thermocouples are healthy at isothermal condition. Results obtained at different points of time, separated by nearly 28 days, are shown in Fig 4 and 5.

However, the analysis showed that for some fuel sub-assemblies, the difference in the values shown by X and Y thermocouples at isothermal condition was quite high. Choosing a value of ± 0.4 °C as an outlet from global average, it can be concluded that there are at least five FSA locations, where the difference exceeds this value. The list of thermocouples is given in Table 1. This may be compared with the list of thermocouples who have more relative difference without referring to global average.

It's now planned to repeat the process at other isothermal conditions namely 180°C and 400°C, and is expected by July 2015.

Conclusion

One of the global conclusion that can be arrived is there are some outliers that have a deviation more than ± 1°C, as revealed by the cross-calibration technique. However, the effect of radiation and ageing in the thermocouples is quite unpredictable, leading to the fact that those thermocouples which are outliers at isothermal condition may behave better at higher temperatures. Hence, it is necessary to repeat the process at other isothermal conditions (maximum 400°C) and to reliably detect the outliers. It is planned to carry out this in the near future, as an extension of this work.

Table 1: Five FSA positions where the difference exceeds the limit

S. No	Thermocouple name
1	TNA006
2	TNA007
3	TNA014
4	TNA017
5	TNA0035

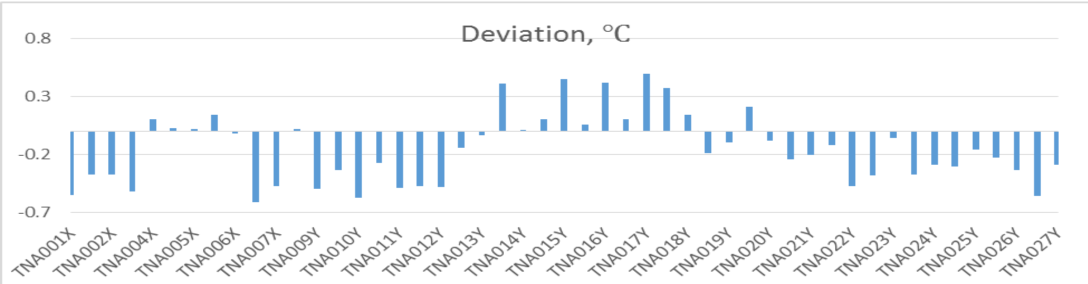

Figure 4: Cross calibration for selected thermocouples, first attempt, for different core thermocouples identified by their tag numbers

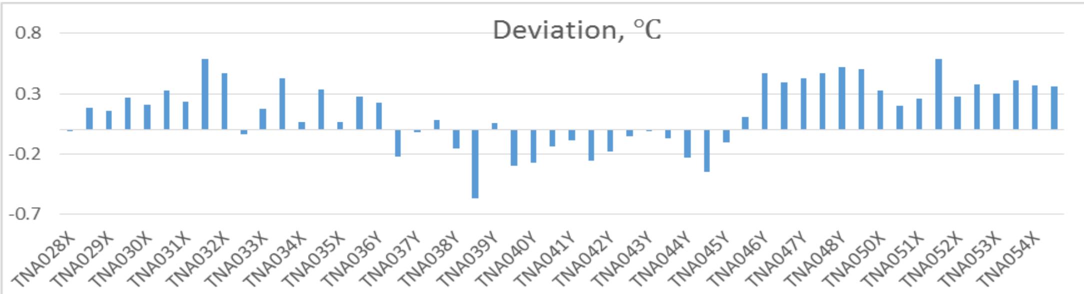

Figure 5: Cross calibration for selected thermocouples, second attempt, for different core thermocouples identified by their tag numbers.

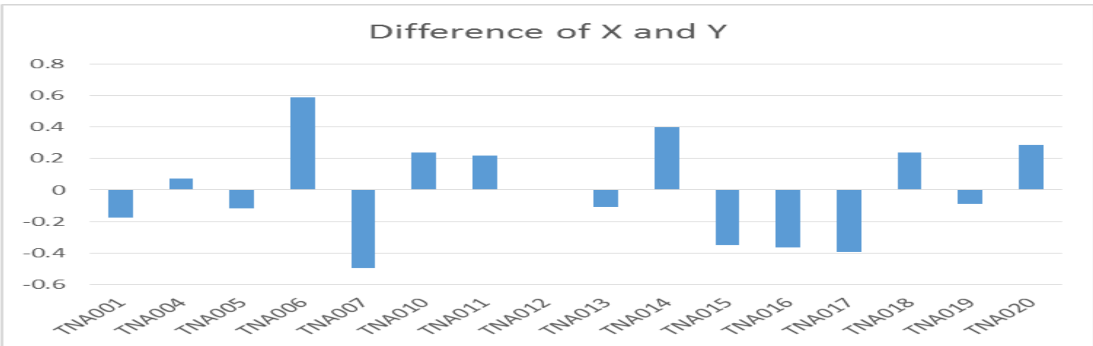

Figure 6: Cross calibration of duplex thermocouples at select locations.

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