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Development of Temperature Measurements and Calorimetry for the Neutral Beam Test Stand Operation at KAERI

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Introduction

Operation of the Neutral Beam Test Stand(NB-TS) at Korea Atomic Energy Research Institute(KAERI) now reaches to 80 kV-20A for about 10 seconds. Experiments with this kind of enormous power and energy necessarily entail many temperature measurements at various locations of the system, and most of the beam line components require to be monitored of their temperatures. We have been implementing temperature measurement utilizing K-Type and T-Type thermocouples(TCs) and a Pt-100 resistance temperature detector for the instrumentation and control and for establishing calorimetry during the operation of the NB-TS facility.

1. Temperature measurements utilizing thermocouples

Most of the temperature measurement needs were met utilizing many of the K-type thermocouples; a T-type thermocouple was adopted to the outlet of the calorimeter for a more refined measurement results.

Signal readings from TCs were achieved through the utilization of the National Instruments' SCXI-1102 and were sent to PXI-1101 on the DC potential region and then sent to the control room where PXI-8176 finally processed the signals.

Some of the thermocouple signals were processed with the AD595 chip. This chip processes the thermocouple signals and then outputs 10mV/℃.

There were some thermocouples whose signals were processed by other than the NI's PXI system or the AD595 sensing chip. These were accomplished utilizing individual indicators for the thermocouples. An example of this case is controlling the baffle temperature and the LN_2 level in the reservoir during the operation of the cryosorption pump operations.

2. Installation of Pt-100 sensor and its readout module

Conspicuous advantages of the Pt-100 sensor over the thermocouples are that for the Pt-100 the cold junction is not necessary and higher stability with wider linearity is possible. Thus implementation of the temperature measurements utilizing the Pt-100 sensors has been achieved. A temperature measuring module "TZ4ST-R4C" supplied by "Autonics" was considered fitting to our purpose. As we should supply the temperature signals to a differential amplifier, we obtained signal voltage – temperature characteristics of the modules when we connected a 250Ω resistor across the output of the module to find out the performance characteristics.

Operational examination of the Pt-100 signal reading module revealed that following relationship holds when we attached an exactly 250 **Ω** resistor across the output terminals:

$$y = 0.04x + 1.000$$

Here x is the temperature input and y is the voltage output from the readout. Thus, a 1℃ difference would correspond to 40 mV in voltage difference. The temperature signal voltage was applied to the A/D converter of the National Instruments' PXI system and then sent to the control room through the fiber optic cable; the received signal could then be processed for the temperature values and for the estimation of the absorbed beam powers.

3. Temperature measurements of the NB-TS Operation

A. Electron dump temperature measurements

During the ion source operation, electrons back-streaming from the deceleration grid or exit grid hit the electron dump, making the electron dump surface hotter. This heated surface could deform or damage the structure as well as the cooling channels imbedded inside the ion source structures. Thus monitoring the temperature of the electron dump surface has been decided upon, also with the optical signal transmission to the control room. The measuring sequence is that first the TC signal is amplified to a directly readable temperature signal using the AD595. The final temperature measuring module was fabricated and installed near the ion source.

B. Temperature measurement needs for the cryosorption pump operations

Control function of the baffle temperature and the liquid nitrogen level for the 5000L LN_2 supply system for the cryosorption pump operation also utilized the temperature measurements. If the baffle is cold enough that the liquid nitrogen need not to be supplied further, then the exhaust valve on top the baffle would be closed, and vise versa. For the level control in the LN_2 reservoir, there were installed two thermocouples in each of the reservoirs; one is onto the higher location and the other onto lower location of the reservoir. When the lower TC sensor shows higher temperature than a predefined value, liquid nitrogen should have to be replenished. When the upper TC sensor showed lower temperature than a preset value, it would be apparent that the reservoir is full of liquid nitrogen and thus the supplying valve is made to be closed.(1).

C. temperature measurements and the estimation of the neutral beam energy

It is expected that if we measure the temperature both at the inlet and the outlet of the calorimeter, the difference of the two temperatures would yield the quantitative measure of the neutral beam power. The following relationship holds for the absorbed energy by the coolant water from the neutral beam:

$$Q = mc\int_{0}^{\infty} \Delta T(t)dt \qquad (1)$$

Where Q is the absorbed energy(cal), m is the mass flow rate(l/sec), c is the specific heat(1 cal/g℃), $\Delta T(t)$ is the temperature difference between the inlet and outlet of the coolant flow, and dt is the time increment. Presently the estimation works of the absorbed energy during the beam extraction experiments are under way using the above relationship.

Conclusion

Many of the temperature measurement needs of the neutral beam test facility have been met through the adoption of K-type and T-type thermocouples and Pt-100 sensors. Monitoring the electron dump temperature, control of the LN_2 supply system for the cryopump operation, and coolant temperature monitoring are some of the examples of the temperature measurements in relation to the NB experiments. Further activities are being made for the beam energy estimation by calorimetry using the temperature measurements.

References

(1) “Construction of the LN_2 Supply & Control System of the Cryosorption pumps of the NB-TS at KAERI”, Jae Sung Yoon, Sang Ryul In, and Ki Sok Jung, transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 2005.