Study on Nuclear Test Scheme and Test Results for Safety Neutron Measurement System in Research Reactor

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1. Introduction

Nuclear test of safety class neutron measurement system (NMS) in research reactors (RR) has been recognized key data during commissioning stage. Most of test results hardly tell the difference between test result and commissioning outcome. However, several parameters such as linearity and sensitivity need to pay more attention to the test data even though it is not significant. In particular, taking account for the importance of nuclear test, it will be introduced in this paper to verify how the acceptance criteria was determined, if test methodology was suitable, and what the deviation of the detector's sensitivity influenced whole performance.

2. Nuclear Test Setup for Safety NMS in RR

2.1 Nuclear Test Setup for Safety NMS

Nuclear test are involved in the type test sequence for safety NMS in RR which generally proceeds in following order as shown in Fig. 1.

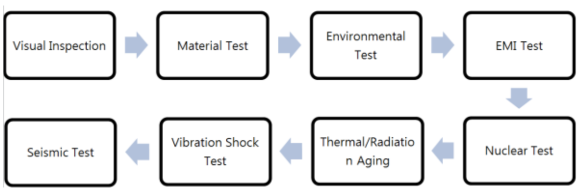

Fig. 1. Type Test Sequence of Safety System.

Before the nuclear test, every process is almost identical to the other case of safety system. Nuclear test was performed with a Wide Range Fission Chamber (WRFC) which is used as a detector of NMS in targeting research reactor. The test specimen is prepared for continual test with being connected via the field cables to the signal processing unit.

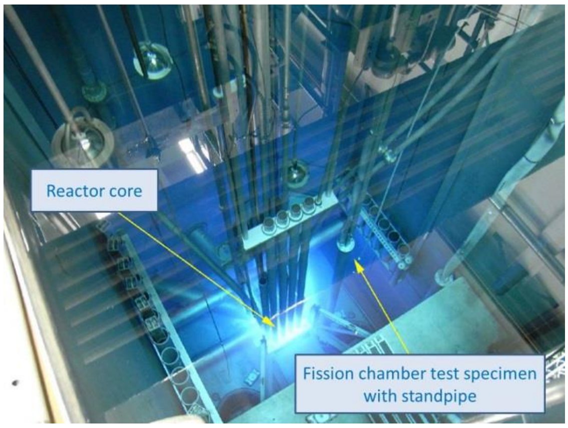

Fig. 2. Nuclear Test Setup of NMS in RR.

The WRFC was mounted electrically isolated in a dedicated movable standpipe in the reactor pool as shown in Fig. 2 with the detector axis parallel to the standpipe axis, ensuring the same vertical position with respect to the reactor core for all measurements. WRFC was placed in the reactor pool at two different locations, referred to position 1 (low neutron flux, far from the reactor core, SE-Pool1) and position 2 (high neutron flux, close to the reactor core, NE-Pool2), to achieve the required neutron fluxes. This scheme was employed to always operate the reactor at power levels above 2.5E-3%FP to be able to stabilize the reactor at the chosen power level and to improve the accuracy of the reactor power measurement by the reference instrumentation.

2.2 First Nuclear Test Result for Safety NMS

Data was obtained at two different positions within the reactor pool, corresponding to reactor power levels of 9.8E-6%FP to 100%FP. In addition to the parameterization, the linearity of the electronics response was tested as a function of the reactor power. Fig. 3 shows the pulse signal, mean square variance signal, and the combined wide range log power signal measured by as a function of the reactor power level.

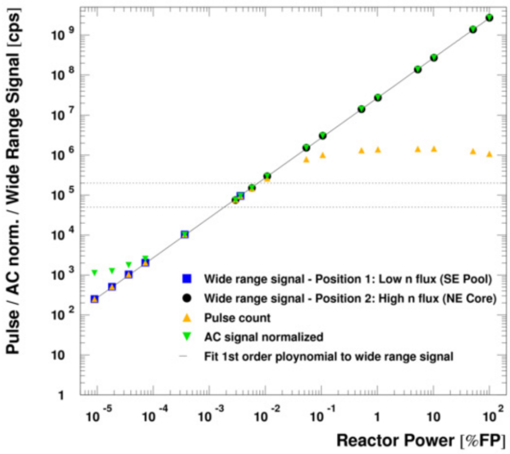

Fig. 3. First Test Result of NMS with curve fitting.

Mean square variance signal is converted AC signal normalized and the dotted lines mark the start and end of the overlap region in which the wide range signal is interpolated between the pulse count and the AC signal normalized. A first order polynomial was fitted to the data obtained with the modified NMS electronics. The residuals of the wide range signal to the 1st order polynomial fit as a function of the reactor power. The error lied within the tolerable range under statistical and systematic uncertainties which is acceptance limit of 1%FS on the logarithmic analog outputs. For the linear neutron power analog output current, calculated value from the measured detector DC current signal with the nominal transfer function of the signal processing electronics met the requirement showing little deviation between the calculated output current and the expected output current corresponding to the reactor power level.

3. Second Test Result for NMS and System Modification

For the first nuclear test which was performed in 2015 evaluated the performance of the fission chamber with the integrated system. The test results of the NMS electronics response and the system integration aspects showed the deviation attributed to the anomalous fission chamber response. The investigation of the test specimen concluded that it was filled with different gas mixture from what it used to be. A re-evaluation of the nuclear data indicated that the DC sensitivity for the linear power signal among the NMS outputs deviated from the specification by a factor 2 to 3. The DC sensitivity of a fission chamber means the sensitivity of the DC current signal used for linear power signal. At any rate, such the large deviation provides a chance of excess on the inbuilt margins in the NMS and consequently impaired its performance at high neutron fluxes above 5.9e+09 nv to 1.0e+10 nv to the extent of nonconformance to the requirement.

The circuit modification is aimed at the extension of the DC current output, from 2 mA to 3 mA as feasible as it can. This modification allows the full measurement not to be saturated before the maximum level of DC current. The modification of the signal conditioning modules in the NMS constitutes as followings; High voltage module and DC current input module. These modules were modified as shown in Fig. 4 and then tested in the field with the relevant procedure. The nominal output current of the high voltage module was increased from 2 mA to 3 mA, which requires the replacement of concerned components on the modules. At the same time, the input range of the DC current was adjusted from 0-2 to 0-3 mA, in order to fit the current that is supplied by the high voltage module to the fission chamber.

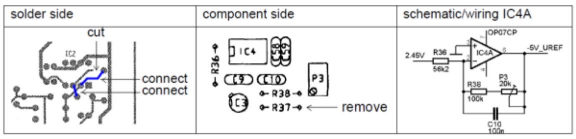

Fig. 4. Modification of NMS Electronics Circuit.

4. Conclusions

Thus far, the issue on nuclear test for the NMS in RR has been summarized with field experience and this practical approach was suggested based on test data. The nuclear test finally ended up the circuit modification and retesting, however it sheds on the light this case should be handled with precarious attention factoring in the severity of the linear power signal.

REFERENCES

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[2] C.G. Clayton, Nuclear Geophysics: Selected Papers on Applications of Nuclear Techniques in Mineral Exploration, Mining and Process Control, (1983), 261-263.