4.2 RELOAD STARTUP PHYSICS TESTS FOR TIANWAN NUCLEAR POWER STATION

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ABSTRACT

This paper briefly describes the test purposes, test items, test schedules and test equipments for reload startup physics tests on Unit 1 and 2 of Tianwan Nuclear Power station (hereinafter, TNPS). Then, an overview of the previous thrice tests and evaluations on the tests' results are presented. In the end, the paper shows the development and work direction of optimization project for reload startup physics tests on Unit 1 and 2 of TNPS.

1. INTRODUCTION

TNPS owns two VVER-1000/428 reactors imported from Russia, and the single reactor electrical-capacity is 1060 MW. The reactor core is composed of 163 hexagonal assemblies, with each assembly incorporates 311 fuel rods, 1 central tube, 18 guide tubes and 1 instrumentation tube. The two reactors are put into commercial operation in May and October, 2007 separately and operating in the 4th fuel cycle in 2010. By now, six times' reload startup physics tests were fulfilled in the two reactors.

2. PURPOSE OF RELOAD STARTUP PHYSICS TEST

In order to verify the accuracy of core design and the correctness of reload safety evaluation report, and offer a support to the station's safety and stable operation, core neutron physics measurements tests must be carried out on refueling core. TNPS' reload startup physics tests are to:

a）Ensure the reactor reached criticality safely after refueling.

b） Verify the refueling core to meet the requirements of design and safety analysis.

c） Verify the reactor operation to meet requirements of the technical specification.

d） Check the In-Core In strument System (hereinafter, ICIS) and Neutron F lux Monitoring Equipment (hereinafter, NFME)

e） Progressively raise the reactor power to rated value, to ensure the reactor operation meet requirements of design and safety.

f） Obtain the necessary operating data.

3. TEST PROGRAM AND PROCESS

The list of items and processes of reload startup physics tests are shown in Figure 1.

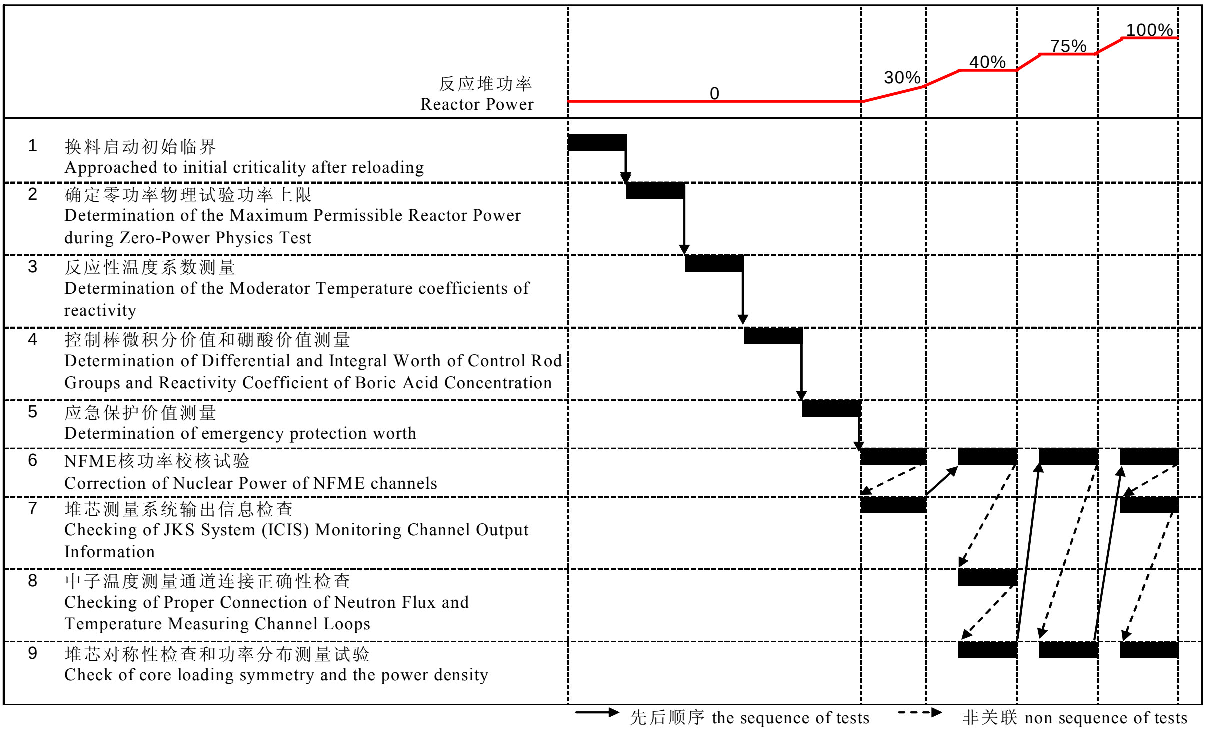

Figure.1 Schedule of reloading start-up physics tests

3.1 The initial critical test after reloading

The initial critical operations after reloading are as the following four main stages:

a） Withdraw the Control and Protection system (hereinafter, CPS) control rods groups 1-9 to the upper extreme position and group 10 to 60% position from the core bottom;

b） Continuous to inject pure wate r into the reactor with flow rate less than 30t/h, until the concentration of boric acid decreases from 16g/kg to upper lim it of startup interval (namely the calculated critical boric acid concentration+1g/kg);

c) Stop dilution and mix boric acid in the reactor, pressurizer and make-up water deaerator until the difference of boric acid concentration between them less than 0.5g/kg;

d) Continuous to inject pure water into the reactor with flowrate about 10t/h, until there is stable indication of reactor period and continuous increase of neutron flux density. Equalize the concentration of boric acid in the primary circuit ,pressurizer and make-up water deaerator, then keep the reactor power to the minimum controlled level (5 × 10-3 ~ 1% Nnom) by periodic movement of the CPS control rod group.

3.2 Determination of maximum permissible reactor power during Zero-Power Physics Test

During test to maintain constant steam flow rate of SG, introduce positive reactivity into the core by moving group 10 of CPS control rod, then the reactor power and primary circuit coolant temperature start to increase, continuous to increase reactor power until the heating rate of coolant in primary circuit reaches 10 ℃/h. The corresponding current of ionization chamber at this moment is considered as the Doppler heating point. Taking 1/60 of this current value as the maximum allowable current value, that is, maximum permissible reactor power at the stage of physical start-up

3.3 Measurement of the moderator temperature coefficient of reactivity

Test of the moderator temperature coefficient of reactivity is performed through measuring the reactivity change while decrease and increase the coolant temperature of primary circuit. Then through minus the calculated fuel temperature coefficient with isothermal temperature coefficient, the moderator temperature coefficient of reactivity can be obtained. Test is performed at two different CPS control rod positions, that is, at the height of 80%~90% and <30% from the core bottom.

3.4 Determination of differential and integral efficiency of CPS control rod groups and reactivity coefficients of boric acid concentration

Measurement of differential and integral efficiency of CPS control rod groups is performed by decrease (increase) the concentration of boric acid, while periodic downward (upward) movement of CPS control rod group to compensate the reactivity change caused by boric acid concentration variety and keep the reactor in the near-critical state. The initial position of CPS CR group 10 is 80- 90% while finial position is <30% from the core bottom. During the test, the CPS CR group 9 moves following group 10 with the overlapping 50%.

3.5 Determination of Emergency protection efficiency

According to the calculation results, select a most worth CPS control rod as the sticking rod, which should be as close to the ionization chamber used to measure reactivity. Before the test, the temporary change of the CPS control rod power supply should be performed by instrumentation personnel, so as to ensure the selected most effective control rod sticking at the upper limit switch after pressing emergency protection button.

Lift CPS control rod group 10 to introduce positive reactivity. When the reactor power increases to nearly 1%Nnom level, operator presses the emergency protection button, and then all CPS control rods drop except the selected rod. After about 1 minute's recording of parameters, drop the selected rod by instrumentation personnel. Then the operator injects boric acid into the core in order to bring the reactor to hot state.

3.6 Calibrate nuclear power readings from NFME channels

The test is designed to check the differences between nuclear power readings from NFME channels and reactor thermal power at heating-up and every stable stage. When doing test, the correctional coefficients of NFME channels are determined to ensure the veracity of powers readings from NFME channels and to ensure the differences is less than 2%Nnom.

3.7 Checking of proper connection of Neutron Temperature Monitoring Channels (hereinafter NTMC)

The test needs to move downward and upward one single control rod of CPS group 10. Before and after movement, the change of relative power of FA with moved control rod is larger than that of other FAs, and the father the distance from the control rod, the smaller the relative power changes. At the same time, the relative power of FA symmetrical with the control rod changes oppositely, also to the symmetric position as the center, the father the distance, the smaller the relative power varies. This can prove the corrective connections of NTMC.

3.8 Checking of output information of ICIS monitoring channel

The test purposes are to check of operability and reliability of control channels impacting conditions of in-core local protection as well as reactor thermal power calculations, to check of operability and reliability of energy release control channels impacting recovery of energy release field, and to assess ICIS output information of reactor condition monitoring parameters.

During test, the following parameters are checked: the reactor condition monitoring parameters, coolant temperatures indicated by resistances in primary circuit, coolant temperatures indicated by thermal couples at outlet of FA, temperatures indicated by regulators of NTM C, current indications of SPND, linear energy release per indications of SPND, protection parameters readings from SHC-P (min DNBR and linear energy release), the relative power of FA, ratio of volumetric non-uniformity of energy release and so on.

3.9 The core symmetry checks and power distribution measurement

Through the relative deviation analysis of power distribution, the symmetry of core fuel loading can be verified. The compliance of measurements and design values of power distribution can be evaluated, the reliability of ICIS in measuring power distribution can be verified as well as.

4. TEST EQUIPMENTS

TNPS introduces a fully digital instrument and control system, which make it very convenient in data measurement. The data collection, recording, processing and analysis can be performed automatically by computer. The layout of test equipments is shown in Figure 2.

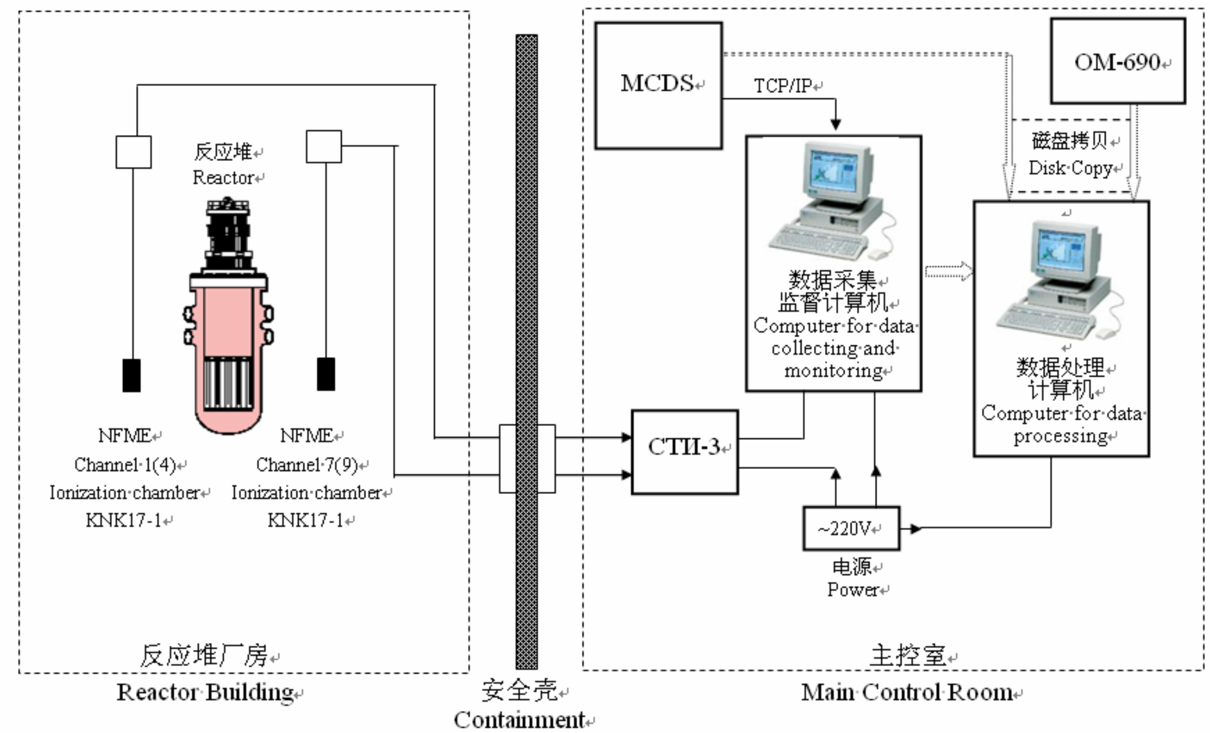

Figure.2 Layout of temporary apparatus of reloading start-up physics tests

5. AN OVERVIEW OF PREVIOUS TESTS AND DEVELOPMENT OF OPTIMIZATION OF RELOAD PHYSICS TESTS

The duration of previous thrice tests on unit 1 and 2 of TNPS are compared as following Figure 3.

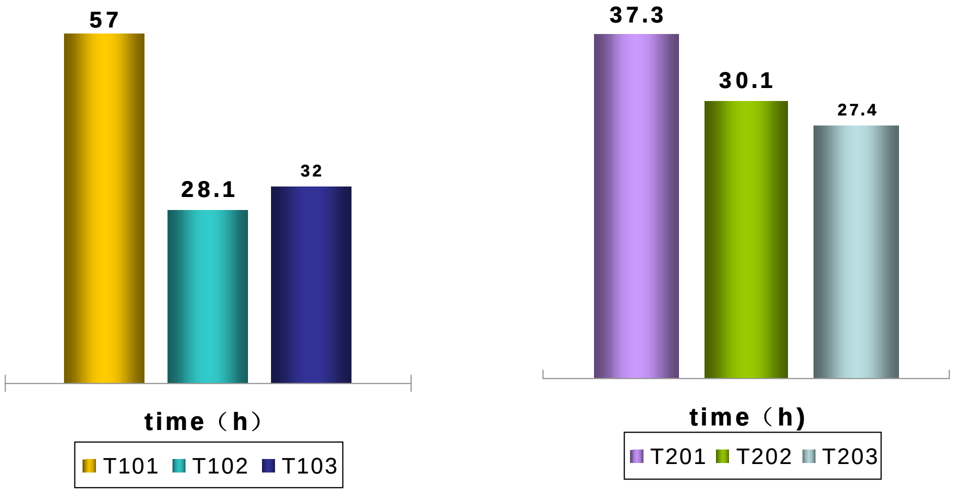

Fig.3 Test duration of previous thrice tests on each unit

In order to optimize the outage duration and improve economics of the plant, TNPS had been carrying out optimization work on reload startup physics tests from the first outage. By now the following optimization work has been carried out:

a） To take measurement of emergency protection efficiency as the last test at zero power stage. After test the reactor can be bring into criticality and the reactor power can be upgraded so as to shorten test period;
b） According to the advice of the Russian designer, one time's emergency protection efficiency measurement was canceled (namely the way that all CPS control rods drop);
c） The National Nuclear Safety Administration approved the removal of the test to check the connection correctness of control rods and its drive mechanism;
d） Based on the analysis results by institute, the xenon balance test have been shortened from the initial 48 hours to the current 12 hours.

The following optimization work will be carried out continually:

a） To cancel the measurement of maximum permissible reactor power;
b） To cancel the measurement of differential and integral efficiency of CPS control rod group 9;
c） To execute the measurement of temperature coefficients of reactivity at only one CPS control rod position instead of two.

d) Gradually reduce the mix time of the boric acid in the reactor.

e) To cancel the operation of injecting boric acid after the test of emergency protection efficiency measurement;

f) Shorten the time of the xenon balance to 6 hours.

6. CONCLUSION

Three times outage were successfully completed on each unit at TNPS, and the test results agreed well with the acceptance criteria. Through the several times reloading startup physics tests, the physical persons gained much experiences. However, on the basis of tests' feedback and good practice of other plants at home and abroad, the optimization of physical tests will be executed further to shorten the outage duration and improve economics of the plant.