COMMISSIONING STATUS OF HANARO, KOREA MULTI-PURPOSE RESEARCH REACTOR

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ABSTRACT

The 30MW Korea Multipurpose Research Reactor, HANARO, located at KAERI site has achieved its initial criticality on February 8, 1995. Non-nuclear commissioning was started in the middle of 1993, and all the system performance tests were successfully finished at the end of last year, 1994. The fuel loading for initial core was completed. Nowadays, many activities of nuclear commissioning are ongoing under zero power condition.

Besides on the reactor commissioning, some experimental facilities are in progress on design, fabrication and purchasing.

This report describes the outlines of the major activities and experiences of system commissioning and presents the future plan in HANARO reactor.

Introduction

At present, there are two research reactors in KOREA, TRIGA MARK-II 250KW and TRIGA MARK-III 2MW which were constructed in 1962 and 1972 respectively.

But the utilization of these reactors have been limited in coincidence with the recent trend of nuclear research and development because not only the neutron flux level is relatively low but also the facilities are old to be retired soon.

To meet the recent various requirements for example, nuclear basic research, production of radioisotope for medical and industrial applications, development and research of nuclear materials a new powerful research reactor project, HANARO, was started 10 years ago.

The major milestones are followings :

1987. 12. Construction permit acquired from MOST (Ministry of Seience & Technology)
1989. 3. Ground breaking
1993. 2. Reactor installation
1993. 7. Started system commissioning
1994. 12. Finished system integration test
1995. 2. Fuel loading & first criticality

In the one and half years from the beginning of the system commissioning in July, 1993 to fuel loding of this year KAERI engineers had led the system performance tests. Partially, some manufacturers and construction people had participated in field works.

HANARO has about 40 systems for reactor operation. Each system has been verified its function through construction acceptance test, system performance test and system integration test.

Summary of Design

HANARO is a light-water cooled and heavy-water reflected open-pool type reactor. The reactor is located at the bottom of a concrete shielded, stainless steel lined pool of dimineralized water.

The core heat is removed by two loops of primary cooling system. When the power is less then 50% of full power the reactor can be operated by one loop with one pump and one heat exchanger. If the forced primary cooling function is not available the core residual heat is removed by a natural circulation through the primary loops with a gravity dump of secondary cooling water from yard basin or by a natural convection of pool water through the flap valves located inside pool.

The reflector system contains 4,700 liters heavy water and has two circulation pumps (one is standby). The system continuously circulates the D_2O in the reflector tank to dissipate up to 2.5MW at full power condition. A 6″ rupture disc is installed at the suction side of pump to prevent the overpressure to the inner shell of the reflector tank.

The reactor is composed of inner and outer core. The inner core consists of 23 hexagonal flow tubes and 8 cylindrical flow tubes. The outer core has 8 cylindrical flow tubes embedded in the reflector tank. In normal operation, 36-element fuel assemblies are loaded in 20 hexagonal flow tubes while 18-element fuel assemblies are loaded in 12 cylindrical flow tubes.

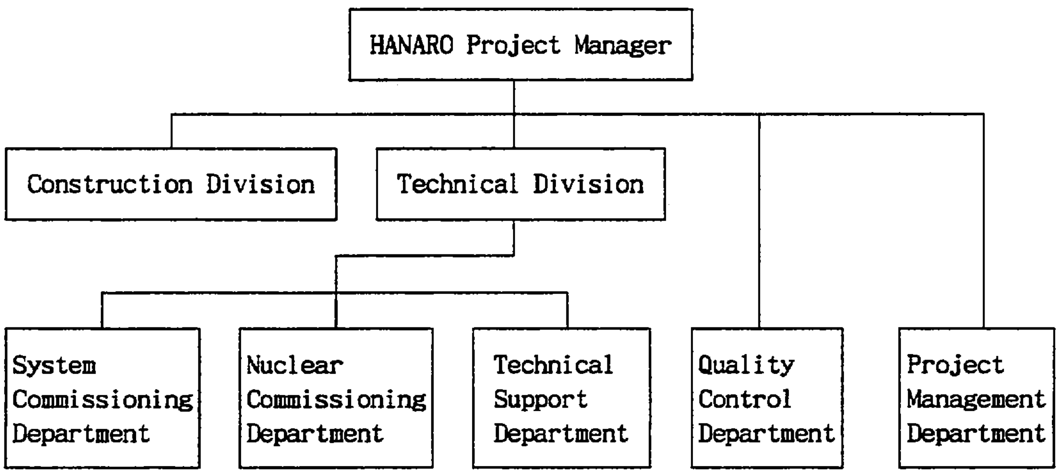
The fuel of HANARO is low enriched (20 w/o U-235) U_3 Si-Al alloy. The active length of the fuel element is 700mm.

The reactor is controlled by 4 shutoff and 4 control absorbers, The material of the absober is hafnium shaped hollow cylinder. The driving concept between shutoff and control absorbers is basically different. The shutoff absorber element is actuated by a hydraulic pressure, while the control absorber element is moved by a stepping motor turning a ball screw.

The secondary cooling system consists of a cooling tower, 50% three pumps and heat exchangers. The thermal capability of cooling tower is 33.5MW.

Commissioning

1) Organization



Most commissioning engineers have involved in the system design of HANARO and prepared lots of commissioning documents.

2) Schedule

Four(4) degrees of different schedules have been used for the management of the overall commissioning programs.

Level 1 : Project Master Schedule
Identifies important project milestones

Level 2 : Start-up Summary Schedule
Identifies primary critical paths and main commissioning activities at the system level.

Level 3 : 6 Month Schedule
Indentifies detail work plans for coming six(6) month with the progress of the work including interfaces between all systems.

Level 4 : 3 Weeks Schedule
Identifies daily activities for three(3) weeks based on the the Level 3 schedule.

The table 1 shows the actual commissioning schedule. The completion of the system commissioning was delayed by six(6) months compared with the original plan due to the unexpected interferences in the field.

3) Test Procedures (Documentation)

Commissioning documentations including commissioning plans, start-up manuals, and commissioning procedures etc, shown in the table 2 had been started two(2) years before the beginning of the system commissioning. These commissioning documents were prepared based on the Safety Analysis Report, Design Drawings and Documents, Technical Specifications and Manufacturer's information.

Parts of the commissioning procedures have been revised during commissioning to incorporate the field interferences and these changes served as a good reference to the complement of the various Operating Procedures. The commissioning Procedures were practically used as a training manual for the commissioning personnel and as a guidelines for all the testing activities.

4) Major Activities

- Utility Supplies

In order to ensure the safe and reliable electric power supply, the following function tests have been carried out according to the appropriate test procedures.

- Standby power transfer tests
- Full load tests
- Independence and separation tests
- Protection and logic tests

Especially, the Reactor Protection System (RPS) with three(3) redundant channels requiring separate Class 1E grade of power was subjected to the severe test criteria based on the International Codes and Standards.

Service water and demineralized water have been supplied from the main production facilities of KAERI, through the common underground gallery.

- Flushing

It was the flushing work for process pipings and equipments that a lot of time and manpower have been used up prior to the start of the system performance test. It is important to concentrate more in a system base flushing rather than a component base flushing and to check the cleanliness of the pipings repeatedly.

It was a good chance to experience that any installation defects and faults like system leakage or unreasonable vibration could be detected and repaired during this period. Careful consideration must be given to the quality control of the flushing work.

- Instrumentation & Control

I&C work requires a sufficient time to work and a skilled technical manpower to achieve the complete verification of the integrated system performances from the field instruments to the control logic and display. System-level function tests have been carried out after the confirmation of the calibration and setpoint adjustments of each component. The followings are the special test activities performed during I&C commissioning work.

- Real-time dynamic function test of the reactor power control algorithm
- Response time testing for trip parameters of safety system
- Examination of cause and solution for Electro-Magnetic Interference(EMI) noises

- Design Data Confirmation

It has been verified, as shown in the table 3 that commissioning test results are compatible with the design data calculated by design and analysis groups.

- **Integrated Pre-operation Test**

As a final commissioning program, integrated pre-operation was performed to verify the integrated reactor operating performances by checking the system-to-system interlocks with all process system running. This test program is the last commissioning stage to decide the appropriateness of the initial fuel loading. The major test activities are as follows :

- Operation transient function tests
- Interface logic checks
- Failure mode tests

Failure mode tests including loss of electric power, loss of instrument air and control computer failure are to demonstrate that the system transient behaviors with displays and alarm functions after each failure conform to the design specifications.

Future Plan

Nuclear physics tests have been in progress as increasing the number of fuel loading step by step since the initial criticality on Feb. 8, 1995. At present, the fuel loading for initial core was completed. The zero-power test is scheduled to be finished by August, 1995 and then power increasing will start and it will take about 9 months to reach full power.

Nuclear commissioning of power increasing stage include the various programs to confirm the core physics characteristics and heat removal capability and natural convection coolability which could not be carried out during cold function test.

Planned experimental facilities around HANARO are listed below

- In-core irradiation test facilities
- Radioisotope production facilities
- Neutron beam application facilities
- Neutron doping silicone production facilities
- Neutron activation analysis facilities

The project schedule indicated that the basic components of these experimental facilities would be equipped until the end of 1996.

Coclusion

Since there was not a verified reference reactor similar to HANARO, a lot of design changes and trial and error have been experienced during design and commissioning stage. The commissioning data is being accumulated through the system pre-operation test, zero power and power increase tests. All these experiences and data will be useful for reactor operation, in-service inspection, maintenance and upgrade work.

Throughout the system commissioning test programs, all system performances were verified and approved by regulatory body then finally the initial criticality was successfully accomplished as intended. It can be said that all these achievements made a remarkable contribution to the development of a new research reactor.

Conclusively, HANARO will be a good reference of new research reactor. The design improvements and R & D activities experienced in HANARO will be of help to the development of research reactor technology.

References

1. Safety Analysis Report of the KMRR, KAERI/TR-322-92, KAERI, 1992. 12.
2. System Performance Test Reports, KAERI, 1994. 12
3. Design Manual KM-321-DM-P001, KOPEC, 1992. 7.
4. Design Manual KM-711-DM-P001, KOPEC, 1992. 7.

Table 1. Commissioning Schedule

HANARO RESEARCH REACTOR COMMISSIONING	1993						1994												1995					
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Non-nuclear Commissioning																								
1. Electric System																								
◦ Incoming and Distribution		energized ▽ ■	■	■																				
◦ UPS & DC					■	■	■	■																
2. Water Supplies	■	■	■																					
3. Cooling System																								
◦ Secondary cooling system						■	■	■	■															
◦ Primary cooling system (including vibration test & analysis)										■	■	■	■	■	■	■								
◦ Fuel Channel Flow Test															■									
4. Reflector System												■	D₂O charged ▽ ■	■										
5. Reactivity Control Unit Performance Test											■	■	■											
6. Instrumentation & Controls													■	■	■	■	■	■						
System Integration Test																								
1. Electric Power Failure Test															■									
2. Computer Failure Test																■								
3. Integration Pre-Operation Test																	■	■						
Nuclear Commissioning																								
1. Fuel Loading for Initial Core																				first criticality ▽ ■	■	■		
2. Core Characteristics Measurement																				■	■	■	■	■ →

Table 2. Commissioning Procedures

HANARO

Items	Q'y
1. Construction Acceptance Tests	<u>57</u>
- Mechanical Eq.	12
- Electrical Eq.	19
- Instrument	26
2. System Performance Tests	<u>40</u>
- Mechenical System	8
- Process System	14
- I & C System	9
- Electric System	9
3. Integrated System Tests	<u>7</u>
- System Failure	3
- Integrated Pre-Operation	1
- Core Flow Measurement	3
4. Reactor Performance Tests	<u>30</u>
Total	**134**

Table 3. Test Results of System Commissioning

HANARO

Major Parametes	Design Value	Commissioning Results
1. Primary Cooling System		
- TPTH* flow	703 kg/s	750 kg/s
- OPOH* flow	454 kg/s	460 kg/s
- TPTH Pressure	316 KPa (g)	360 KPa (g)
- OPOH Pressure	200 KPa (g)	215 KPa (g)
2. Secondary Cooling System		
- 2 pumps flow	915 kg/s	930 kg/s
3. Reflector Cooling System		
- Flow	43.3 ℓ/s	47.5 ℓ/s
- Pressure	433 KPa (g)	440 KPa (g)
4. Reactivity Control Unit		
- Shutoff Rod Drop time	< 1.13 sec	1.027~1.076 sec
- Control Rod Drop time	< 5 sec	0.53~0.65 sec
5. Response Time of Reactor Protection I&C		
- Response time of flow & pressure in primary cooling sys.	< 300 msec	242~266 msec
- Neutron power measurement	< 100 msec	54~84 msec
- Lograte measurement	< 1.5 sec	67 msec

* TPTH : Two Pumps Two Heat Exchangers

* OPOH : One Pump One Heat Exchanger