REPLACEMENT OF PUSPATI TRIGA REACTOR PRIMARY COOLING SYSTEM AND SAFETY CONSIDERATIONS

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ABSTRACT

PUSPATI TRIGA Reactor (RTP) is the only nuclear research reactor in Malaysia. It has been safely operated and maintained since 28 June 1982. Over 28 years of operation, some of the reactor systems have been upgraded or replaced to ensure the functionality and safety of the reactor. One of the major reactor systems which is primary cooling system is used to remove heat generated in the reactor core. The former primary cooling system consisting of single unit of shell-and-tube heat exchanger, three centrifugal pumps and piping system was replaced with a new system due to decreasing of the cooling performance. The new primary cooling system, consisting of two units of the 1.5-MW plate-type heat exchangers, new three primary pumps and new piping system was installed in accordance to the specified AELB requirements and guidelines of Nuclear Malaysia Safety, Health and Environment Committee (JKSHE). This paper summarises the replacement process of the former RTP primary cooling system. The activities involved preparation before and during construction and installation phases as well as safety consideration based on International Atomic Energy Agency (IAEA), Atomic Energy Licensing Board (AELB) requirements and Occupational Health and Safety Act (Act 514) were discussed and evaluated.

ABSTRAK

Reaktor TRIGA PUSPATI (RTP) ialah satu-satunya reaktor penyelidikan nuklear di Malaysia.Ia telah selamat dikendalikan dan disenggarakan semenjak 28 Jun 1982. Sepanjang operasi selama 28 tahun, beberapa sistem reaktor telah dinaiktaraf dan diganti untuk memastikan kefungsian dan keselamatan reaktor.Salah satu daripada sistem reaktor utama, iaitu sistem penyejukan primer digunakan untuk menyingkirkan haba yang terjana di dalam teras reaktor. Sistem penyejukan primer RTP pada asalnya terdiri daripada sebuah penukar haba jenis petala dan tiub dan tiga unit pam empar serta sistem perpaipan telah digantikan disebabkan penurunan dalam prestasi penyejukan. Sistem penyejukan RTP yang baru terdiri daripada dua unit penukar haba jenis plat 1.5MW, tiga unit pam empar dan sistem perpaipan yang baru telah dipasang sejajar dengan keperluan AELB dan pematuhan terhadap peraturan

Jawatankuasa Keselamatan, Kesihatan dan Alam Sekitar (JKSHE) Nuklear Malaysia. Penulisan ini merumuskan proses penggantian sistem penyejukan RTP yang asal. Aktiviti-ativiti yang terlibat dalam persediaan sebelum dan selepas fasa pembinaan dan pemasangan serta mengambil kira keselamatan berdasarkan garis panduan daripada Agensi Tenaga Atom Antarabangsa (IAEA), peraturan-peraturan Lembaga Pelesenan Tenaga Atom (AELB) dan Akta Kesihatan dan Keselamatan Pekerjaan (Akta 514) telah dibincangkan dan dinilaikan.

Keywords : primary cooling system, plate type heat exchanger, safety consideration

INTRODUCTION

The PUSPATI TRIGA Reactor (RTP), a pool type reactor with 1-MW thermal power, achieved its first criticality on 28 Jun 1982. Since then, some of the reactor systems have been upgraded and replaced in order to ensure the functionality and safety of the reactor. Figure 1 shows current primary cooling system of RTP. It consists of single unit of shell-and-tube heat exchanger, three units of centrifugal pump and piping system. After more than 27 years of successful operation, replacement part of the primary cooling system is needed due to degradation in cooling performances of heat exchanger. The heat exchanger plays an important role to ensure the stability and safety operation of the reactor. During one of the earlier inspections, it was found that 12 of the 174 tubes of the heat exchanger need to be plugged to prevent leakage. This reduction equates to at least 7% loss in heat transfer efficiency. Other problems with the heat exchanger include scaling and corrosion especially on the shell side. Therefore, it was proposed that a new heat exchanger be procured and installed such that operational safety of the reactor could be strengthened.

Fig. 1. Current RTP's Primary Cooling System Design

SAFETY CONSIDERATION

Safety aspect is the main concern and it was applied throughout the replacement process. Prior to that, all required guidelines and recommendation documents were initially prepared. Atomic Energy Licensing Act (Act No. 304, 1984), Occupational Safety and Health Act (Act No. 514, 1994) must be complied with. IAEA guidelines such as Code of Conduct [1], as well as Atomic Energy Licensing Board (AELB) and the Department of Safety and Health (DOSH) regulations were practiced to ensure the safety. License conditions for the RTP as stipulated by the AELB as well as the safety procedures of the Nuclear Malaysia Safety and Health Committee (JKSHE) must also be adhered to.

Paragraph 20 of the IAEA Code of Conduct on the Safety of Research Reactors [1] states:

The regulation and guidance established by the state of the regulatory body according to national arrangements should :

(a) require clear arrangements for the management of safety by the operating organization, reflecting safety as the highest priority and encouraging the development of a strong nuclear safety culture in the operating organization;

Assessment and verification of safety

(b) require the operating organization to prepare and maintain a safety analysis report and to obtain an

authorization for siting, construction, commissioning, operation, modifications important to safety, extended shutdown and decommissioning.

The general safety objectives recommended by IAEA NS-R-4 [2] and implemented in the RTP Safety Analysis Report [3] are as follows:

a) General Nuclear Safety Objective

The general nuclear safety objective for the RTP facility is to protect individuals, society and the environment from harm by establishing and maintaining effective defenses against radiological hazards.

b) Radiation Protection Objective

To ensure that in all operational states radiation exposure within the installation or due to any planned release of radioactive material from the installation is kept below prescribed limits and as low as reasonably achievable, and to ensure mitigation of the radiological consequences of any accidents.

c) Technical Safety Objective

To take all reasonably practicable measures to prevent accidents in nuclear installations and to mitigate their consequences should they occur; to ensure with a high level of confidence that, for all possible accidents taken into account in the design of the installation, including those of very low probability, any radiological consequence would be minor and below prescribed limits; and to ensure that the likelihood of accidents with serious radiological consequences is extremely low.

To accomplish the safety objectives, acceptance criteria for both operational states of the reactor and accident conditions were considered in the design of the facility. It was established in accordance with the IAEA Safety Series No. 35-G1 [4], Malaysian Law, i.e. Atomic Energy Licensing Act, (Act 304, 1984) [5] and related Radiation Protection (Basic Safety Standard) Regulations 1988 (BSS Reg. 1988)[6] as follows:

Performance criteria

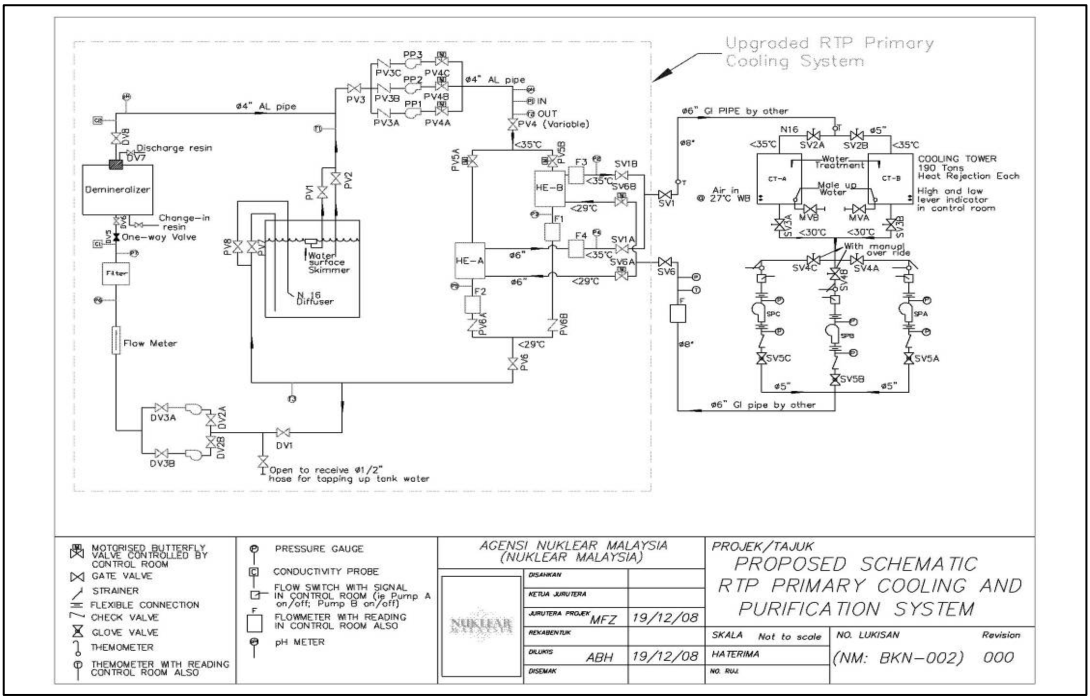
The integrity of the reactor core and fuel is assured, and core cooling is maintained at all times. For assuring the core and fuel integrity, the maximum temperature of fuel cladding surface is limited to the value of onset of nucleate boiling and the core is kept covered with water at all times. In addition, criteria to achieve safety objectives and to meet the engineering requirements are: -

i. To shutdown the reactor safely under all operating and accident conditions.
ii. To remove residual heat after reactor shutdown.

The condition of natural circulation for heat removal provides that the reactor is capable of removing the residual heat after shutdown effectively.

SCOPE OF WORK

Replacement of the primary cooling system involves replacement of the single unit 1-MW shell-and-tube heat exchanger with two units of 1.5-MW plate type heat exchanger, substitution of three units of current centrifugal pump with three new units of centrifugal pump and upgrading two units of instrumentation and control system to a new single unit integrated control system or *Supervisory Control and Data Acquisition* (SCADA) System. SCADA was added to provide control of the operation of pumps, valves and heat exchanger directly from the control room. This system has a very good and user-friendly interface and can be integrated with instrumentation and control system of the reactor console in the future. Besides, the new primary cooling system also required several changes in the piping arrangements to facilitate the increasing of water flow rates in the future. Figure 2 and Figure 3 illustrate the current and the proposed layout of RTP's primary cooling system respectively.



Source: Mohd Fazli Zakaria, 2008

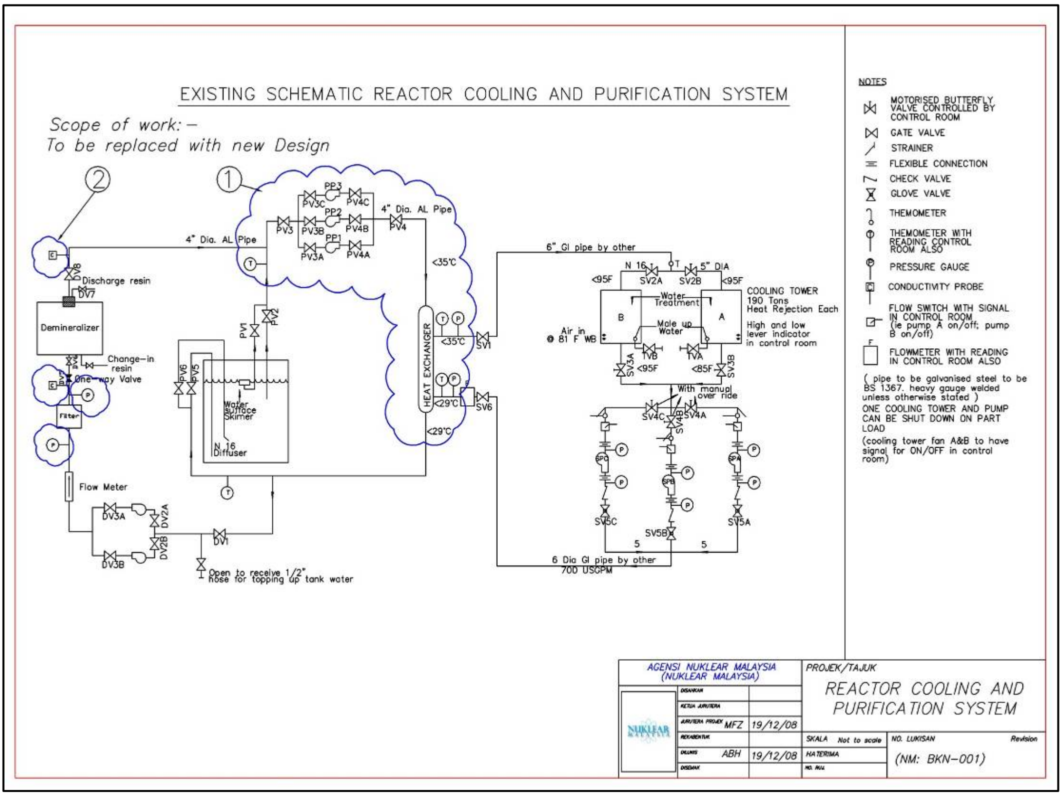
Fig. 2. Current schematic diagram of RTP's Cooling System

PREPARATION BEFORE CONSTRUCTION AND INSTALLATION

The construction phase took place commenced on 30th September 2009 until 19th January 2010. Before construction and installation phase begin, application of approval as well as preparation of site, equipments and manpower were carried out.

Application of Approval

Before construction and installation process start, a preliminary safety analysis report has been prepared in order to confirm the commissioning procedures. The proposal was submitted to Major Facilities Safety Subcommittee (JKKU) for evaluation and recommendation prior to approval from Safety, Health and Environmental Committee (SHE Committee). Recommendation from JKKU was obtained on 27 July 2009 and subsequently approval from SHE Committee on 27 August 2009. After the approval of JKSHE, preparation of site, equipments and man power were started.



Source: Mohd Fazli Zakaria, 2008

Fig. 3. Proposed Schematic diagram of RTP's Primary Cooling System

Preparation of Site

Site is located at the basement of the reactor building. Housekeeping was conducted to ensure that the site is fully prepared for construction.

Preparation of Equipments

The major equipment such as pumps, heat exchangers, pipes and construction tools were delivered and stored at the site before construction start to avoid delays of the works.

Preparation of Manpower

All the construction crews were equipped with safety briefing and working instruction. Internal working permit was issued to all the contractors. Schedule of works were also planned properly to ensure all the works are done smoothly. For safety purpose, the contractor needs to apply the Permit To Work (PTW) every day before start the works. The permit must be reviewed and approved by the Work Supervisor and Area Supervisor before work can commence. In addition, all the workers have been constructed to wear full Personal Protective Equipment (PPE) during the jobs as required in OSHA.Besides applying PTW and wearing PPE, the workers also needs to apply for Themoluminescence Dosimeter (TLD) with purpose of personal radiation monitoring.

CONSTRUCTION AND INSTALLATION PHASE

Construction and installation phase involves three phases as shown in Figure 4. For safety requirement, staff from Health Physics Unit (KFK) of the Division of Radiation Safety & Health (BKS) required to conduct the radiation survey as part of the job progresses. This is to ensure that the radiation level is properly monitored to avoid any unexpected exposure to the workers.

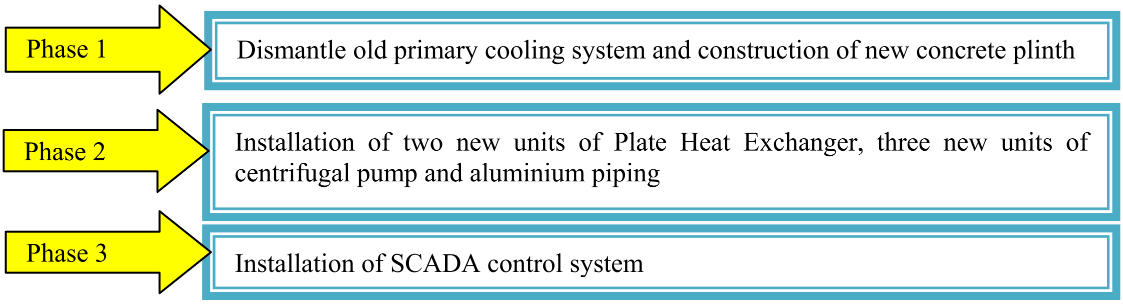


Fig. 4. Construction and Installation Phases

Phase 1: Dismantling Old Primary Cooling System and Construction of new Concrete Plinth

This phase involves dismantling of the old system including shell-and-tubes heat exchanger, pumps, piping system, electrical system and related support system. Before dismantling the system, the water in the primary system needs to be drained out. In order to do that, the incoming and outgoing pipe to the reactor tank located after the demineralizer was cited and capped. Figure from 5 to 10 show the sequence of activities during this phase accordingly.

Fig. 5. Delivery of Plate Heat Exchanger

Fig. 6. Dismantling of Shell and Tubes Heat Exchanger

Fig. 7. Removing the Heat Exchanger from Basement

Fig. 8. The hollow part of the Heat Exchanger sealed

	
Fig. 9. Hacking the Heat Exchanger's	Fig. 10. Construction of new concrete plinth concrete Support

After dismantle, the unused component such as heat exchanger, pumps and pipes were send to Waste Technology Centre (WasTeC) for temporary storage before other applications or final disposal.

Phase 2: Installation of Two New Units of Plate Heat Exchanger, Three New Units of Centrifugal Pump and Aluminium Piping

This phase involves installations of two units of 1.5-MW Plate Type Heat Exchanger, three units of centrifugal pumps and aluminium piping system. The installation job was based on the standard installation procedure of the equipment. The equipments must be certified as required before installed onto the system. The figures below summarises the activities during this phase.

Phase 3: Installation of SCADA Control System

Installation of SCADA system involves the installation a single unit of control board located at the basement and two unit of Personal Computer (PC) located in the Reactor's Control Room. This system introduced a sophisticated control system which enables the operator to control the system remotely from the control room. The system will help to minimize the start up and shutdown checklist time and also optimize the operation time. In the mean time, manual control system using control board are still applied for the safety reason. Figure from 15 to 17 shows the SCADA System installed.

Fig. 11. Installation of plate heat exchanger

Fig. 12. Position of pumps

Fig. 13. Pump Connection

Fig. 14. Pump and Heat Exchanger Connection

Fig. 15. Control board

Fig. 16. Inside Control board

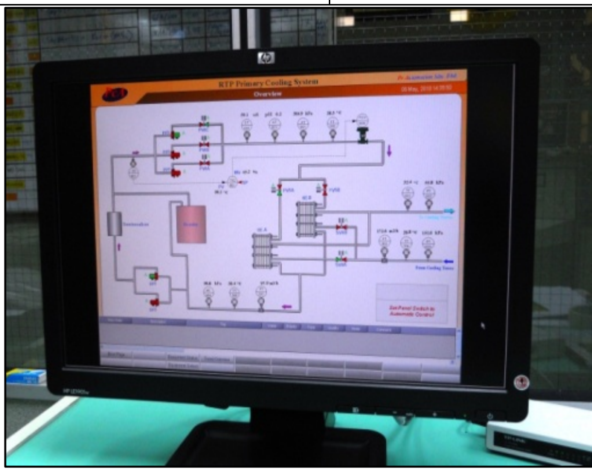


Fig. 17. Monitor display

COMPLETE SYSTEM

After going through the construction and installation phase, finally the complete system successfully installed as proposed. Figure 18 shows the complete system of new RTP's primary cooling system. In order to ensure functionality, safety and reliability of the new system, testing and commissioning has been conducted. Testing and commissioning activities was started on 20th January 2010. The result from testing and commissioning has been verified and approved by the internal safety committee and AELB.

Fig. 18. New RTP Primary Cooling System

CONCLUSION

Replacement of the RTP's primary cooling system was successfully implemented. The new system has been installed according to the requirement prior to safety consideration. The replacement has resulted in increasing of cooling performance of the reactor. An effective cooling system is very important for the reactor to maintain the integrity of the reactor components as well as to ensure the safety and sustainability of the reactor system.

REFERENCES

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[2] IAEA Safety Standard, "Safety of the Research Reactor", NS-R-4, 2005.

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[4] IAEA Safety Series No. 35-G1, "Safety Assessment of Research Reactors and Preparation of Safety Analysis Report", 1994.

[5] Malaysian Law, Atomic Energy Licensing Act No. 304, 1984 (Act 304).

[6] Radiation Protection (Basic Safety Standard) Regulations 1988 (BSS Reg. 1988).

[7] The Occupational Safety and Health Regulations, (1996).

[8] Malaysian Law, Occupational, Safety and Health Act No. 514, (1994).

[9] IAEA Safety Series No.115, International Basic Safety Standard for Protection against Ionizing Radiation and for the Safety of The Radiation Sources, 1996.

[10] Standard for Modification of Research Reactors, LEMTEK/53, Dec 2009.