AGEING/OBSOLESCENCE MANAGEMENT AT THE ZED-2 RESEARCH REACTOR

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Abstract

The Zero Energy Deuterium (ZED-2) Research Reactor first achieved criticality in 1960 September. Ageing of Systems, Structures and Components (SSCs) as well as the obsolescence of many original components had led to the Facility being in a reactive mode with respect to maintenance rather than a preventative maintenance mode. Through the implementation of an Ageing Management Plan to access the effects of Ageing Related Degradation Mechanisms (ARDMs) on SSCs and a Critical Spare Parts Obsolescence Plan (establishing new specifications for components, procurement of new components and building a replacement inventory) the Facility is returning to a preventative maintenance state rather than a reactive maintenance state.

Upgrades and refurbishment of the original equipment and components is underway within the Facility. This paper describes the programs being carried out in the Facility and focuses on the upgraded nuclear electronics, renewed moderator level control system and spare parts inventory system. Implementation of the above mentioned programs will enable the Facility to continue to fulfill its mandate as an integral part of AECL's Vision and Strategic Outcome: "*To be a global partner in nuclear innovation*" and that "*Canadians and the world receive energy, health, environmental and economic benefits from nuclear science and technology with confidence that nuclear safety and security are assured*", respectively.

1. Introduction

Atomic Energy of Canada Limited's (AECL) Zero-Energy Deuterium (ZED-2) Research Reactor is a versatile, heavy-water moderated, low-power reactor (Figure 1). The unique features of ZED-2 include the ability to readily change the position, spacing and coolant type of the fuel assemblies in the reactor. Its major historic role has been providing reactor core physics data in support of qualifying advanced fuel designs and validating reactor physics code development for design and safety analysis for CANDU reactors. In addition, the reactor has the capability to simulate in core CANDU conditions, i.e. 300ºC and 860 MPa, heat and cool the moderator, poison the moderator, and calibrate neutronic equipment. Since its initial operation in 1960, the Facility has undergone some improvements over the years but is largely operating with original systems, structures, and components and is expected to continue operations indefinitely, supporting development of new reactors, components and instruments, and advanced fuel cycles including thorium fuels.

While the reactor structure and building are structurally sound, reactor instrumentation and process components are subject to ageing and obsolescence i.e., the design is circa 1960 and there is an increasing unavailability of spare parts. Failure of components has created unplanned events and has the potential to result in extended shutdowns, if the equivalent replacement parts were not managed effectively through a structured and aggressive program.

This paper is to highlight the current ageing/obsolescence issues, management strategy and implementation to demonstrate an improved and reliable Facility that is consistent with ZED-2's mission and mandate.

2. ZED-2 Reactor Upgrade Plans

Over the last two years, ZED-2, through the use of engineering and technical resources, has addressed ageing issues and established a critical spare parts inventory system. Executing equipment and component upgrade projects in tandem with a busy operating schedule while dealing with technical challenges due to breakdown was a significant achievement for a Facility the size of ZED-2. Issues with respect to obsolescence, technology change and inadequate information detailing the ageing items made the replacement/upgrades challenging. Currently, ZED-2 is engaged with various upgrades, as shown in Table 1, to ensure that Systems, Structures and Components continue to perform their required safety function and that ageing related malfunctions and failures are minimized.

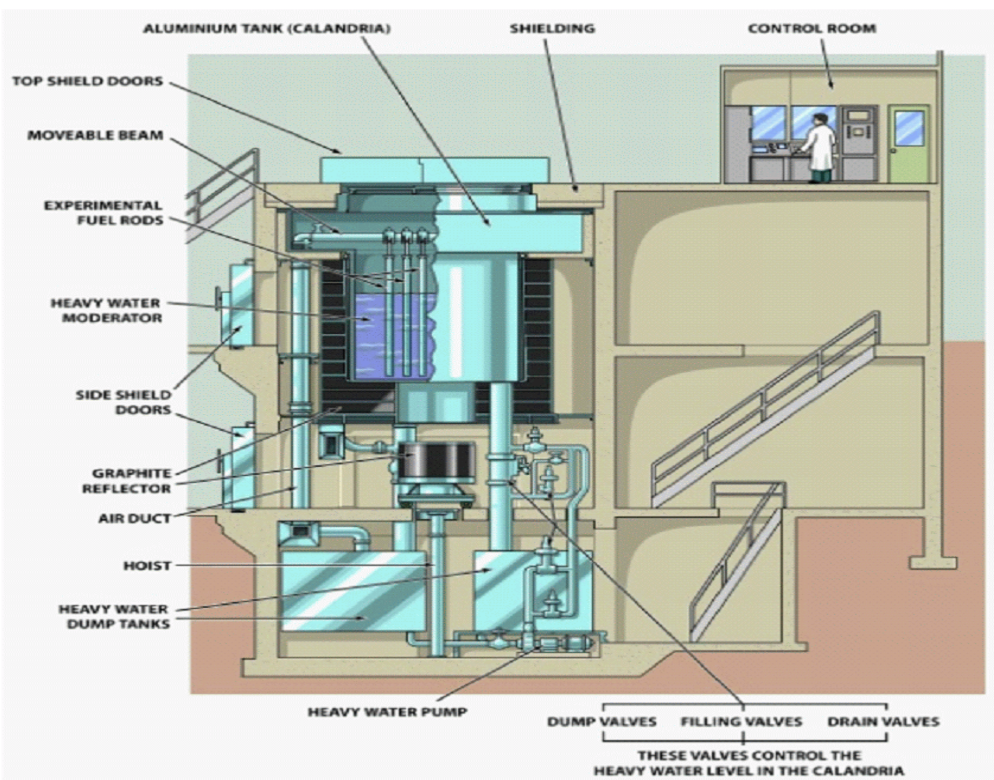

Figure 1 ZED-2 Reactor Cross Section

ZED-2 Structures/Systems/Components	Improvement Work Plans/Achievements
Reactor Safety Trip Relays	More than 80 relays being replaced.
Console Instruments	Replaced paper chart with Digital Graphical Recorders.
Dump Valve Electronics	Upgraded with new control relays and capacitors.
Dump Valve Electromagnets	3 magnetic latches were manufactured with new material, newly-wound coils and new armatures. Installation is complete.
Dump Valve Mechanical Accessories	New air cylinders, micro-switches, solenoid valves, valve gaskets and various fittings.
Heavy Water Control Valves	5 replacement pneumatic control valves of different sizes were procured and are to be installed.
Heavy Water Transfer Pumps	2 new “seal-less” magnetic drive pumps were procured and are to be installed.
Heavy Water Chiller	Replace circa-1981 10 ton Dunham-Bush package with a new system including refrigeration, evaporator and condenser servicing 27 Tons of heavy water.
HVAC Units for Reactor Hall	Air Conditioning Units are being assessed with an aim to lower the heat and humidity in the reactor hall.
Control Room Electrical Power Supply	A power conditioner was installed to reduce electronic noise in the power supplied to the control room.
Passive Data Acquisition System (DAS)	Installation of the DAS in the control room is ongoing to capture all the safety system signals and will provide multi-channel, high resolution, sequence of data that is desired for post-event analysis.
Refurbishment of the Accurate Height Probe (measures moderator level in vessel).	New replacement components such as drive motor, planetary gear, synchro transmitter and receiver, magnetic brake and other electrical and mechanical spare parts were procured. Installation of the new relays for the level measurement is in progress.
Refurbishment of the Coarse Height Probe	New replacement components such as potentiometer and pinion were put in place.

Refurbishment of Shut-Off Rods	New replacement components such as drive motor, gears, bearings, potentiometers, limit switches and other spare parts were procured. Installation is pending on the operation schedule.
Replacement Reactor Safety System (RSS) components.	Report on the work scope and budgetary estimate of the whole system replacement and upgrade was issued in 2013. Facility has explored use of Wide Range Fission Chambers to replace Ion Chambers.

Table 1 Various Upgrades in the ZED-2 Reactor

3. Replacement of Obsolete Relays

Obsolescence management has largely focused on the various ageing relays which are used to trip the reactor by activating heavy water dump valves and shut-off rods or to perform logic sequence of actions to achieve certain control and measurement processes. The performance requirements of the obsolete relays were gathered from historical documents and if not available, extensive resources were applied to search and identify suitable off-the-shelf replacement relays, in some cases sourcing from the railroad industry (Table 2). Special performance features such as speed of response, high current carrying capacity, and high reliability for multiple operations were also considered in the selection and evaluation of the substituted relays to ensure that they meet the required criteria and performance expectancy.

The existing configuration (as shown in the Figure 2 Existing Relay Panel) will not physically allow installation of newly purchased replacement relays. As a new rectangular shape relay would not match the existing octagonal plug/socket (as shown in Figure 3). A new panel plate is required and has been designed. The design of the panel adopts the "patch" concept so that all existing relays will be mounted in the new panel.

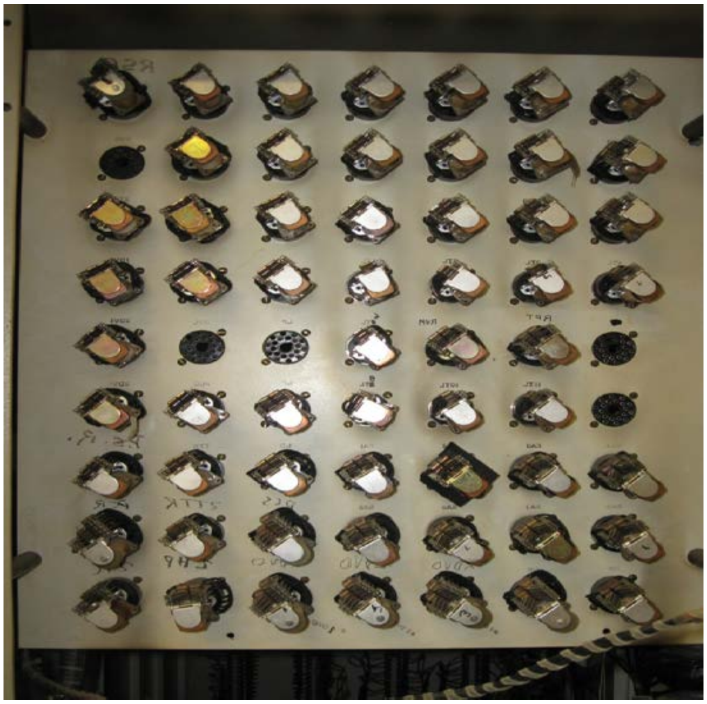

Figure 2 Existing Relay Panel

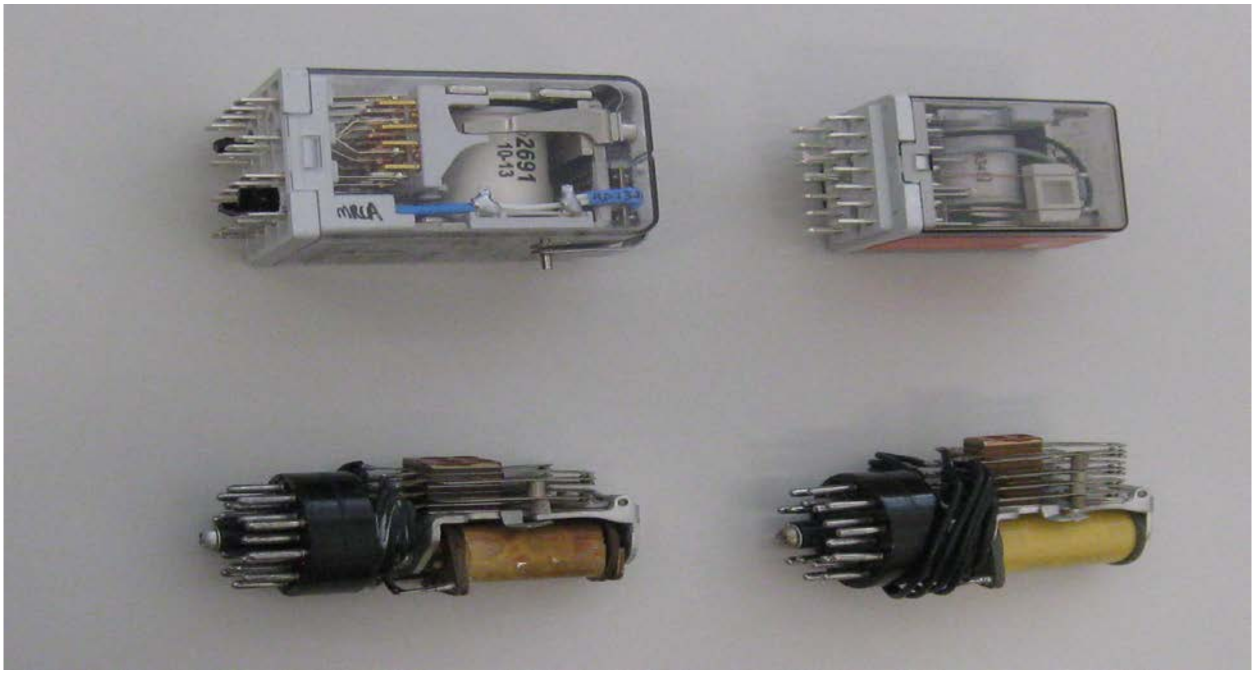

Figure 3 Comparison of New Replacement (top) and Obsolete Relays (bottom)

The replacement of existing relays can be implemented in a controlled fashion that allows testing of the system after each relay is replaced resulting in minimal interruption to reactor operation. The procedure for replacement is as follows.

1. Design and fabricate a new relay panel plate with a layout that will accommodate all new relay sockets.

2. Design small patch adaptors with openings to accept the existing sockets.

3. Patch these adaptors on top of the new panel plate with screws.

4. Replace the old panel with new panel. Remove all the existing relays and sockets from the old relay panel and transfer them to the new panel, like for like, without change to wiring.

5. Replace an old relay when it fails. Remove the old relay together with the old socket and the patch adaptor. Install the new relay socket onto the new plate directly and a corresponding new relay onto the new socket. The wiring applied to the new socket will follow the installation manual of the new relay or the related engineering change document.

6. Preferably a progressive replacement program can be implemented in 2 to 3 years such that one new relay can be installed per month as determined by the Facility operation and maintenance schedule, as per the step 5.

In addition, twelve trip circuit relays have been replaced with modern equivalents and new timers for controlling moderator transfer pumps have been installed.

4. Replacement of Moderator Level Control Components

The moderator control system, as shown in Figure 4, includes 5 pneumatic control valves and 2 centrifugal pumps for transferring and controlling the flow of heavy water into and out of the calandria vessel; thus, rate of rise and reactor power are controlled.

The components are detailed in Table 3. Valves V-15, V-16, and V-17 are used to feed the heavy water into the calandria via the outlet of two transfer pumps (P-19 and P-20). Valves V-48 and V-49 are drain valves that drain heavy water from calandria back to the dump tanks in the sub-basement. These diaphragm-type valves manufactured by Black, Sivalls and Bryson (BS&B) and the centrifugal pumps manufactured by Byron Jackson are the original installs. The new valves are required as the existing consumptive spare parts (e.g. valve diaphragms and actuator diaphragms) are running out, becoming obsolete and no longer available, such that one custom-molded rubber diaphragm may cost more than a new and modern replacement valve and may take 20 weeks for fabrication. Therefore, the Facility has recently purchased 5 new kindred valves and 2 seal-less magnetic drive pumps complete with adequate spare parts as per Table 3. The new pump design is a close-coupled configuration with no mechanical coupling or seal components thus pump/motor alignment and leaks are not an issue.

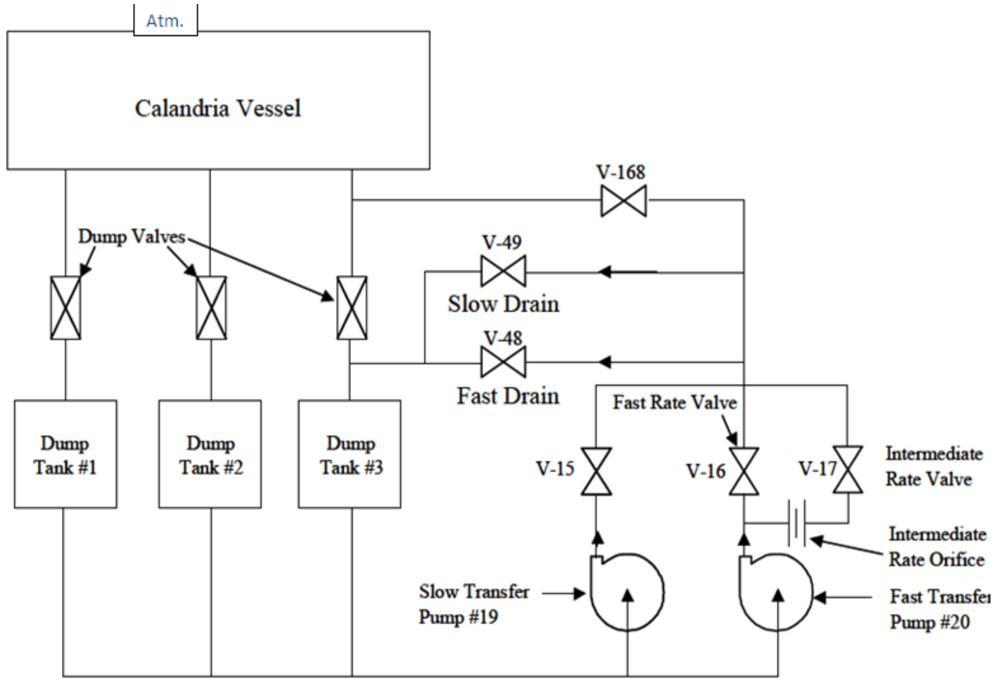

Figure 4 Heavy Water Moderator Transfer System Schematic

The original moderator transfer system piping, all the valve bodies and pump heads were designed and made with aluminium due to its lower neutron absorption cross section. Presently, stainless steel valves and pumps are popular and aluminium fittings are difficult to source. After consultation and investigation with the subject experts, it was determined the galvanic corrosion between the two dissimilar dielectric metals when the old aluminium piping and new stainless steel fittings are mechanically jointed together can be minimized with application of isolating gaskets and bolt sleeves thus avoiding metal to metal contact. The expert advice and the required materials are to be included and implemented in the new work plan for the coming valve and pump installation.

5. Spare Parts Inventory System

International Atomic Energy Agency (IAEA) Ageing Management principles [1] require that Ageing Related Degradation Mechanisms (ARDMs) are analyzed and actions for mitigation of issues are investigated and proposed. ZED-2's ARDM Database/Matrix (Figure 5) was developed, based on equipment screening and condition assessments, to monitor and record system performance to minimize ageing related malfunctions and critical failures. There is no high and only one medium entry in this figure and ARDMs have no significant impact on achieving the target life of the SSCs, due to the benign operating conditions of the low-power reactor, good chemistry control in moderator, and continuous housekeeping and maintenance. The Critical Equipment and Spare Parts List and Spare Parts Database (Figure 6) have also been developed for managing spare parts inventory for critical components and include information such as technical data, final use and tracking capability. Thus it is ensured that adequate spare parts are available and properly maintained, or that commercial replacements are readily available for procurement on short notice. The Facility is routinely updating spare parts into the database, checking inventory level and procuring adequate quantities for future use.

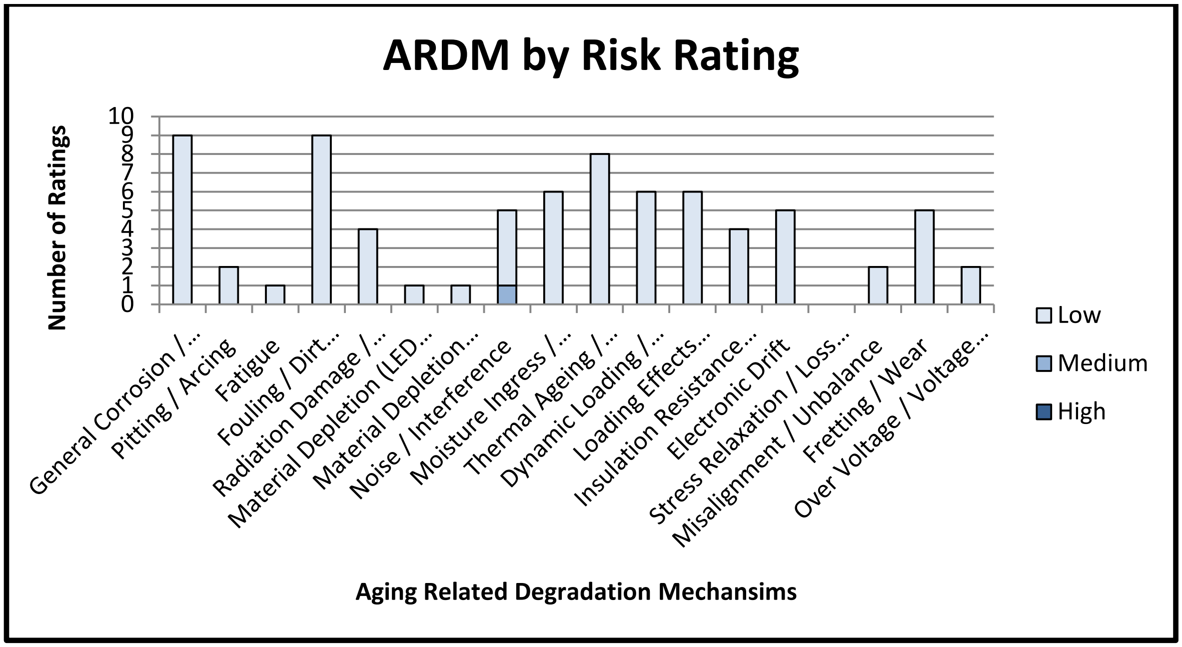

Figure 5 ZED-2's Ageing Related Degradation Mechanism Database/Matrix

Maintenance Card			
Part:	LOPA2	**LAST REVISED DATE:**	26/07/2013
Manufacturer:	Sigm		
Model #:	Series 6	**Part Location:**	Safety System
Serial #:	6FY2A2B-100G-SIL	**Spare Location:**	
Drawing #:		**IEER:**	
Description:	4PDT, Balanced Armature Relays Permanent magnet instead of a spring on the armature, silver contacts, 100 ohm coil, 16 mW power consumption, pull-in point 12 mA DC max, drop-out point 3 mA DC min		
Calibration Method:			
Maintenance Performed:			
Date:		**Work #:**	
Maintenance:	· ·		

Figure 6 ZED-2 Spare Parts Database Sheet

6. Summary

ZED-2 reactor has been in service since 1960 and the effective implementation of an Ageing/Obsolescence Management will ensure that the reactor continues to operate safely and reliably well into the future. Many of the ageing components in ZED-2 were obsolete and difficult to replace in case of defects/malfunctions. Proactive exercises have been taken for establishing new specifications, searching for the modern equivalents and the building of the replacement inventory. The Facility has recently replaced many ageing electrical relays and other electronic components with properly selected items to minimize unexpected component failure and the impact of extended reactor shutdowns. ZED-2 is further progressing to replace the existing control valves, heavy water transfer pumps and other major equipment in the near future. The significant achievement with respect to Spare Parts and Ageing Management was indicated by the lower number of unplanned occurrences and down times, and increasing reliability and availability of the User Facility open to Canadian universities and research institutions to further advance nuclear physics experiments, design code validation and reactor instrumentation applications. The improved work place, upgraded equipment and a more predictable operation mode are all contributing to ZED-2's mandate as an integral part of AECL's Mission-Ready Science and Technology infrastructure.

7. Reference

[1] IAEA Specific Safety Guide No. SSG-10, "Ageing Management for Research Reactors," 2010.

Item	Relay ID	Original Relay Model	Replacement Model	Type	Descriptions	Application	Status	Quantity required
1	EA7, , 2TA, 2TB, , DV1, DV2, DV3	C.P. Clare No. 37 (or 38) H.F.	Mors Smitt D-U309-T	4PDT	110 VAC coil, plug-in socket type, 5A contact rating, 18mA coil current	Relays used for various reactor trip/control logic.	Acquired, to be installed	39
2	MTA, MTB, RVM, RPT	C.P. Clare No. 37 (or 38) H.F.	Mors Smitt AM-400-115-SZZ-1	4 Form Z	110 VAC coil, plug-in socket type, 5A contact rating, 18mA coil current	Relays used for reactor trip and start-up testing.	Acquired, to be installed	4
3	DVO, RSR, PCR, CR, PCS	C.P. Clare No. 41 E.C.	Mors Smitt D-U213-T	4PDT	125 VDC coil, plug-in socket type, 8A contact rating, 18mA coil current	Relays used for driving shut-off rods and pump timers.	Acquired, to be installed	7
4	1TA, 1TB, 1TRB, PC, V1, 1DA, 2DA, 3DA, 1DB, 2DB, 3DB	Klockner-Moeller DIL00-20/56	Eaton XTRE 10B40A	8PST Heavy Duty Power Relays	110 VAC coil, typ. coil current less than 0.5A	11 Relays located in Main Cabinet	Installed	11
5	RM	Klockner-Moeller DIL00-44/56	Eaton XTRE 10B40A	8PST Heavy Duty Power Relay	110 VAC coil, typ. coil current less than 0.5A	1 Relay located in Main Cabinet	Installed	1
6	TL	C.P. Clare 6.3 VAC Relay No. 24 H.F.	OMRON MKS2P AC6	DPDT	6.3 VAC, 60 cycle coil, 8 pins circular arrangement	Trip alarm signals locking	Acquired, to be installed	9

Table 2 ZED-2 Obsolete Relays and Modern Equivalents

Item	Relay ID	Original Relay Model	Replacement Model	Type	Descriptions	Application	Status	Quantity required
7	LOPA1, LOPA2, LORA1, LORA2, LINA, LOPC, LORC, STRT1, STRT2	Sigma	Series 6 6FY2A2B-100G-SIL	4PDT, Balanced Armature Relays	Permanent magnet instead of a spring on the armature, silver contacts, 100 ohm coil, 16 mw power consumption, pull-in point 12 mA DC max, drop-out point 3 mA DC min	Relays are in Various Amp Chassis	Available in AECL Stores	9
8	Timer T	Microflex HM305A6	Omega PTC-13 90-240 VAC	Configurable	Wiring to the pins changed	Timer T is used in the control of Fast Transfer (high flow rate) Pump P-20 running for 60 seconds.	Acquired, to be installed	1
9	Timer 1TT and 2TT	Microflex HA405A4A6	Mors Smitt Relay/Timer WDE4-110-BVC 0.5 Second fixed	4PDT	Wiring to the pins changed	Timers are used in the start-up testing of control logic	Installed	2
10	DVR	Agastat 2212A9	Agastat 7012AC	DPDT,	110 VAC 60 cycle, 8 pins, delay time set for 5 seconds	Dump Valve Magnet Control Time Delay Relay	Installed	3
11	R2 to R8	C.P. Clare C700188	OMRON MC4N –CR 110/120 VAC	4PDT	120 VAC Coil, 20 pin Coil 525 ohm (5500 turns)	Accurate Heavy Water Indicator	Acquired, to be installed	7

Table 2 (continued) ZED-2 Obsolete Relays and Modern Equivalents

Valve/ Pump	Existing Model #	Material	New Model #	New Material	Application	Valve/Pump Size
V-15	BS&B 70-26016	Aluminium	ITT 2433R-M1-34-3216-P1	Stainless Steel (316)	0.07 cubic meter per minute, slow feed control valve	0.75”
V-16	BS&B 70-26012	Aluminium	ITT 2433R-M1-34-3274-P1	Stainless Steel (316)	0.9 cubic meter per minute, fast feed control valve	3.0”
V-17	BS&B 70-26013	Aluminium	ITT 2433R-M1-34-3216-P1	Stainless Steel (316)	0.24 cubic meter per minute, intermediate feed control valve	1.5”
V-48	BS&B 70-26014	Aluminium	ITT 2433R-M1-34-3274-P1	Stainless Steel (316)	1.133 cubic meter per minute fast drain control valve	3.0”
V-49	BS&B 70-26015	Aluminium	ITT 2403R-M-34-3216-P1	Stainless Steel (316L)	0.006 cubic meter per minute, slow drain control valve	0.5”
V-168	Jamesbury GR-2814-46ST	Aluminium	Not required		This valve is a rather new ball valve, no need for replacement.	3”
P-19	Byron Jackson SM (Series # T- 407944-S)	Aluminium	MPL42LF-V25N-180TC	Stainless Steel (316L)	Slow Transfer Pump	1.5” x 1”
P-20	Byron Jackson SM (Series # T- 407945-S)	Aluminium	MPL84-V40N-210TC	Stainless Steel (316L)	Fast Transfer Pump	3” x 1.5”

Table 3 Replacement Control Valves and Pumps