INTEGRATED SYSTEMS AND TOOLS FOR REPEATABLE NUCLEAR KNOWLEDGE MANAGEMENT & OPERATING EXPERIENCE IMPLEMENTED AT THE UNIVERSITY OF UTAH NUCLEAR RESEARCH REACTOR FACILITY

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ABSTRACT

The University of Utah Nuclear Engineering Program (UNEP) operates and maintains a 100 kW TRIGA (Training, Research, Isotopes, General Atomics) reactor. UNEP trains students in operating and maintaining the TRIGA reactor. The knowledge coincidental to daily operation of the TRIGA reactor, laboratory activities, class assignments, procurement and maintenance of the facility are all-together integrated under one "umbrella" which UNEP has implemented as the DevonWay tracking on-line system. The University nuclear engineering programs usually do not follow nuclear industry based systems of strictness in tracking and recording the activities and therefore in developing the system of organized and preserved knowledge repository. Recognizing the importance of tracking the knowledge in systematic and for future generations easy-to-use manner, and of using that methodology when teaching a new nuclear work force, UNEP has implemented a new approach in the nuclear engineering curriculum and in the daily management of the nuclear research reactor facility.

1. Introduction

UNEP has developed an integrated system and tool in assuring a repeatable knowledge management of activities related to the operation, maintenance, use and upgrade of the reactor as well as other laboratory activities. This on its own represents a support to the overall nuclear engineering programmatic approach on active learning derived from the Bloom's taxonomy of cognitive domain. This our newly created *book of repeatable knowledge* is derived from the DevonWay "Track & Trace" software adopted as a repository of our accumulated knowledge as it daily accumulates at the facility; this repository is equipped with a search engine that allows for an easy review of the information and securely accessible by those associated with UNEP [1]. The facility life cycle is defined per yearly inspections conducted by the U.S. Nuclear Regulatory Commission (NRC). The repository then serves too as a purpose of an easy review of the daily activities inclusive of its management, repairs, maintenance, procurement, equipment list, classes, labs, engineering analysis and planning [2]. This new system thus prevents the loss of valuable reactor operating and associated training and teaching experiences and practices [3].

Due to the inherent safety of TRIGA reactors, UNEP offers yearlong training course for university students to become proficient in operating and maintaining the TRIGA reactor as well as eventually obtain a reactor operator's license from the U.S. NRC [4]. The class attracts students from wide ranging disciplines including science, engineering, and humanities. Students enrolled in the class assist in maintaining all aspects of the reactor including monthly, semi-annual, annual, and biennial surveillances. These surveillances include detailed procedures of how they are to be performed that must be followed exactly as stated. Due to the procedures requiring an exact implementation, misunderstandings in verbiage among students may result in a procedure being performed incorrectly. Due to the wide-ranging disciplines students come from, it is important to write procedures in a manner that all understand quickly and accurately in the training process. As a result of the class being taught on an annual basis, complete turnover in those that assist the full-time reactor supervisor is frequent thereby necessitating complete retraining on an annual basis.

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Collection of lessons learned from students assisting in the surveillances allows for clarification in the procedures to catch the most frequent errors. This is especially true in surveillances that are performed on a less frequent basis such as the biennial fuel inspection. Capturing lessons learned from all of the surveillances on a regular basis allows for the full-time reactor staff to improve policies and procedures, making them more easily understood by those with less experience. Most recently, this is performed following the biennial fuel inspection of the UUTR. A surveillance being performed on a biennial basis results in lessons learned being easily forgotten if they are not documented promptly and implemented into the procedures.

2. Continuous Improvement and Corrective Action Program Software

UNEP has partnered with DevonWay Company and began using their software called “Track & Trace” in 2012 to implement a correction action tracking program [5]. DevonWay software is in use by over 80% of the nuclear power plants and other industries in the US, to meet their CAP needs [6]. The software is web-based and user-centric and is hosted by DevonWay in its certified data centre. Most users are able to quickly and easily grasp navigating and using the DevonWay software. Because DevonWay is cloud-based, accessing the software can be completed from various locations and reports can be retrieve easily [7].

An important factor of the DevonWay software is that it is easily customizable and adaptive for many different factors. UNEP has been able to modify and make new modules to track procedure revisions to purchasing and financial tracking [8]. With little computer training, new modules can be generated to perform various functions as found needing in the facility or as aspects of the facility change. DevonWay is useful in that records and documents can be found as easy as searching on Google. A simple search can be conducted using a key word or advanced searching techniques can be used to find detailed records as seen in Figures 1 and 2 respectively.

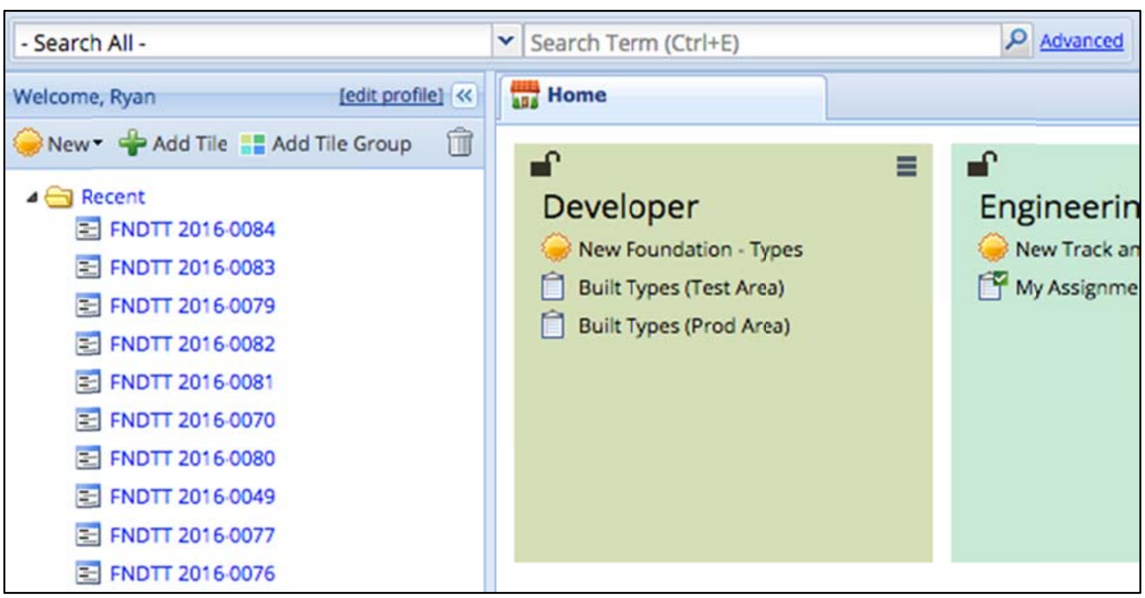


Figure 1: DevonWay Simple Search Screen

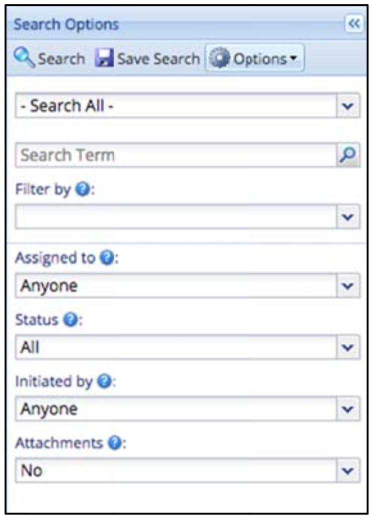
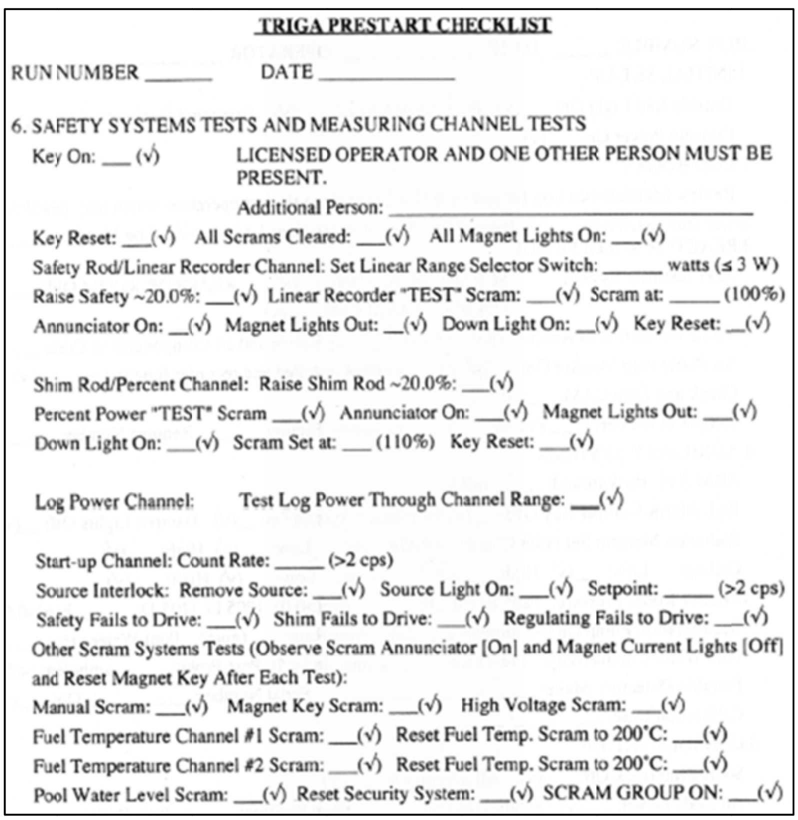


Figure 2: Advanced Search

3. Software use in Knowledge Management Example

UNEP has frequent turnover due to the nature of new students arriving and experienced students graduating and moving on to careers. In order for UNEP to continue new and innovative research a robust and simple-to-use method for transferring knowledge from experienced students and staff to new students and incoming staff is needed. This is also essential for safety and operating experience using procedures [9]. The procedures for operating and maintaining the reactor were minimal and not as robust as a strong nuclear safety culture would require in 2012 [10]. An example excerpt for the old pre-2012 procedure to start-up and operate the reactor is given in Figure 3 with an example of the new and improved procedure to start-up and operate is given in Figure 4.



TRIGA PRESTART CHECKLIST

RUN NUMBER ______ DATE ____________

6. SAFETY SYSTEMS TESTS AND MEASURING CHANNEL TESTS

Key On: ___ (√) LICENSED OPERATOR AND ONE OTHER PERSON MUST BE PRESENT.

Additional Person: ________________________________

Key Reset: ___(√) All Scrams Cleared: ___(√) All Magnet Lights On: ___(√)
Safety Rod/Linear Recorder Channel: Set Linear Range Selector Switch: ______ watts (≤ 3 W)
Raise Safety ~20.0%: ___(√) Linear Recorder "TEST" Scram: ___(√) Scram at: _____ (100%)
Annunciator On: __(√) Magnet Lights Out: __(√) Down Light On: __(√) Key Reset: __(√)

Shim Rod/Percent Channel: Raise Shim Rod ~20.0%: ___(√)
Percent Power "TEST" Scram ___(√) Annunciator On: ___(√) Magnet Lights Out: ___(√)
Down Light On: ___(√) Scram Set at: ___ (110%) Key Reset: ___(√)

Log Power Channel: Test Log Power Through Channel Range: ___(√)

Start-up Channel: Count Rate: _____ (>2 cps)
Source Interlock: Remove Source: ___(√) Source Light On: ___(√) Setpoint: _____ (>2 cps)
Safety Fails to Drive: ___(√) Shim Fails to Drive: ___(√) Regulating Fails to Drive: ___(√)
Other Scram Systems Tests (Observe Scram Annunciator [On] and Magnet Current Lights [Off] and Reset Magnet Key After Each Test):
Manual Scram: ___(√) Magnet Key Scram: ___(√) High Voltage Scram: ___(√)
Fuel Temperature Channel #1 Scram: ___(√) Reset Fuel Temp. Scram to 200°C: ___(√)
Fuel Temperature Channel #2 Scram: ___(√) Reset Fuel Temp. Scram to 200°C: ___(√)
Pool Water Level Scram: ___(√) Reset Security System: ___(√) SCRAM GROUP ON: ___(√)

Figure 3: Old Start-Up Procedure Excerpt

Procedure	UNEP-001	Rev. 14	Page 6 of 9
Prestart / Operation / Termination Procedure			

4.30 Verify Linear Power SCRAM annunciator is ON. ________

4.31 Verify Magnet Lights are out. ________

4.32 Verify Rod Down Lights are ON ________

4.33 RESET Reactor Console Key ________

4.34 Raise shim rod to ~20% ________

4.35 Perform percent power "TEST" SCRAM by holding down percent test button and turning test signal dial through 110% Percent Power indication SCRAM occurred at: _______ (110%) ________

4.36 Verify Percent Power SCRAM annunciator is ON. ________

4.37 Verify Magnet Lights are out. ________

4.38 Verify Rod Down Lights are ON ________

4.39 RESET Reactor Console Key ________

4.40 Test log power through channel range by holding down log test button and turning dial through entire range ________

4.41 Record Fission Counter count rate: _________ (>2 cps) ________

4.42 Remove the neutron source and verify the following: ________

- 4.42.1 Check Source Interlock light ON. ________
- 4.42.2 Press safety rod up button and ensure rod fails to drive. ________

Figure 4: New Start-Up Procedure Excerpt

Figure 3 displays that the old procedures were little more than a checklist with a few key words and little information for a new or unfamiliar operator. The old procedure also only required checks instead of initials and formal procedure tracking mechanisms. The new procedure excerpt in Figure 4 shows that each step is clearly written with initials for each step. The method to track procedure updates and keep track of which version of the procedure is the most up-to-date was also lacking before use of the DevonWay software. Now any staff member or student in UNEP can log into the DevonWay software system and lookup which version of the procedure is approved for use as seen in Figure 5. Figure 5 also shows that a pdf retrievable document of both the outgoing and the new approved procedure can be obtained.

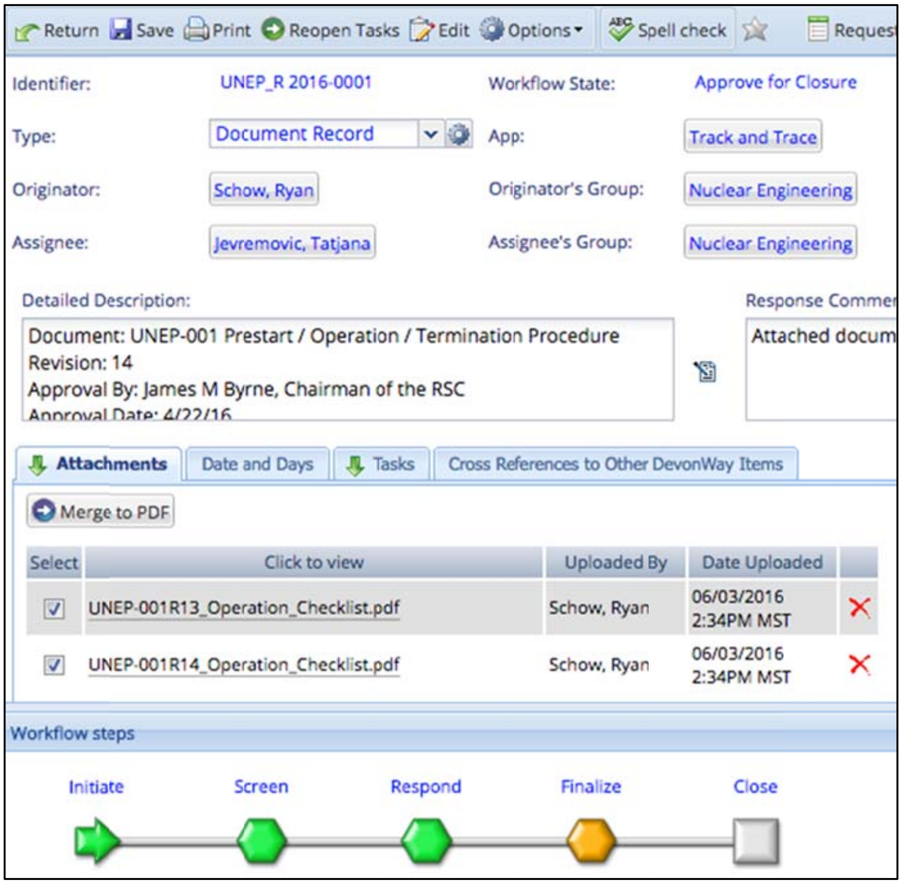


Figure 5: DevonWay Procedure Tracking Display Screen

All maintenance, repair, and purchase activities are also stored and searchable in the DevonWay software. Historically, when an infrequently performed surveillance or repair occurred it was difficult to locate the hard print paperwork to see what purchases were made and repairs conducted. Now with the easily searchable DevonWay software, each operator or staff member can quickly and securely search and find all pertinent documents and receipts for given repairs and surveillances. This has allowed for a continuity of knowledge that was not accessible in the past.

When a student is about to graduate, the student must complete an upload of their information and research into the DevonWay database. This allows future students to be able to search and learn from the experience and research conducted by others in the program. Without this knowledge transfer, valuable time and efforts are wasted while students re-learn and re-produce previously completed research by past students.

4. Software use for Operational Experience Example

An infrequently performed surveillance on the TRIGA reactor at UNEP is the biennial fuel and control rod inspection. At intervals not to exceed two years, the US NRC regulations and technical specifications require that all fuel elements and control rods be visually inspected for damage or deterioration. It is necessary to perform this procedure in a careful manner in order to prevent reactivity transients, reduce personnel exposure, and prevent contamination. The biennial fuel inspection involves systematic removal, inspection and logging of each element. Minimal handling of the fuel is suggested because of the risk of dropping the fuel from the fuel handling tool to the tank floor where damage to the cladding or locator pin may occur. To inspect the control rods, it is required that the assemblies be removed from the tank and disassembled. The old procedure that was used prior to 2012 is given in most of its entirety in Figure 6.

BIENNIAL FUEL ROD INSPECTION

OBJECTIVE:

To insure that the integrity of the fuel is maintained.

PROCEDURE:

Log __________ Run # _________

1. Check out the reactor and fully withdraw the safety rod but do not go to power. Maintain an operator at the console until the reactor is shut down.
2. Remove two fuel elements from the B-hexagonal ring (worth @- $2.50, see Kimura, p. 71) and place in storage during inspection. Record movement in Operations Log and below.

Preplanned Fuel Movement Sequence

Elements	Core Position	Storage Position	Condition

3. Remove elements in the order listed on the reverse side of sheet, bring them to a position where their complete circumference is visible. Inspect the submerged rods with binoculars. Record their condition in the TRIGA Fuel Log book and check the Operation Log as done when returned to their original position. (Line through positions which do not contain fuel rods.)
4. Record in the Operations Log as the inspection of each rod is completed. Do not reinstall damaged rods in the core. Leave them in the storage rack on the side of the tank. Refer to TS 4.4.

Figure 6: Old Biennial Fuel Inspection Procedure

Figure 6 demonstrates that many details are not included and requires previous experience in conducting the inspection. Operational experience was used during the fuel inspections conducted in 2014 and 2016 to improve the procedures so that inexperienced operators and students could perform the task succinctly and safely. This is all tracked in the DevonWay software so that any student or staff member can access and review the lessons learned and best practices. The information can be easily searched and found in the DevonWay software. The new procedure is 10 pages long with excerpts given in Figure 7. Prerequisites, precautions, limitations, and detailed step by step instructions with initials are now given and required. Five pages of lessons learned were recorded and are reviewed as preparation before new fuel and control rod inspections.

Surveillance	UNEP-002	Rev. 4	Page 2 of 10
Biennial Fuel / Tank / Control Rod / Reflector Element Inspection			

1 PURPOSE AND SCOPE

1.1 This procedure is performed to meet the technical specification requirements for the biennial fuel, control rod, tank, and reflector inspection. The fuel inspection consists of the inspection of all fuel elements including storage pits, heavy water elements, graphite elements, thermal irradiator, and control rods. It involves the systematic removal, inspection, and logging of each of the fuel elements.

2 PREREQUISITES — INIT

2.1 The reactor is secured. ________

2.2 A Senior Reactor Operator is present to supervise the fuel handling activities.
SRO:______________________ ________

2.3 Lower the reactor pool grating to allow access to the reactor pool area. ________

2.4 Test fuel handling tool on non-fuel element prior to use. ________

2.5 Test and ensure underwater camera is operating properly. ________

2.6 Ensure all instruments for radiation surveys are calibrated and in good working condition. ________

2.7 Make entry of Fuel Movement in Operations Log. ________

2.8 Develop preplan for fuel movement and get approval from Director and Reactor Supervisor:

Fuel Element #	Core Position	Storage Position	Reactivity Worth
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________

Reactor Supervisor: ______________________

Director: ______________________

3 PRECAUTIONS AND LMITATIONS

3.1 Allow at least 10 days after shutdown to allow fuel elements to cool down prior to moving fuel elements to storage (SAR 9.2.5).

3.2 Ensure that all reactor control systems are on and functioning properly during all fuel inspection operations (TS 3.2.2 and 3.2.3).

3.3 A licensed Reactor Operator shall be at the Reactor Control Console during fuel movement and rod removal, or any reactivity insertions into the core.

3.4 Stored fuel is maintained in a geometry with a multiplication factor of 0.9 or lower (TS 5.4).

3.5 Minimal handling of the fuel is suggested because of the risk of dropping the fuel from the fuel-handling tool to the tank floor.

3.6 Ensure the fuel handling tool is locked up and secure when not in use.

Figure 7: New Biennial Fuel Inspection Procedure Excerpts

5. Conclusion and Future Work

Due to the easy and accessible DevonWay software, UNEP has been able to both transfer knowledge and work from research that has been completed and conducted. This has allowed incoming students to be able to pick up and complete work and research in a safe and efficient manner. The operational experience that is also recorded in the DevonWay software database has also improved operations of the TRIGA reactor as well as reduce rework or issues that could have possibly occurred without the lessons learned being reviewed. UNEP will continue to look for new and innovative ways to implement the DevonWay software to improve and enhance research and operations.

References

[1] Schow, R., Jevremovic, T., “Bridging the Nuclear Generation Practical Training Gap”, The American Nuclear Society Winter Meeting, Washington DC, November 10-14, 2013.

[2] International Atomic Energy Agency (IAEA), “Knowledge Management and Its Implementation in Nuclear Organizations,” IAEA Nuclear Energy Series No. NG-T-6.10, April 2016.

[3] International Atomic Energy Agency (IAEA), “Nuclear Accident Knowledge Taxonomy,” IAEA Nuclear Energy Series No. NG-T-6.8, May 2016.

[4] Schow, R., Jevremovic, T., “A Novel Paradigm in Training and Educating Nuclear Engineering Students About Effective Nuclear Safety Culture”, NESTet Nuclear Engineering Science and Technology, Madrid Spain, November 17-21, 2013

[5] Jevremovic, T., “The Utah Nuclear Engineering Program and DevonWay are Developing One and Unique Approach to PLiM for Securing the Nation’s Nuclear Future,” 3rd International Conference on NPP Life Management (PLiM) for Long Term Operations (LTO), IAEA CN-194, Salt Lake City, Utah, International Atomic Energy Agency (2012).

[6] DevonWay, Inc., Supplies innovative software solutions for Continuous Improvement (CI) and Enterprise Asset Management (EAM) for utilities, San Francisco, CA.

[7] Jevremovic, T., Schow, R., McDonald, L., Rey, A., “Unique Approaches in Emphasizing the Role of Reactor Laboratories and Facilities for Training and Education of Future Nuclear Engineers ‘Without the Borders’, PHYSOR 2014 – The Role of Reactor Physics Toward a Sustainable Future, Kyoto, Japan, September 28 – October 3, 2014.

[8] Schow, R., Jevremovic, T., “Feeding the Nuclear Safety Culture Pipeline,” 24th International Conference on Nuclear Engineering (ICONE24), ASME, June 26-30, 2016.

[9] Electric Power Research Institute (EPRI), “Enterprise Knowledge Management System for Nuclear Power Plants,” EPRI Report 1013108, January 2005.

[10] Jevremovic, T., “Introducing the University of Utah Nuclear Engineering Facilities: Operational Protocols, Training Practices, Outreach Activities and Research,” National Organization of Test, Research and Training Reactors TRTR, 2013 Annual Meeting, St. Louis, Missouri, September 23-26, 2013, TRTR.