edcetera | engineering

Managing a Nuclear Plant Project

By

James N. Salapatas, PE, PMP

Course 503
4 PDH (4 Hours)

PO Box 449
Pewaukee, WI 53072
(888) 564 - 9098
eng-support@edcet.com

Table of Contents

Managing a Nuclear Plant Project

INTRODUCTION

The United States of America had 55 operating nuclear plants in 2022 that provided 20% of the nation's electric power.[1] According to the World Nuclear Association to meet the goal of low carbon emissions nuclear plants must be built and maintained more efficiently.[2] Nuclear power plants undergo seasonal scheduled refueling outages that result in greater efficiency and reliability. When a unit shuts down for refueling the outage could last up to two months. Reactor operators typically defer much of the non-critical maintenance work until a refueling outage. They conduct the maintenance in parallel with the refueling.[3]

This is a case study about managing a nuclear plant project during a scheduled refueling outage. The project involves the replacement of two large valves which are part of the Drywell Shutdown Cooling System, a critical system in nuclear plant safety for boiling water reactor plants. The valves are in a radioactive area of the plant. The task of replacing two large valves, weighing almost two tons each, in a contaminated environment involves many complex activities and many people. It involves Project Management. An added challenge to performing work in a nuclear plant is managing and controlling the work in a contaminated environment.[4] At one time or another most of the project management practices were present in this project, some effective some less effective.

[1] www.eia.gov/today in energy
[2] *World Nuclear Association 2018@ Report 2018002*
[3] www.eia.gov/today in energy
[4] NRC 10 CFR (Part 20) Occupational Dose Limits, Appendix C

CRANE

(OLD)

ANCHOR DARLING

(NEW)

This is an actual valve replacement project[5]. Some of the project conditions have been changed for training purposes. A cast of characters has been created to illustrate the project conditions. Any similarity between people working in any nuclear plant and the characters in the case study is purely coincidental. The course is presented in five parts. PART 1 contains the economic analysis decision to replace the valves. PART 2 presents the key team members having an interim meeting to solve some unexpected project problems. PART 3 contains two technical reports. PART 4 contains a Lessons Learned Overview, Outage Lessons Learned contributions to the Nuclear Industry data base and the project close-out reports. PART 5 Appendix contains an overview of the US nuclear electricity generation industry, describes nuclear reactors, the nuclear workers who maintain the nuclear plants, and a Glossary of Terms with some illustrations of plant equipment.

KEY WORDS
Project Management
Plant Outage
Reactor Cooling System
Shutdown Schedule
Lessons Learned

[5] COMED DRESDEN, Morristown Illinois

PART 1

Project Cost Analysis

Part 1 contains the problem identification, five alternative options to address the problem, a cost risk analysis for each option and the final decision to plan the project.

The problem is the excessive leaking of the Reactor Shutdown Cooling System Motor Operated Valves A-549 and B-549. Failure of any one valve during plant operations would result in an unexpected costly forced outage.

1. Option 1-Do Nothing
2. Option 2-Repair the valve seats during the next outage
3. Option 3-Weld buildup seats and machine to specifications
4. Option 4-Replace the valve seats
5. Option 5-Replace the CRANE flexible wedge gate valve with a new ANCHOR DARLING double disc gate valve

   A cost risk analysis was conducted for each option using the following factors to determine the total cost of each option.

- Forced Outage Risk
- Forced Outage Cost[6]
- Replacement/Repair Cost

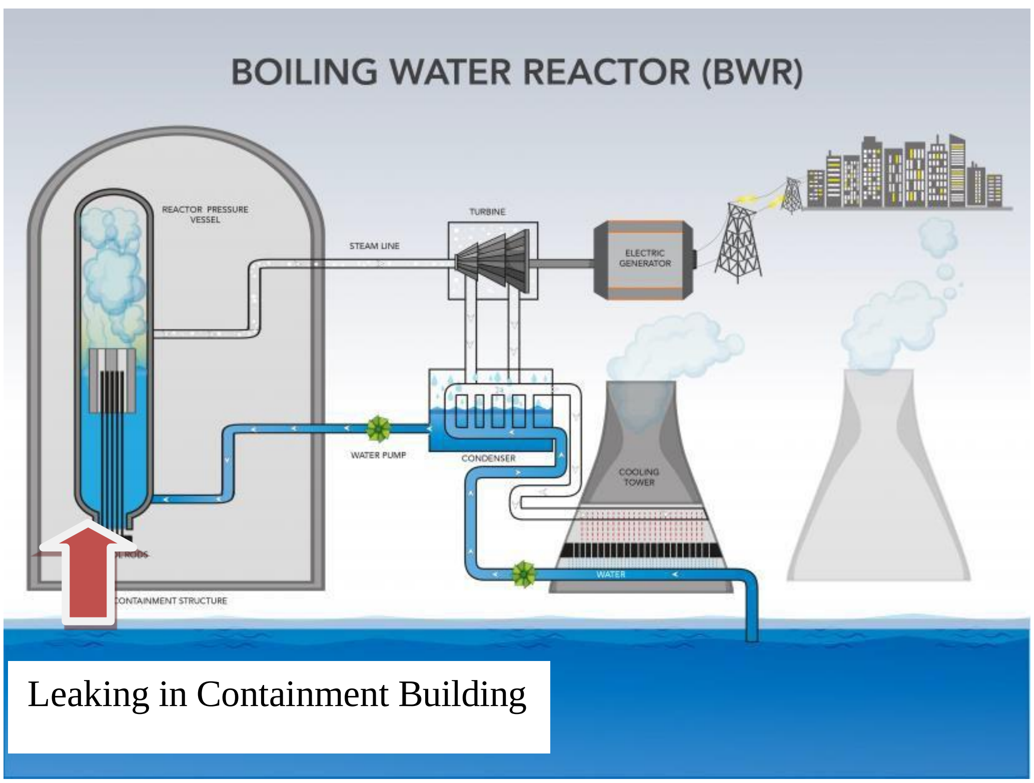
For each Option:
Forced Outage Risk X Forced Outage Cost +
Replacement/Repair Cost = Total Cost

Option 5 was selected to plan and schedule the project.

[6] Outage Cost is calculated based on lost plant revenue = $250,500/day

PROBLEM IDENTIFICATION

There is excessive leaking of the Reactor Shutdown Cooling System Motor Operated Valves A-549 and B-549. The Dry Well Shut Down Cooling System is a critical system in nuclear plant safety. The failure of one of these valves during plant operation could cause a forced maintenance outage on that unit. The plant has been forced down two separate times in the past three years to make repairs to the valve seats in these valves. Due to the unplanned nature of each of these shutdowns the outage duration was 19 and 23 days. Also, when the failures occurred there were no replacement parts readily available, thus repairs to the valve seats were the only economical alternative.



OPTIONS AND RISK COST ANALYSIS

Option 1 "Do Nothing" This is an option. However, the Project Team estimated that doing nothing at this time had a 25% chance of leading us into another forced maintenance outage during the cycle. The cost of this would be –0- dollars for the repair and 25% of a 21-day forced outage cost ($1,312,500 total costs).

Option 2 "Repair the valve seats during the next outage" Just making repairs in the past to the valve seats has been unsuccessful. The Project Team again estimated this option would fail by attempting repairs to the valve seats. The time determined that there was a 20% chance of a forced outage during the next cycle if we only made seat repairs. The cost of the repair would be $150,000 plus 20% of a 21-day forced outage cost of $1,050,000 ($1,200,000 total cost).

Option 3 "Weld buildup the seats and machine to specifications" This type of repair again has not been successful in the past for making permanent repairs to valve seats. A risk evaluation has determined that there is a 15% chance of a forced outage during the next cycle if we only made the valve repair. The cost of the repair would be about $200,000 plus 15% of a 21-day forced outage cost of $787,500 ($987,500 total cost).

Option 4 "Replace the valve seats" Seat replacements on similar valve have been unsuccessfully attempted many times throughout the industry. A risk evaluation has determined that there is about a 15% chance of suffering a forced outage in the next cycle if we make this repair. The cost of the repair would be about 250,000 plus 15% of a 21-day forced outage cost of $787,500 ($1,037,500).

Option 5 "Replace the CRANE flexible wedge gate valve with a new ANCHOR DARLING double disc gate valve." The anchor Darling double disc gate valve is much better suited for the application. A risk evaluation has determined that there is less than 1% chance of suffering a forced outage in the next cycle if the valve replacement method is selected. The cost of the repair would be about $750,000 plus the 1% of a 21-day forced outage cost of $52,500 ($802,500 total cost).

RISK-COST ANALYSIS

Application	Forced Outage Risk	Forced Outage Cost	Replacement / Repair Cost	Total Cost
Option 1	25%	$1,312,500	$0	$1,312,500
Option 2	20%	$1,050,000	$150,000	$1,200,000
Option 3	15%	$787,500	$200,000	$987,500
Option 4	15%	$787,500	$250,000	$1,037,500
Option 5	1%	$52,500	$750,000	$802,500

The RISK-COST ANALYSIS has determined that there is less than 1% chance of suffering a forced outage in the next cycle if the valve replacement method is to **"Replace the CRANE flexible wedge gate valve with a new ANCHOR DARLING double disc gate valve."** The cost of the replacement would be about $750,000. **Option 5 is selected.**

IMPLEMENTATION STRATEGY

- Project Management[7] will be used to plan, schedule, and monitor the outage project work.

- The project will be accomplished during the refueling outage and is estimated to take less than 17 days to ensure the outage duration and critical path are not jeopardized

- A specialty contractor will be used to cut-out the existing valves automatically and weld the new valves into place.

- All preparatory work on the new valves will be done off-site in the fabrication shop.

- All piping will be sufficiently restrained to ensure no movement when the initial cuts are made for removal.

- The key project team members are:

Outage Manager	Design Engineer
Area Manager	Radiation Protection
Project Manager	Installer (Field Engineer)
Task Manager	

[7] The Guide to the Project Management Body of Knowledge (PMBOK® GUIDE).

PART 2

The Key Team Members and The Meeting

This part contains a description of the outage key team members and a portrayal of a meeting by the team members to solve an interim problem during the outage.

The project cost analysis recommended an implementation strategy that involved the selection of the following key team members to provide management and leadership to the project.

- Outage Manager
- Area Manager
- Project Manager
- Task Manager
- Design Engineer
- Installer (Field Engineer)

To illustrate the meeting, a brief character description for each team member was created presenting each team member's education, experience, background, role, and current situation. Any similarity between people working in any nuclear plant and the characters in the case study is purely coincidental.

The project cost analysis recommended an implementation strategy to use project management. An added challenge to performing work in a nuclear plant was managing and controlling the work in a contaminated environment.[8] This meeting occurred during the plant refueling outage to solve unexpected problems encountered with the removal of the valves and the increase in radiation exposure.

[8] NRC 10 CFR (Part 20) Occupational Dose Limits, Appendix C

KEY TEAM MEMBERS

Title: *OUTAGE MANAGER: Charlie Cunningham*
Professional License/ Education: *Electrical Engineering /MS, Nuclear Engineering/MS*
Experience: *25 Years Nuclear Operations, Plant Management*

This is the eleventh hour of your twelve-hour shift. You don't know whether it's light or dark outside. You haven't stopped going since you entered the building, and everybody has been griping to you about their problems. They haven't asked for help or advice; they just keep telling you about their gripes. You finally got away by yourself and are preparing the next shift turnover report. You are recapping progress against the plan. The dose count is already over the budget. Several days have been lost on the critical path due to unexpected discoveries of internal damage to a couple of valves in the Drywell Shutdown Cooling System. Now this. Given the severity of the situation, your objective is to assign an owner to the problem, finish your shift turnover report and go home. You are dogged tired.

Title: *AREA MANAGER: Rodney Best*
Professional License/ Education: *Electrical Engineering/MS, Nuclear Engineering/MS*
Experience: *15 Years Nuclear Operations, Plant Management*

This is your third outage, two were unplanned and one was planned. You've been a task manager and design engineer. You know what it's like being on the floor or hiding behind a computer terminal. Somehow being an Area Manager adds a new dimension to your perspective about outages. Before, you were never in charge, always asking for approvals, always being second guessed. This assignment is different. Your AREA is your KINGDOM. You can say what goes on or what does not go on! That means orchestrating the in and out movement of people and equipment, being a traffic cop. It's a tough job, but somebody has to do it. Your objective is to coordinate all the work done in your area and to minimize conflicts and interferences.

Title: *PROJECT MANAGER: Fred Alzheimer*
Professional License/ Education: *Nuclear Engineering/Ph.D., Mechanical Engineering/MS*
Experience:*13 Years Nuclear Operations. Project Management*

You have been through several outages, some planned and some unplanned. You started on the floor as a lead mechanical and over the years had different assignments, each more challenging than the last. One time you were the project manager of an unplanned outage. You have this assignment because you are the best, most qualified engineer in the field. You also have extensive knowledge of how this equipment should be maintained and run. Not everybody appreciates your expertise and knowledge especially the maintenance people. Your objective is to see to it that the equipment under your project is always reliable and operates efficiently.

KEY TEAM MEMBERS

Title: *TASK MANAGER: Mark Stevenson*
Professional License/ Education: *Electrical Engineering/MS, Nuclear Engineering/BS*
Experience: *23 Years Nuclear Operations & Maintenance, Project Management*

You are new at this game. It's not really a game it's serious business. You have been temporarily transferred over from another nuclear plant here because you had participated in several unplanned outages. In fact, that's the reason you got transferred over to this plant. You are focused, decisive, and a skilled engineer. This is your first planned outage. But you have a keen appreciation for safety requirements and the urgency of getting your tasks completed on time. Your objective is to get all the resources you can to get your tasks done for this project and get back to your regular maintenance assignment.

Title: *DESIGN ENGINEER: Ted Martindale*
Professional License/ Education: *Nuclear Engineering/ Ph.D., Chemical Engineering/MS*
Experience:*10 Years Nuclear Operations, Project Management*

Nuclear Chemistry was supposed to be tough. Nothing is as tough as going through an outage. Having a Ph.D. in nuclear engineering doesn't mean squat in outage work. Trying to meet schedules, working with those Neanderthals in the plant, changing design on the floor, making updates, and changing the schedule, now that's tough. You're the fourth engineer assigned to this job. Looks like the others escaped but left a mess. You're fed up with this whole scene. You are ready to quit. But you know that the Task manager needs you to help solve this problem. Your objective is to get to the root cause of the problems quickly, tell'em what they need to be done and go hide in the lab.

Title: *FIELD ENGINEER: Frank Moskowitz*
Professional License/ Education: *Mechanical Engineering/MS, Nuclear Engineering/BS*
Experience: *20 Years Nuclear Operations & Maintenance*

This is the second overtime shift you've worked this week. Your crew just finished the work package. And this happens! Something must be done. Your crew is close to burnout, with both fatigue and dosage. You are beat. You told the Task Manager about the situation, and he said to standby while he calls the Outage Control Center (OCC). You know that OCC knows, that because you've seen it and done it before, you can handle this situation and get the job done better than anyone else. But, right now, your objective is to get out of here and go to bed.

THE MEETING

"What just happened?" Charlie Cunningham listened as the voice on the speaker phone droned on about what had just happened. …*and very high levels of internal pipe contamination were discovered. This forced the use of glove bags to perform decontamination.* It was still dark outside. Soon the sun would be rising. It was 5:43 AM, and Charlie, the Outage Manager who came in at midnight, was almost halfway through his shift. With both hands free, he reached for his logbook with one hand and grabbed the computer mouse with the other. The screen came alive in color with little pictures resembling drawings, reports, and the plant schematic. He double clicked on the plant and then double clicked on the Drywell. The screen split and filled, one half with a three-dimensional picture of a valve and the other half text.

The text was clear and concise. Two Drywell Shutdown Cooling System motor operated valves were to be replaced: valve A-549 and valve B-549. The dose estimate for the job was 25 REM[9]. The two valves had a long history of leakage problems. After reworking the valve seats several times during the last outage it was decided to replace the valves with new ones. It was determined that the risk was less and that it was more economical to replace the valves than to try to cut out the old seats, weld in new ones and then still must rework those seats, all during shutdown. Valve replacement was expected to be a big task and entail significant radiation exposure. The Task Manager was Mark Stevenson. The Project Manager was Fred Alzheimer, and the Area Manager was Rodney Best.

Charlie stood up, walked over to the window, and looked out into the morning darkness. "Damn…damn"...he mumbled and thumbed through the log still in his hand. The log entry was brief, met with Mark. Yes, that was over a month ago...Mark came to see me. He was stressed with what was happening. He complained about the engineer's planning decision. Valve replacement should have been MOD not EX. Task going south. Check with Fred for history. Check with Rod for interferences and coordination.
The log triggered a lot more estimates... Charlie remembered that during the planning there were four different design engineers in charge. Due to a variety of reasons, each

[9] *REM(Roentgen Equivalent Man)Unit of biological damage, Appendix C*

these people moved on to other assignments. The third engineer in charge simply felt that the task was expected to be a simple replacement of two worn out valves with two new valves. Thus, he planned the replacement task as an Exempt Change and not a Modification. Mark had big time concerns about this approach. He had told the design engineer that the modification process provides for a more thorough review of the work to be performed. He told the engineer that there were many unknowns when valves are cut open. The MOD process allows for such contingencies. Thus, it would include additional time and expansion of the work if piping and welding problems are found. The engineer did not feel that this would have any significant effect on the progress or outcome for doing the work. Mark said that the engineer didn't think any of that was necessary. Big mistake!

The fact of the matter is that once the valves were cut out, a host of unexpected and unpredicted findings demanded more effort and resources. Many unforeseen and unexpected problems increased the work scope and the job exposure for 25 REM to 45 REM[10]. And, we're not done with the B-549 valve replacement yet.

Charlie punched Rod's extension number on the speaker phone. It rang only once and... “I’m either on the phone or away from my desk. Please leave a detailed message and I'll get back to you as..." Charlie cursed as the voice mail message continued. He looked out the office door to see who was sitting at the administrative desk. It was either Tom or Maxine. Tom was a contract employee working for Maxine who was on maternity leave. It was Tom. "Hey Tom, get hold of Rodney Best and tell him to meet me on the floor, Drywell valve B-549, now!" Still talking, Charlie checked his dosimeter, grabbed his safety glasses, and pushed through the double doors at the end of the hallway leaving Tom to search the phone directory for Rodney Best.

An hour later Tom was still trying to find Rodney Best's extension number when Charlie returned. This time he had company. Tom did not recognize the other three men, but they got close enough so he could read their name tags. The tall, skinny guy was Ted...somebody... he could not really see the last name. There was a dude with cowboy boots whose name was Mark Stevenson. The third guy, who looked like a weightlifter, Tom labeled Mr. Muscle. His name tag read Frank Moskowitz. All four men walked into Charlie's office. Mr. Muscle shut the door. Tom could hear loud talking...almost shouting.

---

[10] NRC 10 CFR (Part 20) Occupational Dose Limits, Appendix C

Managing a Nuclear Plant Project

The door opened and Ted, holding a small stack of papers walked over to Tom and said, "How about making three copies of these for us. Bring them in when you're done." Tom made five copies. It never failed, whenever he made the exact number of copies people asked for, they always wanted more. Tom figured he'd outsmart them this time and make a couple extra copies. Plan, anticipate, and allow for contingencies. That's what Tom was learning in his project management class. Tom was a mechanical engineer and was taking some graduate courses. He also worked for an engineering firm. In the last several years Tom was doing a variety of odd jobs, some technical some administrative. This job was great. He got to be inside an operating nuclear plant and participate in a real outage. This is the stuff you read about in magazines and newspapers, he estimated. Tom set the two extra copies aside, but he could not keep from looking at them. Soon he was reading.

The door suddenly opened but no one came out of the office. Tom looked up from his reading and sunlight streamed across his face. Charlie's east window took in the full morning sun, and it spilled over into the administrative area. "Hey Tom, get in here!" It sounded like Charlie, but it was hard to tell because of all the commotion inside.

As Tom stepped into the office all the men, who were all talking at the same time, stopped. It seemed forever before someone spoke. "Tom, we need you to help us with some problem solving." It was the cowboy who was doing the talking. "Tom, you remember that project management training we had several months ago?"

Tom started to speak, but Charlie interrupted…" this here is Ted Martindale, the current design engineer, Mark Stevenson, the task manager, and Frank Moskowitz, the field engineer. Mark just brought in the latest A & B Valve Status Reports. Tom, you remember, we've done all this meeting stuff before. We need a list, what just happened? where are we now? What do we need to do to finish the job. …and what did we learn for next time! We need you to grab a marker and start writing" …Then, as if it was rehearsed, everyone in unison said, "But, first let's get some more coffee."

Meeting Flip Charts 1 0f 3

What Happened!

- Unexpected high contamination in B Reactor cooling system
- Rework scaffolding in A because of congestion, more hours needed
- Unexpected use of Glove Bags A and B Decon, more hours needed
- Weld machine installed backward for B valve; more hours needed
- Untrained local 597 pipe fitters used instead of PCI; more hours needed

Meeting Flip Charts 2 0f 3

Where are Now!

- A valve radiation exposure increased from 25Rem to 43 Rem
- A actual valve hours have increased 50% over scheduled estimated hours
- B valve radiation exposure increased from 35 Rem to 50 Rem
- B actual valve hours have increased 50% over scheduled estimated hours

Meeting Flip Charts 3 0f 3

Lessons Learned!

- Project work packages should have been a Design Modification NOT Design Exempt work
- Supervision and assignment of Design Engineers need Project Manager approval
- Need better management control of PCI valve cutting contract
- All Nuclear workers need Glove Box training and certification

PART 3

DRYWELL VALVE STATUS REPORTS & WORK TO BE DONE

This part contains the drywell valve status reports & work to be done:

DRYWELL VALVE A-549 Status & Work to be Done

Stage Completed:

- Shutdown
- Install Drywell Cooling
- Scaffolding Installation

Stage work to be done:

- Cut out Crane Valve
- Install Anchor Darling Valve
- Leak Test and Closeout

417 Hours Over Budget Estimate
1167 Hours Remaining Scheduled Hours

DRYWELL VALVE B-549 Status & Work to be Done

Stage Completed:

- Shut down
- Install Drywell Cooling
- Scaffolding Installation

Stage work to be Done:

- Cut out Crane Valve
- Install Anchor Darling Valve
- Leak Test and Closeout

435 Hours over Budget Estimate
1147 Hours Remaining Scheduled Hours

DRYWELL VALVE A-549 Status & Work to Be Done

The A-549 valve is a 16" double disc gate valve operated by a motor operator that controls suction to the Shutdown Cooling system. The suction comes from the 'B' Reactor Recirculation system suction line and is located near the upper grating of the ground floor level (517') of the Drywell. The valve was scheduled to be replaced early in the Refueling Outage through the Exempt Change process. This valve is being replaced due to excessive leakage and a history of unsuccessful repairs. The original valve was a CRANE brand flexible wedge gate valve and is to be replaced with an ANCHOR DARLING brand double disc gate valve.

The job was a high priority and high visibility job. High priority since the valve unquestionably had to be replaced and high visibility due to the expected high radiation dosage. An ALARA[11] review of the job was done prior to the outage. It was based on the known and expected conditions of the area. As part of the nuclear plant's overall goal of exposure reduction, this outage included a chemical decontamination of the Reactor Recirculation system. Dose rates in the A-549 valve were estimated on the order of 30-60 mR/hr. This dose rate was not unexpected, and the decontamination (decon) process did a reasonable job of reducing dose in the area.

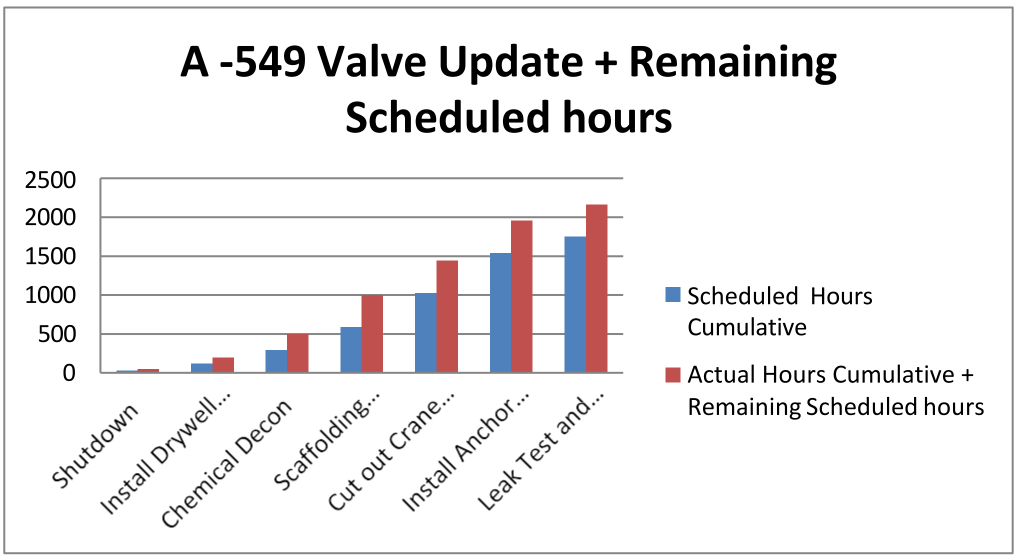
The area was thermally hot and relatively tight to work in. The newly installed Drywell Air Conditioning System helped considerably but the work crew still had a two-hour self-imposed stay time due to the hot working conditions. This stay time was necessary for to avoid heat related physical problems that result to some inefficiency on the job and inherent with turnovers.

The Chemical decon process encountered difficulties which delayed the start of several Drywell jobs. As a result, there were at least six critical path jobs going on in the Drywell at the same time in the same area. This congestion contributed to a variety of job inefficiencies. This job was located on scaffolding with the work platform approximately eight feet off the floor. Once the workers were situated on the scaffolding, there was not much interference but the traversing through the ground floor congestion caused some delays.

The erection of scaffolding and layout of cuts on the A-549 valve were accomplished without incident. However, several unplanned interference problems were encountered forcing

[11] *As Low As Reasonably Achievable (ALARA) Principle of radiation protection*

reconfiguration of the cutting equipment during the actual cutting out of the valve. A walk down of the job which had been performed during the previous outage was limited to visual inspection with cursory measurements. Insulation had not been removed. Field engineering and corrections were expected once the valves were cut out, but a host of unexpected and unpredicted findings demanded more effort and resources that increased the work scope. Very high levels of internal pipe contamination were discovered. This forced the use of glove bags to perform decontamination. [12] This was considered a good practice to minimize the spread of contamination. However, some of the workers were not trained in the use of glove bags. The original task was estimated at 25 REM.[13] to date the total job exposure stands at approximately 43 REM.



A-549 Valve Work Stage	Scheduled Hours Cumulative	Actual Hours Cumulative	Remaining Scheduled Hours

[12] *Michael G. Stabin, Radiation Protection and Dosimetry © 2007 Springer Science + Business Media.*
[13] *Code of Federal Regulation (10 CFR Part 20) Appendix C*

Shutdown	29	50	
Install Drywell Cooling	117	200	
Chemical Decon	292	500	
Scaffolding Installation	583	1000	
Cut out Crane Valve	1027		443
Install Anchor Darling Valve	1537		510
Leak Test and Closeout	1750		213

+ 1167 Remaining Scheduled hours

<u>Work to Be Done</u>

- Complete Crane valve cut out
- Remove cut Crane valve and set up weld equipment
- Place Darling Valve in position
- Weld Darling Valve
- Perform NDT (Non-Destructive Test) on weld[14]
- Perform Leak Test
- Conduct final visual inspection
- Perform System test
- Close Out and file project documents

[14] Nuclear welds use Xray for Non-Destructive Test

DRYWELL VALVE B-549 Status & Work to Be Done

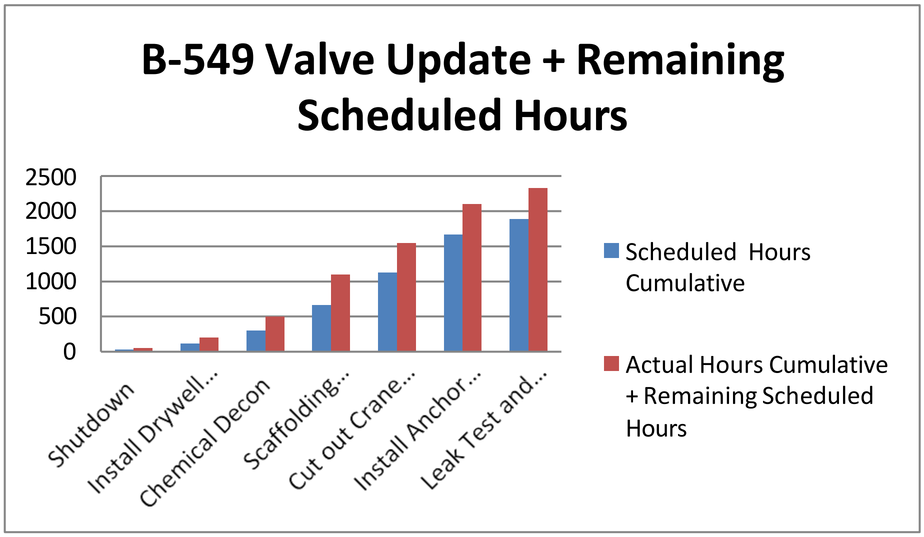
The B-549 valve is the same type and make as A-549 Valve. The B-549 valve is located just above the second-floor grating in the drywell at the 537' level. This valve is a suction to the Shutdown Cooling system and takes its input from the 'A' Reactor Recirculation system suction line. The chemical decontamination results in this area of the reactor recirculation system were not as good as expected. Dose rates through the insulation in the areas prior to the decontamination are on the order of 120 mR/hr. After the decontamination, dose rates were approximately 50 mR/hr.

In the planning stages of this job, glove bag work was considered but it was determined unnecessary because it takes longer than non-glove bag work. However, internal contamination on this section of pipe was extremely high, resulted in glove bag work and added additional time.

The B-549 valve contained an actuator motor that needed to be removed. However, the actuator was in a very limited space and required numerous rigging scaffold rebuilds. A section of 'I' beam had to be cut-out for this operation. This was identified in the previous outage and was planned in the job scope. Once the scaffolding met the space requirements, the actuator was removed.

The cutting operations in the original contract were scheduled to be done using Power Cutting International (PCI) equipment and field technicians. While the PCI technicians were at the job site, they did not do the actual cutting. PCI assigned the cuts to Local 597 Pipefitters who did not have any formal training or experience in the use of power cutting or automatic weld machine operations. Some on-site training was done before the cuts and welding took place. However, both PCI people and Pipefitters were on the job simultaneously. While this task did not affect the original cost it resulted in doubling worker radiation exposure..

On one occasion, a communication problem resulted in the weld machine being installed on the wrong side of a weld. This was recognized prior to the cut and the machine was moved. The valve was cut-out and removed with the internals intact to reduce the time spent and the potential for loose contamination. During valve removal from the Drywell, the rigging stretched, and the load had to be rerigged twice. The valve sideswiped some scaffolding on the way out and knocked the temporary contamination control end covers off the valve adding additional contamination.



B-549 Valve Work Stage	Scheduled Hours Cumulative	Actual Hours Cumulative	Remaining Scheduled Hours
Shutdown	30	50	
Install Drywell Cooling	121	200	
Chemical Decon	302	500	
Scaffolding Installation	665	1100	
Cut out Crane Valve	1124		459
Install Anchor Darling Valve	1668		544
Leak Test and Closeout	1892		224

Work to Be Done

- Complete Crane valve cut out
- Remove cut Crane valve and set up weld equipment
- Place Darling Valve in position
- Weld Darling Valve
- Perform NDT (Non-Destructive Test) on weld[15]
- Perform Leak Test
- Conduct final visual inspection
- Perform System test
- Close Out and file project documents

+ 1227 Remaining Scheduled hours

[15] Nuclear welds use Xray for Non-Destructive Test

PART 4

Lessons Learned & Project Close Out

The first section of this part contains a Lessons Learned Overview template developed in the early stages of Department of Energy (DOE) recording real time experience lessons and best practices for construction and maintenance of nuclear plants. The template includes:

- Category
- Issue name
- Problem/Success
- Impact
- Recommendations

The next section presents the DOE lessons learned standard and DOE OPEXShare.

- Title Page and Table of Contents.

THE DOE CORPORATE LESSONS LEARNED PROGRAM, DOE- STD -7501-95,

- DOE OPEXShare

The latest web-based collection point and collaborative platform for sharing lessons learned

The final section consists of the Project Lessons Learned and the Project Close Out of A-549 Valve and B-549 Valve.

- Project Lessons Learned
- Project Close Out A-549
- Project Close Out B-549

LESSONS LEARNED OVERVIEW

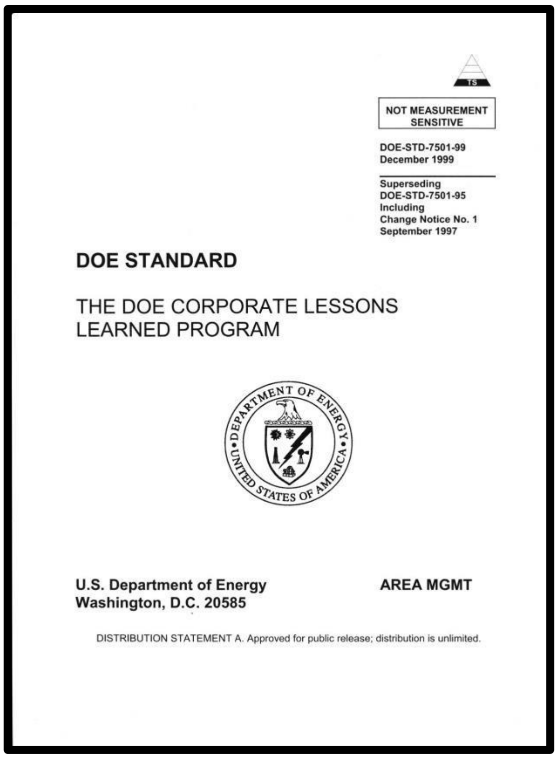
The rate of how nuclear plants are being build and maintained must be increased and become more efficient to meet the goal of low carbon emission according to the World Nuclear Association and Harmony vision.[16] In the early 1980s reporting to the Federal Energy Regulatory Commission, now the Department of Energy (DOE) included real time experience lessons and best practices for construction and maintenance of nuclear plants. The three examples below show simplified method for reporting Lessons learned.[17]

Category	Issue name	Problem/Success	Impact	Recommendation
Project Management	Contract Requirements	Project Manager (PM) not fully involved in contract process	All requirements not included in initial contract award. A modification to the contract was required that added a week to project timeline.	PM must be fully engaged in all contract process. All parties, PM and contract personnel must be informed.
Scope Management	Scope Creep	Stakeholders are continuously adding to the projects scope	PM did not have a plan addressing scope creep and allowed items to be added to the project until the sponsor stopped it. Overall project delay of 3 weeks was the result.	PM must have formal approval process for any proposed scope changes and inform all stakeholders of this process.
Work Package Schedule	Emergent work	Performing Maintenance on mechanical equipment	Substantial work was discovered when repairing a standard valve that doubled the amount of time and also added more material for the work.	Record and establish an Emergent Work factor (Data Base) and use when estimating work packages.

[16] *Lessons Learned in Nuclear Construction Projects, World Nuclear Association 2018@ Report 2018002*
[17] *Projectpractical.com template*

DOE STANDARD

The first DOE Standard method of reporting was published in 1997.[18] This is a 54-page document that contains the following sections:


NOT MEASUREMENT SENSITIVE

DOE-STD-7501-99
December 1999

Superseding
DOE-STD-7501-95
Including
Change Notice No. 1
September 1997

DOE STANDARD

THE DOE CORPORATE LESSONS LEARNED PROGRAM

U.S. Department of Energy
Washington, D.C. 20585

AREA MGMT

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

TABLE OF CONTENTS

1. Overview
2. Definitions
3. Program Description
4. Infrastructure Elements
5. Lessons Learned Development and Dissemination
6. Utilization of Lessons Learned Information

Appendix A Lessons Learned Template
Appendix B DOE Systems Diagram
Appendix C Program Assessment Guide

Today The DOE OPEXShare database is the central, web-based collection point for corporate operating experience lessons learned and best practices from across the DOE complex. DOE OPEXShare is a collaborative platform that is available to government and private users. By sharing lessons learned and best practices from work operations and project management, DOE Overshare subscribers could prevent adverse events and improve processes and performance. DOE OPEXShare replaces the DOE Corporate Lessons Learned database.[19]

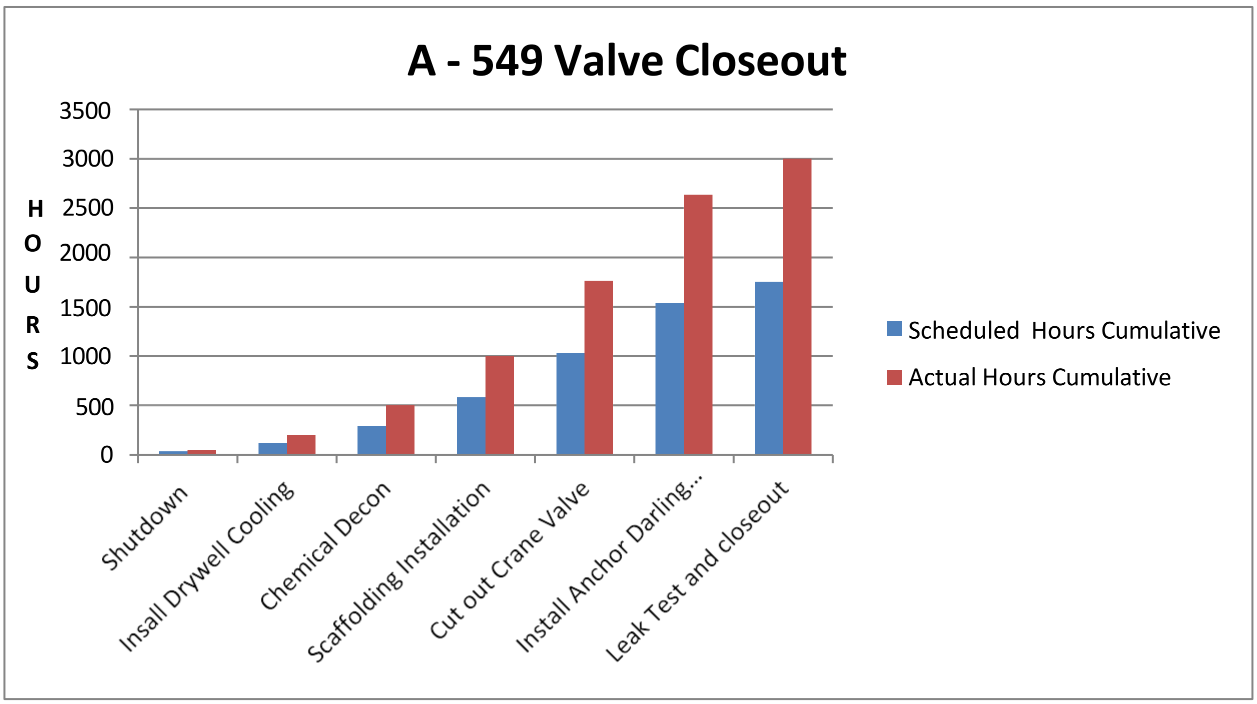
[18] *The DOE CORPORATE LESSONS LEARNED PROGRAM, DOE-STD-7501-95, December 1999*
[19] *US Department of Energy, Office of Environment, Health, Safety and Security*

NUCLEAR PLANT PROJECT LESSONS LEARNED

Category	Issue	Problem	Impact	Recommendation
Valve project work packages **549 A** **549 B**	Design Engineering Estimating Error	Valve project work design packages were estimated as **Exempt Design.** The Outage Valve work packages should have been estimated **Design Modification**	Substantial work was discovered when removing valves that doubled the amount of time. More material was added for the work and increased the radiation exposure.	Large valve work should follow the Modification process that requires X-rays that show defects and porosity and adds the 30% factor standard for emergent work. Visual inspection and three-D pictures of valves will not work.
Valve project work packages **549 A** **549 B**	Engineering Supervision & Responsibility	Four different Engineers were assigned to the outage valve project. This resulted in some conflicts within the work processes.	This conflict caused delays and added radiation exposure to the actual work process tasks replacing the valves.	The Task Manager needs to have formal review and approval when changes are made for design Engineering Responsibility.
Valve project work package **549 B**	Cut Out Stage	Decision made to contract with Power Cutting International (PCI) for the cutting. PCI used local untrained workers for the valve cutting.	Project delays and added radiation exposure occurred due to work done by untrained nuclear workers.	The Outage Manager needs to have formal approval process when labor changes are made to contracts concerning critical tasks for outage work.
Chemical Decontamination **549 A**	Decon Estimate Error	Decon estimate low resulting in Glove Bag work by untrained nuclear workers	Project delays and added radiation exposure occurred due to glove bag work by untrained nuclear workers.	Nuclear workers need to be trained and vetted in glove bag work before being allowed to perform such tasks.
Chemical Decontamination **549 B**	Decon Estimate Error	Decision to rely on Chemical Decon did not result in safe radiation environment.	Project delays and added radiation exposure occurred due to unexpected glove bag work.	Review risks and maximize Chemical Decon requirements after Dry Well Cooling Stage.

PROJECT CLOSEOUT A-549 VALVE

Scaffolding on this project continued to be very tight, requiring many necessary reconfigurations and engineering approvals. The 16" valve bodies alone weighed approximately 2,000 pounds. A complete valve assembly, including the internals but not the operator, weighed 3,000 pounds. The scaffolding had to be reconfigured several times to allow clearances for the various tasks involved such as operator removal, valve body removal, etc., and then just the opposite for reassembly. Temporary slings were used for this work. Valve reassembly was completed, and the valve passed the leak rate test. RWP[20] hours for the A-549 valve were estimated for 1750 hours. The project took 3000 RWP hours.

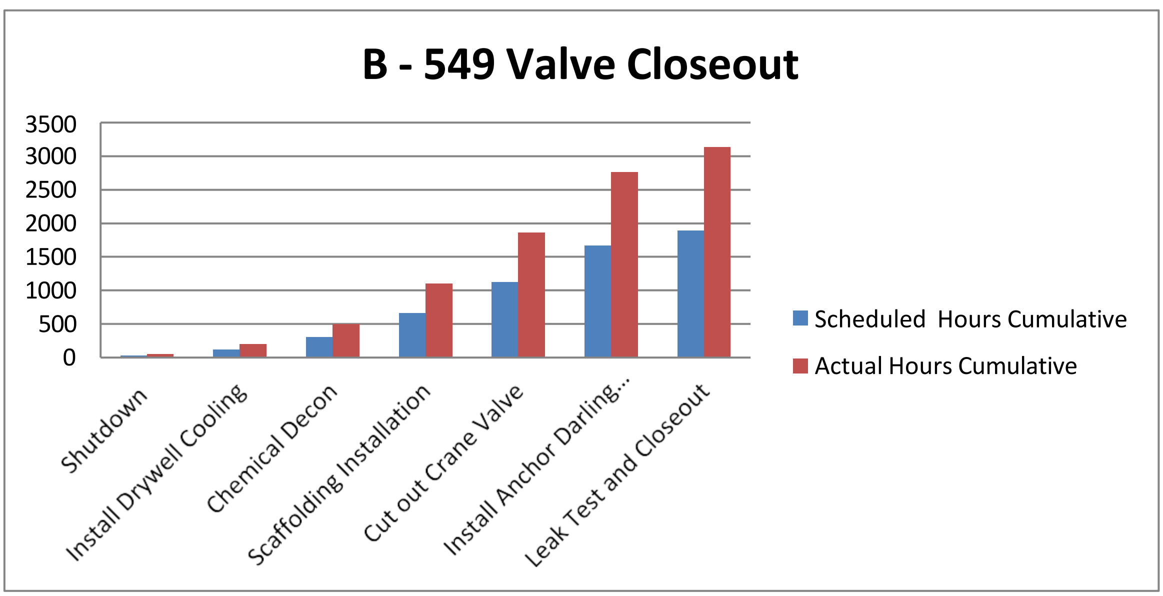


[20] RWP (Radiation Work Permit) identifies the hours permitted for work in a contaminated environment.

PROJECT CLOSEOUT B-549 VALVE

During the automatic welding of the valve, PCI support was at times lacking. As an example: On one occasion, the auto weld machine being used on the 'B' valve broke. The night shift took the machine off the 'A' valve and tried to install it on the 'B' valve. After spending time and dose, it was discovered that the 'A' machine would not fit in the area required at the 'B' valve and it had to be removed. The day shift PCI representative knew where a new motor was located that could have been used on the 'B' machine but no one else did. The night crew did not notify the day shift representative.

During the welding process there was a radioactive materials uptake. Some of the inflatable weld dams were removed on midnights and placed in an unmarked plastic bag. These dams were highly contaminated and the worker removing them from the plastic bag on day shift was unaware of the potential dose. the auto welding is complete. The B-549 valve was estimated to take 1892 RWP[21] hours. Additional time was needed to rig the B pipe back in place and repair the cracks in the pipe. The pipe crack repairs, and clean-up added two and a half weeks to the job. The valve passed leak rate testing. The project took 3130 RWP hours.



[21] RWP (Radiation Work Permit) identifies the hours permitted for work in a contaminated environment.

PART 5

APPENDIX A

U.S. NUCLEAR ELECTRICITY GENERATION

APPENDIX B

U.S. NUCLEAR POWER PLANTS

APPENDIX C

NUCLEAR RADIATION WORKERS

APPENDIX D

GLOOSSARY OF TERMS AND ILLUSTRATIONS

APPENDIX A

U.S. NUCLEAR ELECTRICITY GENERATION

Electricity generation from commercial nuclear power plants in the United States began in 1958.[22] Nuclear plants could have one or more operating nuclear reactors. At the end of 2021, the United States had 93 operating commercial nuclear reactors at 55 nuclear power plants in 28 states. The average age of these nuclear reactors is about 40 years old. The oldest operating reactor, Nine Mile Point Unit 1 in New York, began commercial operation in December 1969. The newest reactor to enter service, Watts Bar Unit 2, came online in 2016—the first reactor to come online since 1996 when the Watts Bar Unit 1 came online. According to the U.S. Nuclear Regulatory Commission as of November 2021, there were 23 shut down commercial nuclear power reactors at 19 sites in various stages of decommissioning.

U.S. nuclear electricity generation capacity peaked in 2012 at about 102,000 MW when there were 104 operating nuclear reactors. At the end of 2021, there were 93 operating reactors with a combined generation capacity of about 95,492 MW. In 2013 through 2019, annual nuclear generation capacity and electricity generation increased each year (except in 2017) even as the number of operating reactors declined. Power plant uprates—modifications to increase capacity—at nuclear power plants have made it possible for the entire operating nuclear reactor fleet to maintain a relatively consistent total electricity generation capacity. These uprates, combined with high-capacity utilization rates helped nuclear power plants maintain a consistent share of about 20% of total annual U.S. electricity generation from 1990 through 2021. Some reactors also increased annual electricity generation by shortening the length of time reactors are offline for refueling.

[22] industry. phphttps://www.eia.gov/energyexplained/nuclear/us-nuclear-

APPENDIX B

NUCLEAR POWER PLANTS

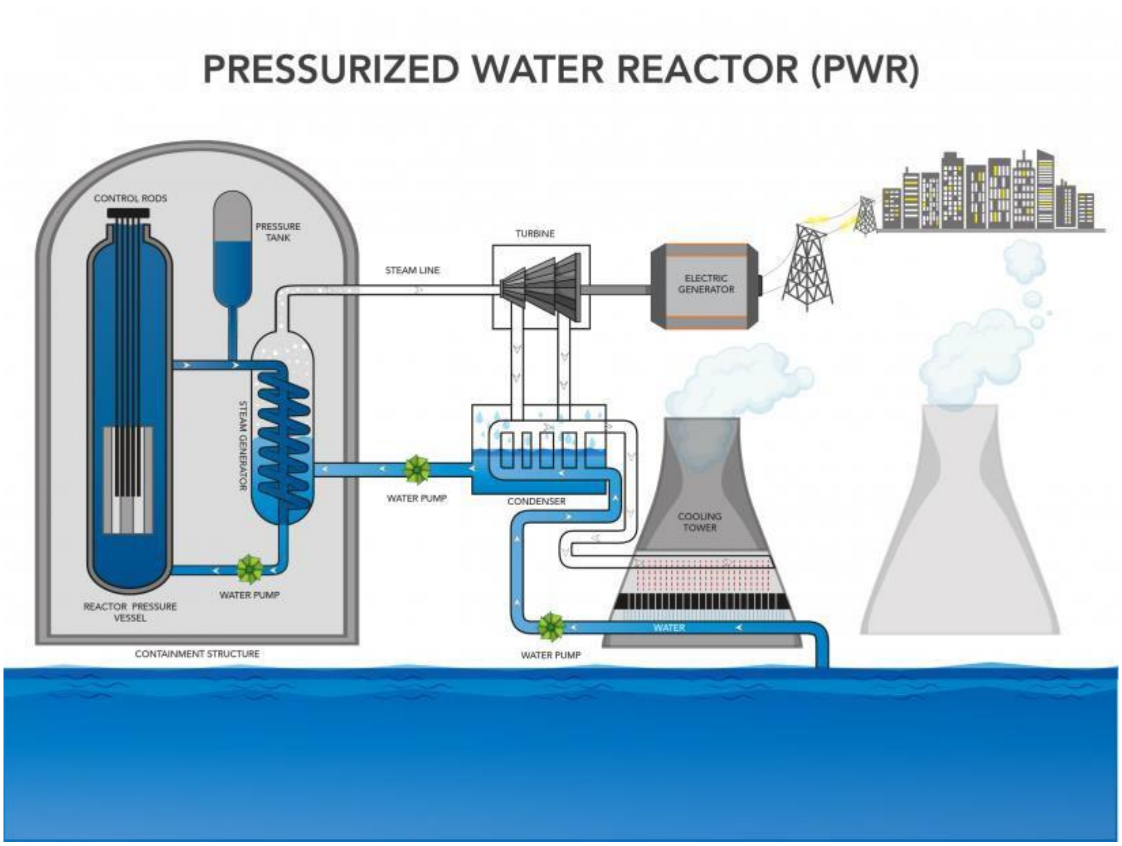
Nuclear reactors are the heart of a nuclear power plant.[23] Nuclear Fission Creates Heat. The main job of a reactor is to house and control nuclear fission—a process where atoms split and release energy. Reactors use uranium for nuclear fuel. The uranium is processed into small ceramic pellets and stacked together into sealed metal tubes called fuel rods. Typically, more than 200 of these rods are bundled together to form a fuel assembly.

A reactor core is typically made up of a couple hundred assemblies, depending on power level. Inside the reactor vessel, the fuel rods are immersed in water which acts as both a coolant and moderator. The moderator helps slow down the neutrons produced by fission to sustain the chain reaction control rods can then be inserted into the reactor core to reduce the reaction rate or withdrawn to increase it. The heat created by fission turns the water into steam, which spins a turbine to produce carbon-free electricity.

In the United States of America all commercial nuclear reactors are light-water reactors. This means they use normal water as both a coolant and neutron moderator. There are two types of light-water reactors operating in America. Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR).

Canada Deuterium Uranium (CANDU)[24] is a Pressurized Heavy- Water Reactor (PHWR) developed in Canada and operates in Argentina, China, India, and Russia. These reactors are heavy water cooled and moderated pressurized water reactors. Instead of using a single large reactor vessel as in the PWR or BWR the nuclear core is contained in hundreds of pressure tubes. The PHWR can be refueled while at full power and does not require refueling outages.

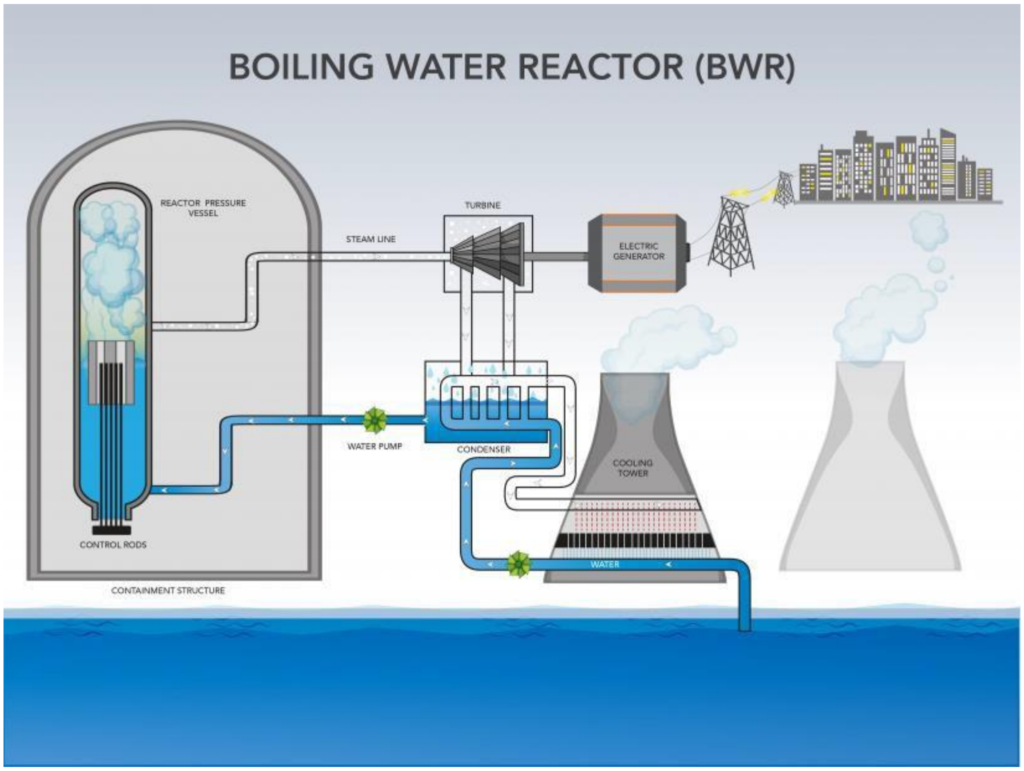
[23] energy.gov/article/nuclear/101: how-does-nuclear-reactor-work
[24] CANDU-Heavy Water Reactor, https://www.cameco.com



Graphic by Sarah Harman | U.S. Department of Energy

More than 65% of the commercial reactors in the United States are pressurized-water reactors or PWRs[25]. These reactors pump water into the reactor core under high pressure to prevent the water from boiling. The water in the core is heated by nuclear fission and then pumped into tubes inside a heat exchanger. Those tubes heat a separate water source to create steam. The steam then turns an electric generator to produce electricity. The core water cycles back to the reactor to be reheated and the process is repeated.

[25] energy.gov/article/nuclear/101: how-does-nuclear-reactor-work



Graphic by Sarah Harman | U.S. Department of Energy

Roughly a third of the reactors operating in the United States are boiling water reactors (BWRs)[26]. BWRs heat water and produce steam directly inside the reactor vessel. Water is pumped up through the reactor core and heated by fission. Pipes then feed the steam directly to a turbine to produce electricity. The unused steam is then condensed back to water and reused in the heating process.

[26] energy.gov/article/nuclear/101: how-does-nuclear-reactor-work

APPENDIX C

NUCLEAR RADIATION WORKERS

Dosimeter badges are issued to nuclear plant employees and all persons visiting a nuclear plant. A dosimeter is a device that measures the amount of radiation a person is exposed to whenever that person is in the vicinity of radiation. These badges provide legal records of accumulated radiation for a lifetime. The information from the badges is typically tabulated on a monthly or quarterly basis depending on the individual's work assignment at the nuclear facility.

Nuclear plants are among the NRC licensees that are required to provide the NRC with an annual report of all individual's radiation exposures. The NRC, in turn, maintains such radiation exposure data in its Radiation Exposure Information and Reporting System (REIRS)[27]. This database represents a resource for responding to requests for exposure information and dose histories. Design engineers and engineering estimators must include dose estimates for nuclear workers who work in contaminated areas when planning and estimating work packages. For example, a nuclear worker exposed to a dose rate 20mR/hr would be available for up to 250 hours of work in a contaminated area.[28]

Nuclear workers who work in contaminated areas are given training and provided instructions. Specifically, NRC requires that all individuals who, in the course of their employment, are likely to receive a dose of more than 100 millirem[29] in a year must receive adequate training to protect themselves against radiation. Also, these individuals have the right to know the amount of radiation to which they have been exposed. In addition, radiation workers have the right to ask the NRC to conduct an inspection if they believe their working environment has safety problems

[27] NRC 10 CFR (Part 20.2206) NRC Report Radiation Exposure- Form 5
[28] NRC 10 CFR (Part 20) Total Effective Dose Equivalent (TEDE) Dose Limits = 5,000 mrem/year
[29] NRC 10 CFR (Part 20) NRC Occupational Dose Limits

Appendix D

GLOSSARY OF TERMS

ALARA: Principle of Radiation Protection, **A**s **L**ow **A**s **R**easonably **A**chievable

BWR: Boiling Water Reactor

CANDU: Canada Deuterium Uranium, Canadian Pressurized heavy- water reactor

Carbon – Free Electricity: Heat created by fission, Solar panels, Wind Generators

Dosimeter: A device that measures the amount of radiation exposure

Fuel Rods: Sealed metal tubes containing uranium ceramic pellets

Fuel Assembly: A bundle of fuel rods

mR/hr: One REM per Hour

NDT: Non-Destructive Test

NRC 10 CFR: Nuclear Federal Regulatory 10 Code of Federal Regulations

Nuclear Fission: A process where atoms split and release energy

PCI: Power Cutting International

PWR: Pressurized Water Reactor

Reactor: House and control nuclear fission

REIRS: Radiation Exposure Information and Reporting System

REM: A unit of measure of exposure for a single radiation dose

TEDE: Total Effective Dose Equivalent- Dose Limits 5,000 mrem/year

Uranium: A dense grey radioactive metal used as fuel in nuclear reactors

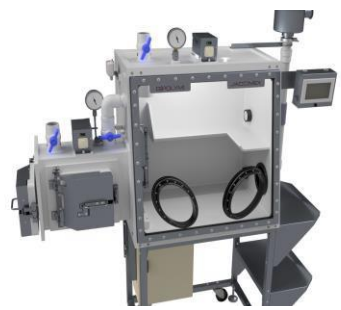
Appendix D

ILLUSTRATIONS

Dresden #1 Nuclear Plant

Dosimeter Badges

Fuel Assembly



Glove Box

Anchor
Darling Valve

Scaffolding