Reactor Decommissioning - Balancing Remote and Manual Activities – 12159

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ABSTRACT

Nuclear reactors come in a wide variety of styles, size, and ages. However, during decommissioned one issue they all share is the balancing of remotely and manually activities. For the majority of tasks there is a desire to use manual methods because remote working can be slower, more expensive, and less reliable. However, because of the unique hazards of nuclear reactors some level of remote activity will be necessary to provide adequate safety to workers and properly managed and designed it does not need to be difficult nor expensive. The balance of remote versus manual work can also affect the amount and types of waste that is generated. S.A.Technology (SAT) has worked on a number of reactor decommissioning projects over the last two decades and has a range of experience with projects using remote methods to those relying primarily on manual activities. This has created a set of lessons learned and best practices on how to balance the need for remote handling and manual operations.

INTRODUCTION

The best practices for how to plan and implement a remote/manual handling plan in reactor decommissioning is very critical to overall project success. This must be done by balancing the cost and risk of specific activities and by using experience drawn from previous projects. SAT has a variety of experiences in reactor decommissioning and the critical lessons learned and guidance will be outlined below. SAT's specific reactor experience is outlined briefly below:

Table I – Reactor Experience

Reactor	Scope/Role
Fort St. Vrain, HTGR, Colorado	On-site operations and remote tooling
Yankee Rowe, Prototype PWR, Massachusetts	On-site support, vapor dome analysis
Dounreay, DFR/PFR Research Breeders, Scotland	Decommissioning conceptual planning
Rancho Seco, PWR, California	Vessel cut-up
Winfrith SGHWR, Heavy Water Reactor, England	Conceptual decommissioning approach
UKAEA Pile 1&2, Graphite Pile, England	Detailed planning, design, and trailing
Zion, PWR, Chicago	Conceptual decommissioning approach
Hanford K-Reactor, Graphite Pile, Washington	Detailed planning, design, and trailing
Humboldt Bay, BWR, California	Planning, conceptual approach
Brookhaven, Graphite Pile, New York	Complete design and planning, operations

RECOMMENDATIONS

The first step of any decommissioning project is the planning phase. This is the only real opportunity to make key decisions about the kinds and scale of the equipment that will be used to do remote activities. Although some tooling and small equipment can be made "on-the-fly" most large equipment will require too much time to develop once operations have begun. Unfortunately, during this planning phase is when the least is known about the actual environment that will be encountered.

At this phase of the project it is critical to have a waste strategy so that key decisions can be made about what types of tasks must be accomplished. In terms of waste minimization it is critical not only to reduce the total amount of waste but also to have as much waste meet lower level requirements. Both the decision on how the work will be performed and what type of waste categories the material will fall under will drive the characterization work.

In simplistic terms, it seems that more characterization is always better. However, this will lead to a problem of diminishing returns relative to effort. Two basic problems limit the actual amount of characterization that can be done. The first is time and cost limitations which are present on all jobs. Although characterization can save significant cost and schedule in operation it has its own cost and schedule to balance. Unfortunately, many characterization routines can be almost as difficult as the final decommissioning work because they may require their own set of remote equipment and safety procedures. The second more subtle issue that affects characterization is the reliability and confidence in the data. Reactor facilities and internals are not homogenous structures. Their materials, exposures, and histories vary widely and it can be very difficult to find an accurate representative sample. One clear example is taking core samples of internal core structures that may have had dramatically different flux exposures, leading to very different activation levels.

Figure 1 - Characterization Survey of Pile 1

There is no simple answer on where to draw the line on characterization. However, some basic recommendation can be made. The first is to make sure that all parties understand that it is inevitable that unknowns will still exist after characterization and that the plan must account for these. There can be a tendency to try to eliminate all unknowns during characterization but this is of course impossible. Another area that can cause problems during initial planning is dose rate modeling. Although theoretical characterization can be good to bound the problem it is not practical to expect these kinds of studies to yield truly accurate values. This is due to the lack of good information to base the analysis on and the unavoidable tendency to be conservative and therefore produce values that are unrealistic. These values may be used as guidelines but should be expected to be general. One real issue that can arise from using erroneous analysis dose levels is that unneeded remote activities are planned. In general, the project team needs to understand what data is absolutely required to make decisions and work for that information.

After characterization the information can be used to make some decisions on equipment, activities, and waste strategies. Again projects will vary, but in general a few rules will apply. First, initial activities are more likely to be remote than later activities. This is because of the obvious result of removing material reducing dose levels. There is also the fact that initially work will be done with a lot less experience and confidence. As the project progresses simple and safe working processes will be developed that allows more manual intervention.

Figure 2 - Brookhaven (Full remote core removal, semi-remote roof removal, fully manual bio-shield removal)

The waste strategy will also play an important role in laying out activities and the nature of these activities will dictate whether they can be done manually or remotely. There is always a desire to maximum the amount of waste that will go into lower level catagories as these are less expensive to dispose of. However, there are many cases when separating low level material from high level material will require additional equipment and steps which have their own cost. A comprehensive waste strategy must look at the remote handling challenges along with the disposal costs.

Another major project assumption needs to be flexibility which requires that nearly every decommissioning activity has a plan for both remote and manual operation. Because of the inevitable unknowns, the actual performance will change relative to the plan and without the ability to adapt the project can quickly come to a stop.

One other lesson learned is not to make a set of equipment for each work activity. Reactors are complex assemblies with a wide variety of materials, access, and safety issues. As the project is divided into the necessary dismantlement steps there can be a tendency to address each as its own stand alone problem. This will lead to a host of separate remote tools and equipment. The reality is that developing and deploying remote equipment risk and this is multiplied when the number of separate pieces of equipment increases. Expect and accept that each piece of remote equipment will require time and energy to fine tune and debug. There will be equipment issues and reducing the total number of equipment items is the only way to really reduce these.

Unfortunately, reactors really are disparate assemblies and do require different techniques. There is no one magic tool that will complete the work. Therefore it is necessary to proceed carefully with design choices. First, always keep a holistic approach to design. Refrain from blinding the design team on each individual problem. The best way to do this is to view the remote equipment as one core deployment device with a set of smaller "tools" for each job. This way one piece of equipment needs to address a variety of issues but special tools can be used to solve individual challenges. This is critical because it allows the equipment development to focus on the reliability and success of this key deployment device. As long as this one piece of equipment is working then there is always room to be flexible in actual operation.

A good project example of how this can be solved is Brookhaven decommissioning. For this project SAT chose to modify a commercial excavator to be used remotely. This allowed the use of Off-the-Shelf (OTS) tools designed for the excavator. During design each activity was planned with this tool kit. However in practice, the actual tools used for each job varied from plan but because the tool kit was flexible all the tasks were completed. The total set of equipment was relatively small but the entire reactor (with manual support) was successfully completed.

Figure 3 - Core removal using bucket, hammer and shear

The design also needs to focus on simplicity and robustness. There are a few tricks to doing this. Although simple is always best, producing a simple design in the face of a variety of design constraints is very challenging. Particularly in a nuclear environment there is a great pressure on designs to address a huge set of regulations, expectations, and unique design challenges. Keeping designs simple is not straightforward. One good way to do this is to modify existing proven equipment. This has been the key way SAT has been successful on a variety of difficult jobs. The second is to have a strong project management team with the control and courage to make sure erroneous design criteria are not introduced. A very experienced and realistic safety and waste team can make or break a project just as much as a good design team can.

These recommendations can only be achieved if a competent remote handling design team is integrated into the overall project team early in the planning. Without the knowledge of designing, testing, and deploying remote equipment then key compromises with other groups cannot be made. It is all too common to have an isolated project team making plans around waste, characterization, and equipment performance without involving experienced equipment designers. Often a performance specification is issued late in planning that creates incredibly difficult criteria on equipment suppliers and thus making the equipment complex and expensive. A voice in decision making for remote handling is just as important to project success as waste, operations, and safety. Expecting to subcontract late in planning is dangerously unrealistic.

Figure 4 - Pile 1 Project Team including safety, waste, remote handling, and regulator

As a specific example, during the planning for the decommissioning of Pile 1 it was decided by the waste and safety team that it would be necessary to isolate individual fuel elements during packaging. This was to provide adequate space for cooling and encapsulation. A quick decision was then made to individually package each fuel element into a special “milk crate”. Luckily, on this project SAT was integrated into the team and brought up the significant challenges and cost of creating this remote handling cell. SAT then proposed a compromise solution using a novel helical waste drum liner that could be bulk filled and still fulfill the waste and safety requirements. This compromise saved the whole project millions of dollars of potential equipment design and fabrication.

Figure 5 - Trialling of Pile 1 Helical Waste Liner

Although it is definitely best practice to use "proven" equipment the extent that this is practical need be recognized. Equipment to remotely decommission reactors will never be purely "off-the-shelf". But that also doesn't mean that fully custom equipment is necessary either. The best way to manage this is to adapt existing designs with the necessary modifications to meet the specifics of that job. Again, striking the balance between keeping equipment "off-the-shelf" versus making critical modifications should be done as part of a larger integrated team.

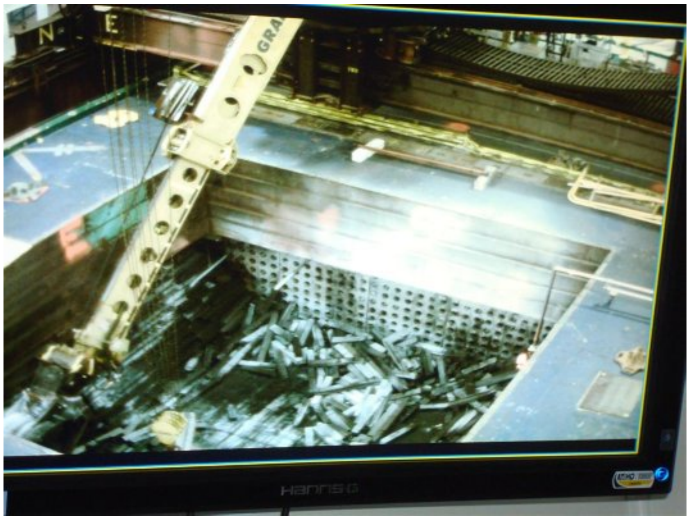

Figure 6 - Modified Commercial Equipment Used in Brookhaven Decommissioning

The other important aspect of having a remote handling provider as a partner is that it allows the whole project team to be involved in design and testing. All new equipment has bugs that must be resolved during manufacture and testing. There can be a tendency of projects to push this risk and responsibility onto the equipment providers. Although this may make sense from a short term contractual perspective, in terms of project success it does not. If a realistic project team recognizes that issues will arise then the whole team can work together to solve them and ultimately deliver the robust equipment that is so very much needed for success. If all the responsibility for resolving these issues is placed on a sub-contractor then these issues will inevitable be resolved but not necessarily to the benefit of the project.

Figure 7 - Integrated Project Team Preparing for Test on K-Reactor Decommissioning Project

The last major point is to be flexible during operation and to have the same project team working through the whole process. One hallmark of success on decommissioning is having a committed on-site team who is willing and able to quickly address issues as they come up. One absolute truth about projects is that they will not go exactly to plan. Trying to drive all risk and unknowns out of a project in planning is impossible. This is well known and yet many projects cannot move forward for the simple fact that they can't draw the line in the sand and move forward from planning to execution. Expect surprises, expect the characterization to be inaccurate, expect equipment problems, expect good and bad days, and expect that new tools and techniques will have to be developed. However, also expect that these can all be solved with a committed team.

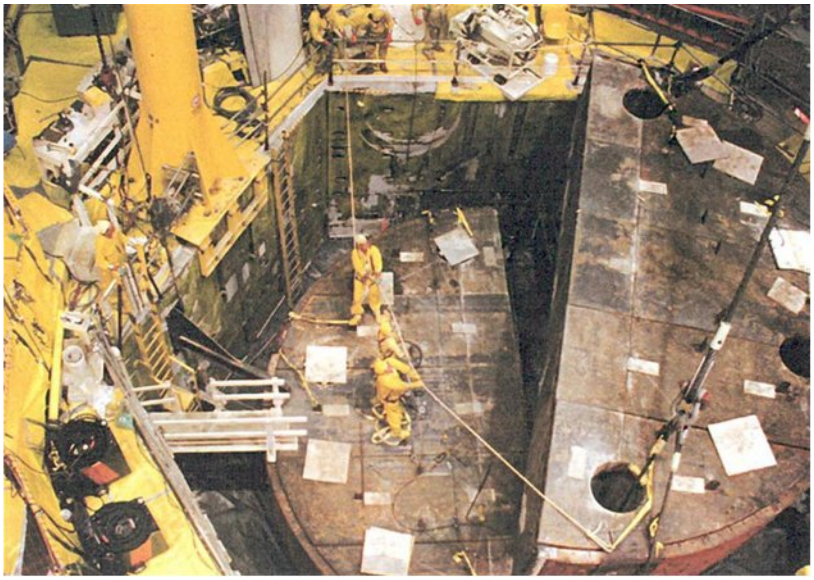

Figure 8 - Fort St. Vrain Decommissioning

On-site team was critical for adapting to new issues for a successfully decommissioning

CONCLUSION

Finding a balance between remote and manual operations on reactor decommissioning can be difficult but by following certain broad guidelines it is possible to have a very successfully decommissioning. It is important to have an integrated team that includes remote handling experts and that this team plans the work using characterization efforts that are efficient and realistic. The equipment need to be simple, robust and flexible and supported by an on-site team committed to adapting to day-to-day challenges. Also, the waste strategy needs to incorporate the challenges of remote activities in its planning.