REFURBISHMENTS AND LIFE EXTENSIONS: LESSONS FROM THE PAST TO GET IT RIGHT IN THE FUTURE

J. Froats
CANDU Owners Group Inc., Canada

Email address of main author: john.froats@candu.org

Abstract. Over the last two decades the nuclear power industry worldwide has worked hard to improve performance and regain public trust and support for nuclear energy. Decisions we make today around life extensions and refurbishments will set the foundation for our performance over the next several decades. Sustaining safe, clean, predictable energy production performance in extended life operation of plants is a necessary condition to earn the privilege of nuclear energy production. Currently nuclear support is strong but remains fragile. We will always be one major event away from another period of decline.

So as growing demand for clean energy intensifies and business pressures drive us all, what can we draw from our experience to set the industry up for success? The first major refurbishment of a CANDU reactor took place in the 1980's at the Pickering A Station in Ontario, Canada. Following a 'G16' pressure tube failure the reactors were re-tubed. The first Unit of four took 56 months to complete. Approximately 3 years later the fourth Unit was completed in 19 months. What enabled the dramatic improvement in schedule? Was the outcome what was expected? What lessons from the history can we learn to shape practices today and set us up for success?

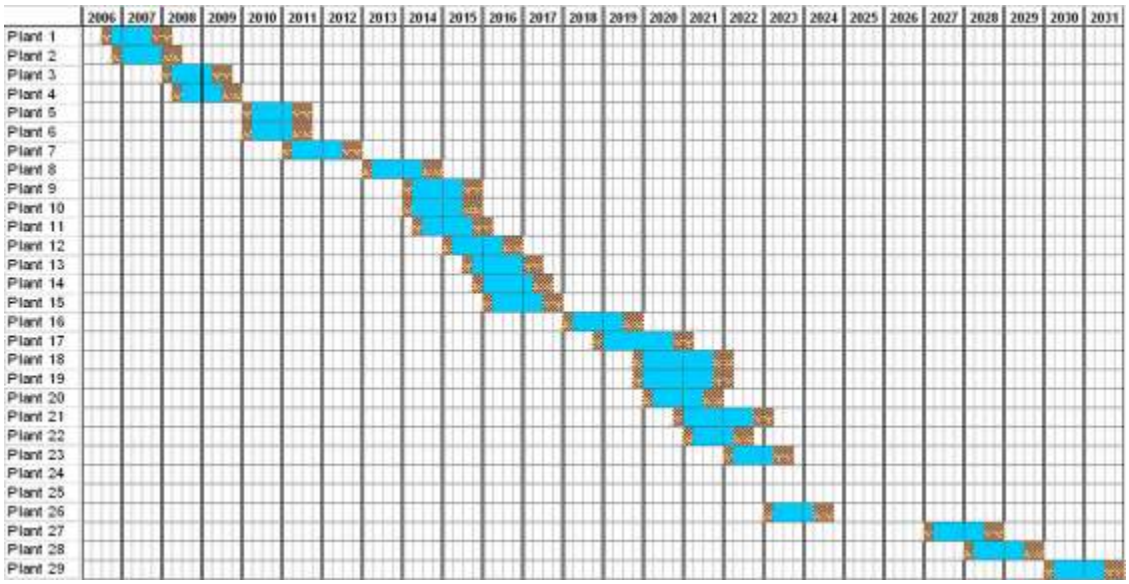
There are many factors that must be considered today including setting the right scope, encouraging the right behaviour 'beginning with the end in sight'. The presentation is intended to provoke thought and highlight some critical areas that heavily influence outcome. The experience from earlier campaigns is used to illustrate the opportunities and the risks.

1.0 Introduction

Prior to the 'G16' pressure tube failure event at Pickering A Station, a total of 59 fuel channels had been replaced using single channel replacement tools and procedures. Suddenly the Station was faced with a massive ramp up in program as full scale replacement became a reality. All four units were re-tubed and worked on over the period of 1984 to 1993. Unit 2 was completed in 56 months. Unit 1 was completed in 43.5 months. Unit 3 was completed in 26.5 months and P4 was completed in 19 months. Many of the lessons learned that enabled the dramatic improvement in performance are equally applicable today. The financial advantage of the last campaign over the first of the series represents over $250 M of generation revenue plus reduced costs associated with reduced execution. Today stakeholders need both predictable, highly reliable generation and efficient use of resources and investment. There is a lot of work to do. This paper looks at the major lessons from the Pickering A experience and is intended to provoke thought and self examination of the current refurbishment and life extension programs.

2.0 What's in store

As we look at the CANDU fleet of reactors it is clear that demand for safe, clean reliable cost effective energy will remain a strong driver in all countries to extend life of these machines. The following figure outlines the currently estimated refurbishment program. Collectively the program represents a larger investment of money and resources than we have ever experienced in the Industry to date. Quality of life and economic growth in all countries is highly dependent on reliable energy and pressure to deliver the refurbished Units on time and on budget will be huge. The expectation will be that the Units perform to a high capacity factor for the second thirty years.



If the lessons learned from the Pickering A experience applied to the refurbishment projects could gain even 10% of the impact that was seen in the earlier campaigns, there is potential savings of over ¼ billion dollars and significant relief on stretched energy capacity and stretched resources.

If we look beyond the time frame of the first refurbishment of the fleet we might wonder if there will be a second refurbishment. We know that energy demands in the next 60 years will remain a societal challenge. We know that some thinking has already begun suggesting reactor life can be extended to 100 years or more. So it is clearly not out of the question. Life extension of pressure tubes will regain focus a couple of decades down the road for sure. Whatever our plan, this period will span 3 generations of nuclear workforce – lessons learned will need to be captured and passed on if the program is to be a success.

3.0 Scope – Beginning with the End in Mind

Steven Covey is often quoted for his axiom "begin with the end in sight". After the early refurbishments at Pickering forced loss rates remained high and capacity factors began a period of decline. At the time of the outages, all the organizations capability was consumed in trying to recover from the unexpected pressure tube rupture. So the business decisions of the day are not in question – the question is what can we learn from the experience to get

improved results going forward. Setting the outcome with clarity can have significant impact on life cycle performance.

Consider for example a Program scope that is targeted to be simply a retube and meet minimum Regulatory requirements. The Plant being returned to service will be a safe plant but may not be an optimum performer in downstream years. Non mandatory inspections, equipment refurbishment, forensic materials necessary to support the next 30 (or 60) years of operation may not be viewed as needed against this type of scope specification. The outage duration may be shorter than if the additional work is completed but the longer term return on the investment may not be optimized. Contrast the scoping decisions for campaigns defined by:

— Complete all work safely and necessary to support forced loss rate less than 2% and capacity factor >90% for the next 5 years and keep a third post refurbishment operating cycle as a possibility.

Clearly scoping decisions would be quite different for the two cases. Business and environmental drivers will cause operating Companies to choose scope definition based on a number of factors including affordability. Perhaps reflecting on the Pickering early experience and the current performance expectations on the Industry should cause us all to reflect on the focus we create. A long term perspective now is essential if we want to optimize life cycle overall performance.

4.0 It's more than Plant Equipment

Most often we focus on the Plant equipment as the asset that needs mid life investment. This is a necessary but not sufficient view of the challenge we currently face. We should look at the task as a holistic investment in assets and programs necessary to get the Plant performance outcome we want. This holistic look should cause us to focus on:

1. The Plant Equipment Asset
2. The Human Capital Asset
3. The Design Basis Asset
4. R&D programming necessary to support operation at 50 years and beyond

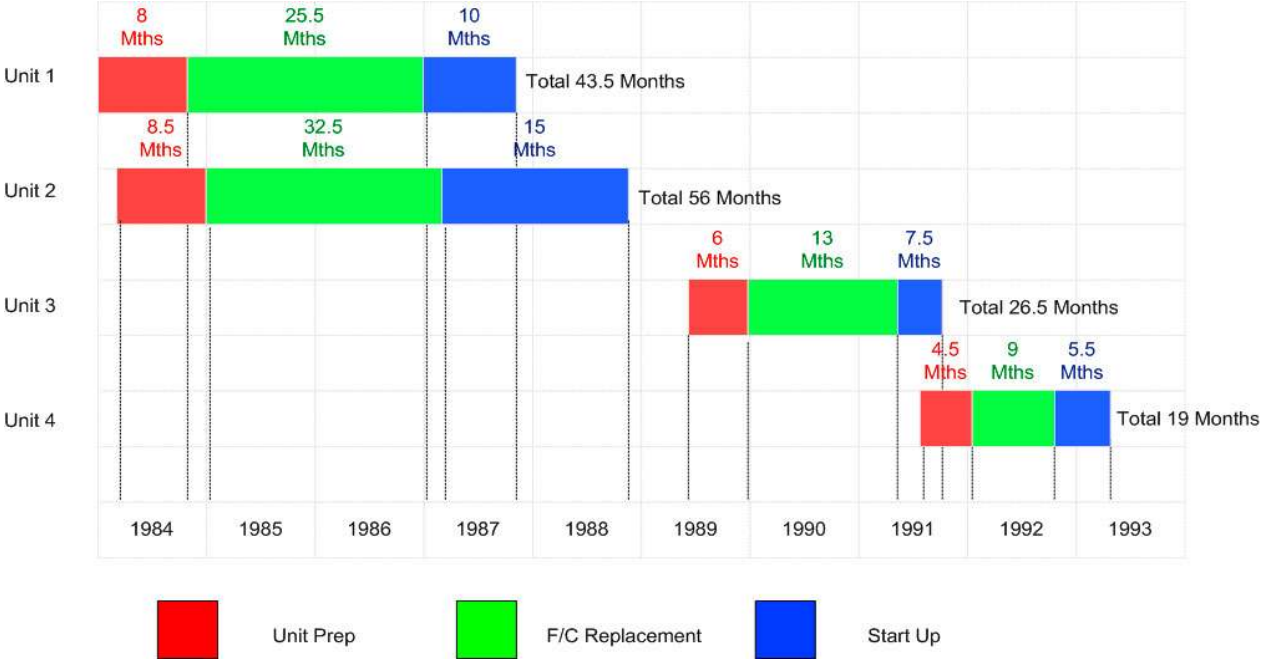
The plant physical asset is the natural focus refurbishment so I won't say anything except in passing. In this area it is key to have the program aligned with the outcome that is desired – as discussed above in scope.

The Human Asset and the Design basis asset are inseparably linked. In the early days of the CANDU program, weaknesses in design basis documentation were compensated for by a highly experienced work force. Original designers and start-up engineers became part of the operational support team and brought their knowledge and skills with them. Over the time frame of the refurbishment programs over half of the workforce will change. Will the condition of training programs and design basis documents be sufficient to sustain high performance post refurbishment with a new workforce? It would seem intuitive that an increased investment is necessary in these areas to make the transition. Is this part of the program that has been set out for your Company? If not there is a risk that likely needs some attention!

For years we have invested in fundamental underlying research to underscore the safety analysis for our Plants. Some investment in this domain will continue to be necessary. However, with enhancements in understanding and risk informed decision frameworks there should be opportunities to make adjustments at least in allocation of the R&D dollar. Suppose we do want to run Plants for 60 years and beyond AND achieve high performance and predictability in the end of the life cycle. Do we have adequate programs to identify aging degradation issues ahead of operating impact? Now is the time to think through the component needed for forensics and inspections necessary to enable operation at 60 years and beyond.

5.0 History Lessons from early Pickering Retube – Opportunities for the Future

The following figure is taken from the "P4 Retube Review" report produced by Mr. R. Brown for Ontario Hydro in April 1993. The report summarized the results of the campaigns on the 4 Units and captures some lessons learned.



By simple inspection we can see the dramatic improvement in schedule performance for the subsequent Units. Specifically:

— Preparation was reduced from 8.5 months to 4.5 months
— The actual Fuel Channel work was reduced from 32.5 months to 9 months
— The start-up phase was reduced from 15 months to 5.5 months

Overall lessons learned translated to action reduced the Program from a 56 month ordeal to a 19 month outage. Same people – different result. What were the factors that enabled the significant difference?

Clearly the unexpected entry into the program was a big factor in the first unit campaign delivery. Equally, tooling improvements were a factor in more efficient channel work. But

his was only part of the story. Key decisions about the approach to the work also had major impacts on the program duration.

Early in the Program, leaders recognized that the success of the program was dependent on the collective knowledge and skills of the Team applied in an aligned manner. In the beginning safety performance was less than adequate and the work often stopped for safety concerns or integration difficulties. Three key initiatives were introduced:

— Integrated teams with accountability for a specific sequence
— Safety as a part of all that was done
— A systematic collection of time losses with analysis and rapid improvement initiatives to resolve the causes of the loss.

Easier to say than do!! The leaders of the Program had the insight to recognize that taking time to communicate the `why we are doing what we are doing' was at least as important as education on how. In spite of significant schedule pressures, Leaders introduced training initiatives including 'stand-down days' to get the alignment of the people and commitment to behaviours like reporting time lost. The investment paid off significantly. Before the investment there were silos and interface difficulties. It was difficult for managers to see the opportunities. Through the alignment and data gathering system, the collective energy of the Team was more effectively focused on the team result. Productivity improvements blossomed throughout the program.

Staff were embedded into the Teams of the first Units to learn and move the learning to other Teams for subsequent Units other units. This investment proved equally powerful to generate improved performance. When you consider we will embark on over 20 campaigns, these lessons seem directly applicable on what we have ahead of us!!

6.0 Thoughts on Moving Forward

While the Pickering A Retube experience is now over a decade old it is still directly applicable to the challenges before us. We must learn from our history and each other in order for the Industry to succeed. As Industry leaders we set the 'end' that we want the people to focus on. We set the tone of co-operation and sharing or autonomy that our people align to. We cause the Industry to succeed as an integrated entity or struggle as discrete components.

We have a task in front of us that is bigger than anything we have dealt with in the history of the Industry. It has taken us 3 decades to enhance our performance to the point where nuclear energy has emerged as an energy choice that the Public and our business stakeholders see as worth `reviving'. The environment of our children and our successors depend heavily on the decisions we make and how we work together to make the next three decades successful and not a repeat of the last 3. There can be no winners and losers. We all have to win. Our industry will always be just one event away from extinction.

So as leaders of the Nuclear Renaissance:

— Have you set the right 'end in sight' for your part of the Industry?
— Have you invested adequately in mining the lessons of those that have gone (or will go) before you?
— Have you set the cultural base for sharing and learning?

— Have you looked at Plant Equipment, the Human asset, the Design Basis Asset and the R&D programming investments necessary to get the desired result?

Our opportunity to succeed together is great. The consequence of failure to get it right will be severe.