2007

Industry Reference Document (10) of (32)

Lessons Learned for Nuclear Construction Projects

5 pages

K.J. Aupperle/High Bridge Associates and C.W. Hess/Burns & Roe
American Nuclear Society 2007 Winter Meeting

Industry Lessons Learned for 21st Century Nuclear Projects

Kenneth J. Aupperle
Charles W. Hess

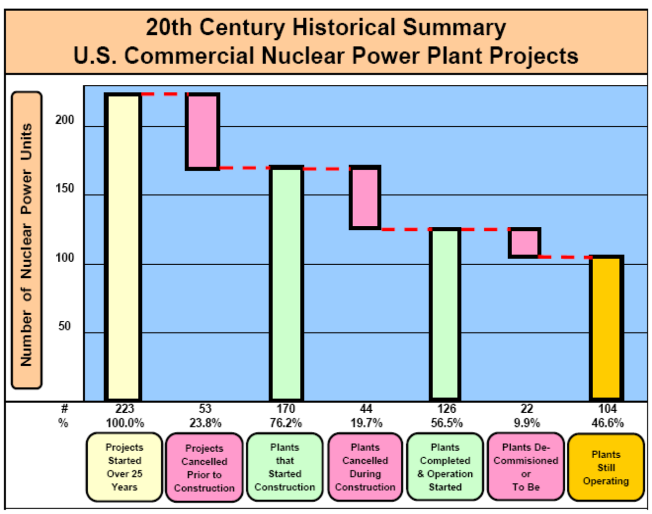
Burns and Roe
800 Kinderkamack Road
Oradell NJ 07649
chess@roe.com

High Bridge Associates
3260 Pointe Parkway
Norcross, GA 30092
kjaupperle@hba-inc.com

BACKGROUND AND INTRODUCTION

In the 25 years from 1965 to 1990, the US nuclear industry announced planning for 223 nuclear power plant projects, began construction for 170 units, and completed 126 reactors for operation, as graphically portrayed in Figure 1. During the process, the industry grew from a theoretical concept to a robust program to assure safety, quality, profitability, and reliable operations. However, a majority of the personnel associated with this transformation have left the industry, and those remaining are focused on operations, outages, and modifications.

Figure 1



This resource and experience shortage presents a challenge to the nuclear renaissance now underway. By large measure, the root causes that led to 44 nuclear construction projects being cancelled at stages of completion up to 100% are still with us. Moreover, the authors believe they are widely misunderstood.

This paper discusses eight case studies to identify the root causes of project success and failure. These root causes are summarized, analyzed, and reduced into a set of recommendations to establish a framework for successful new nuclear power plant planning and management.

RESEARCH APPROAH

Historical information for nearly 100 projects from 1965 to 1990 was compiled from personal files, corporate records, and internet searches of regulatory agencies and intervener organizations, along with personal interviews and a review of contemporary studies. Eight projects were selected for detail review and analysis to distill root cause issues, good practices, and lessons learned. Four projects were selected from the 44 cancelled projects, and four projects were selected from the 126 completed projects. Fundamental project management elements and processes were examined, along with project internal and programmatic external considerations.

The cancelled projects were analyzed to identify the officially stated causes of project failure. A critical review was performed to define and understand the root causes of the stated failure modes. The completed projects were assessed to define and understand the characteristics that created the foundations for success. Failure root causes were compared against successful project characteristics to understand and provide insight into the real reasons some projects failed and some projects succeeded. Lessons learned and recommendations for success were developed.

DISCUSSION AND OBSERVATIONS

NRC records identify 223 docketed nuclear power plant licenses from the mid-1960s to the present. Most of these projects were by the early 1990s. About 76% or 170 of the applications received construction permits under 10CFR50. Operating licenses for 126 of these construction projects were issued. A total of 104 plants are still in operation in 2007. By any measure, this was an ambitious program and a highly successful one in that the plants that were constructed are now among the most reliable and cost effective thermal power plants in the country.

As the nuclear power industry looks forward, planning for another 126 nuclear power plants operating in the US by 2035 might be considered hopeless optimism. Yet, in 1960 with no experience of what a nuclear plant was or how it would work, the U.S. electric utility industry was able to start and execute an aggressive program through a period of time that saw double digit inflation, three economic recessions, and an eruption of regulatory requirements that ratcheted in much change, technical complexity, and increased physical scope and quantities of materials necessary, as outlined in the 1986 paper addressing nuclear power plant cost growth (Reference 3).

In spite of this, the program was considered in the public perception as a failure and America abandoned new nuclear plant construction, as outlined in the 1985 Forbes magazine article "Nuclear Follies" (Reference 5). To some extent, this specter still haunts the industry. The reasons for this are many, but the main reason is that almost all of the projects were failures because they exceeded their schedule and budgetary costs by incredible amounts. Many careers were ended by being associated with these projects, and the legal system was clogged with angry litigants for many years after the plants were completed. The authors believe that the good and bad embodied in the original program need to be reviewed in an objective and critical manner to understand root causes and practices and to avoid the cost and schedule overruns of the past.

Some observations regarding major contributing past issues, lessons learned, and current challenges include:

1. Paradigm Shift from Fossil/Hydro to Nuclear…. A review of the organization of a typical electric utility in the 1960's to 1970's reveals a vastly different organization than the modern nuclear utility operating organization. Utilities of that period had just completed the post-World War II electrification of the nation based on fossil fueled or hydro electric technologies, and were about 50% construction management companies and 50% operating companies. This explains their ability to undertake an aggressive nuclear plant build out program with such confidence. It also led to one of the most common causes of failure; the inability to understand the fundamental differences between building a fossil/hydro power plant and a nuclear power plant.

2. Operating/Small Projects vs Construction/Large Projects Utility Experience Perspective…. The current nuclear utility is essentially a 100% generation company focused on operations, and many have shed their transmission and distribution service roles. Very few of current utility managers have any construction or major projects background. Resource skills are centered on either an operations background or a financial background, and do not provide the experience or understanding of a mega project such as constructing a new nuclear plant. It is alarming that this has led to some initial issues at odds with the successful past performance. For instance, new projects are being modeled on the successful gas turbine projects that have been undertaken in the 1990s. Turnkey contracts are awarded to gas turbine manufacturers who then contract for engineering and construction services. The fact that that approach did not work particularly well in the combustion gas turbine business seems not to deter its adoption as the model for new nuclear plants.

Setting Biological Shield Wall at River Bend

3. Dysfunctional/Inappropriate Contracting Strategies… The 2007 EPRI presentation on "Prudence Resurrected" (Reference 1) discussed many lessons learned and root causes related to over $19 billion in disallowed costs by PUC's from 1981 to 1991. Its author concluded that dysfunctional owner contracting strategies leading to excessive change orders, unnecessary claims, and costly litigation were the leading root cause category of disallowances.

In today's marketplace, turnkey contracts are being negotiated with reactor manufacturers to shed utility risk and with the anticipation that firm fixed pricing will be maximized. This is at odds with the past. Reactor manufacturers were generally not awarded EPC contracts in the past, as they did not have experience in successfully managing large construction projects. The current strategy of awarding an OEM/EPC contract to the organization with the "deepest pockets" seems to be at the heart of this trend and it is alarming to those who remember the past.

Additionally, the recent experience with constructing combined cycle gas turbine plants is inappropriate as a model for a nuclear project. Neither the scope nor the duration of a gas turbine project is analogous to the scope and duration of a nuclear project. The risk profiles of the two projects are so different, that different contracting approaches are necessary.

4. Objective Understanding of Internal and External Project Issues…. The 1984 NRC report (Reference 2) to congress and postmortem of construction quality problems concluded that poor internal project

applicant/utility management practices, along with inexperienced design and construction companies, were the root cause of most project failures. However, years of Prudency Hearings have focused on external issues and drivers like escalation, finance charges, and regulatory changes as the primary contributing factors. This legal parsing of facts and histories has obscured the wisdom gained at such a high price in the past.

HAVE THINGS REALLY CHANGED?

Many positive changes face a management team considering a new nuclear plant. First, the certainty of the life-cycle economic benefit of a new nuclear plant is no longer in question. Nuclear plants are reliable and economically attractive facilities with a hard-won and improving record of success. Second, the environmental impact of nuclear plants in the U.S. is widely recognized to be minimal; with the largest threat being construction itself.

However, it is widely believed that the revisions to the licensing process have solved the problems that forced the cost over runs and schedule delays in the previous projects. This seems to be the result of a revisionist approach to history rather than an objective review of the past. Certainly, the difficulties faced by companies trying to complete a nuclear plant in the regulatory turmoil following the Three Mile Island Unit 2 accident were exacerbated by the 10CFR50 process.

However, if the process was the root cause of the problem, there would have been a uniform history of failures following TMI. ***The authors believe that a careful review of project histories demonstrates that the licensing process and other external issues were a second order cause of past problems, and that internal planning, organization, and management deficiencies were the primary drivers.***

CASE STUDIES

From our compiled data base of information spanning more than 100 nuclear projects, the following eight projects were reviewed in greater detail to distill root cause issues, good practices, and lessons learned:

1. Cancelled Projects –
   a. Marble Hill, Indiana Public Service
   b. Midland, Consumers Power
   c. Shoreham, Long Island Lighting
   d. Zimmer, Cincinnati Gas and Electric
2. Completed Projects -
   a. St. Lucie 2, Florida Power and Light
   b. River Bend 1, Gulf States Utilities
   c. WPPSS 2, Washington Public Power System
   d. Duke 7 Units – Oconee, McGuire, & Catawba

Oconee Station

All of these cancelled and completed projects faced the same external issues and challenges:

- High inflation and interest rates
- Evolving regulatory requirements
- Changing plant design
- Regional economic slowdowns

Examining the cancelled projects leads to the following failure "Root Cause" issues and lessons learned conclusions:

1. Insufficient utility leadership and ownership:
   a. Unclear/changing definition of project expectations, roles, responsibilities
   b. Insufficient project integration
   c. Inadequate resources applied to planning and project management
   d. Problematic "Risk Shedding" mind-set for elements the owner/licensee cannot shed
2. Lack of a nuclear mentality at the management and workforce levels
3. Lack of commitment to quality processes and failure of QA Programs due to inattention to details and required record keeping
4. Owner contracting practices that stampeded contractors into bad practices
5. Inadequate training

Examining the completed projects leads to the following "Keys to Success" and good practices conclusions:

1. Effective utility owner project leadership
   a. Organization, responsibilities, and accountability
   b. Open communications at all levels
   c. Integrated project schedule ownership
   d. Clear and common priorities
2. Project planning and schedule focus
3. Pro-active risk management/mitigation program
4. Technical excellence and nuclear quality mentality
5. Attention to details/documentation
6. Pro-active regulatory posture

CRITICAL CONCLUSIONS AND ISSUES

Much has been done by nuclear energy industry and government leaders to create a framework for a successful Nuclear Renaissance. However, many of the 21st century industry initiatives governing new nuclear plant projects and undertaken to improve the 20th century systems and regulations have sometimes only superficially addressed the root causes. ***Our evaluation indicates that the stated causes of project failures have been sanitized over time to the point that they convey marginal information for planning new nuclear projects.***

Our conclusion is that external organizations and agencies cannot address the root causes of project failure. They can only be addressed by the corporate organizations, project teams, and personnel involved with planning, integration, and leadership. Much of the industry appears unaware of the previous program where one in four projects under construction was abandoned and the average cost over run of "successful" projects was a factor of three times greater than the initial estimate, as illustrated in Table 1 below.

Table 1

Construction Start	No. of Units	Estimated Overnight $	Actual Overnight $	% Over
1966-1967	11	$648/kW	$1354/kW	209%
1968-1969	26	$784/kW	$2308/kW	294%
1970-1971	12	$878/kW	$3057/kW	348%
1972-1973	7	$1291/kW	$4305/kW	334%
1974-1975	14	$1336/kW	$5098/kW	381%
1976-1977	5	$1725/kW	$4633/kW	269%

Reference 7

The Industry has created many systemic improvements related to standardized designs and streamlined regulatory processes. ***However, many old challenges remain and a host of new issues now exist related to a global economy with intense demand side pressures and a degraded US supply chain for personnel and equipment. Unless these issues are addressed successfully, the performance of 21st century nuclear projects will likely be unchanged from the nuclear plant projects of the 20th century.***

RECOMMENDATIONS

1. Planning, Organization, Integration and Leadership…. The major cause of project failure was and will continue to be inadequate planning for the successful organizing and execution of projects. This was the case in the past and it will be the case in the future. Today's advanced reactor first of a kind technology design details will pale in comparison to the current organization and resource issues and challenges. The failure to grasp the intricacies of organizing and planning a mega project such as a nuclear plant construction project will be the largest issue facing the modern utility.

The 2007 EPRI presentation on "Prudence Resurrected" (Reference 1) concluded that deficient owner project organization structures led to poor communications, unclear priorities, conflicting/redundant responsibilities, and lack of accountability. Attempting to out-source the responsibility to companies with "deep pockets" will only obscure the problem until its implications are overwhelming. Additionally, the applicant must own the project schedule and the Quality Assurance program that controls the entire project. ***The owner must control the project directly, and be the primary force in creating and implementing an Integrated Project Team comprised of utility, OEM, and EPC organizational elements. Any owner who fails to recognize this can look to the failures of the past as an indication of the future.***

2. Contracting and Risk Management Strategies…. The second most common root cause of project failures in the past was an owner contracting strategy that had inexperienced companies being given responsibilities beyond their corporate expertise. In the past, this was characterized by fossil power plant assumptions being inappropriately applied to the much more rigorous nuclear power plant project construction project. In the future, it will be the awarding of construction contracts to reactor manufacturer-led consortia with untested internal divisions of responsibility. The obsession with risk shedding will make the internal structures of these consortia very brittle and hard to adapt to the inevitable problems that will face the new nuclear projects. ***The owners must take a pro-active role in leading their integrated project team organizations and risk management/mitigation programs.***

3. Design Completion before Starting Construction…
A major problem in the past was that construction was begun before the engineering and design phase was complete. This is a common practice in fossil power plant construction. However, in an inter-related complex construction project like a nuclear plant, this results in serious complications that, unless managed carefully, will result in major cost and schedule over-runs.

Currently, the drive to "standardized" designs will help alleviate this situation. However, it has also obscured that much of the overall project scope is, in fact, site specific. Engineering and design work must also be completed prior to construction and this effort needs to be identified, planned, and executed. At present, funding for this effort is not generally considered to be warranted prior to receipt of the COL, and will be too late. ***Utilities need to develop schedule and contracting strategies that allow site specific and non-standard yard infrastructure construction to proceed in a manner that recognizes***

design completion interfaces while avoiding creating competing resource and critical path pressures with the power generating block scope of work.

<u>4. Nuclear Culture and Training….</u> The lack of a nuclear construction culture with people trained and devoted to the concept of complete compliance with requirements was a major root cause of many problem symptoms in the past. As mentioned earlier, no organization in the U.S. nuclear design and construction industry has current experience with large nuclear construction projects. This leads to a major Risk Mitigation initiative that the industry needs to fund or the failures of the past are almost certain to be repeated. ***A significant training and testing program needs to be developed rapidly in order to avoid the errors of the past.***

IN SUMMARY

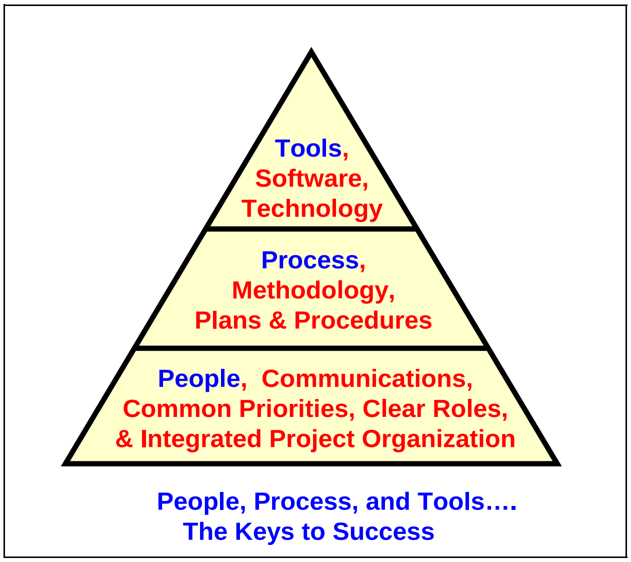
When beginning to plan a new nuclear power plant, there is much to be optimistic about. However, this optimism should not blind the project management team to the challenges facing them. The engineering, design, procurement, and construction processes for a new nuclear plant require the active involvement of the licensee. Unless the modern utilities can step up to this challenge in a proactive way, the nuclear renaissance will be nothing more than a short, unhappy echo of the past.

The authors recommend that owners take the lead in several key areas to assure project success:

1. Apply resources for early planning, planning, planning
2. Use risk-based project management approach
3. Establish a strong integrated management team
4. Provide a firm financial basis for project
5. Select a technology that matches corporate goals
6. Provide appropriate contracting vehicles that permit win-win solutions for owners and contractors
    - Fixed price when basis exists
    - Target cost/incentives/penalties
    - Target milestones/incentives/penalties
    - Cost plus/task based
7. Project Management Leadership
    - Defined roles and responsibilities
    - Communications and coordination
    - Integrated project teams
    - Partnering
8. Training, training, training
9. Involve all stakeholders in process
10. Develop active intervener mitigation plans

To wrap up and as summarized graphically in Figure 2, the Keys to Success lie in a firm project foundation composed of People in an Integrated Project Organization in which Processes and Management Tools can flourish and work effectively. This is a fundamental principle for good project management; it can be clearly seen in the successes of the past; and it is essential for our success with the "21st Century Nuclear renaissance" in the future.

Figure 2



SELECTED REFERENCES

1. "Prudence Resurrected", Mike Laros, Barrington – Group, Inc. EPRI Conference, May 2007
2. "Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants – A Report to Congress," NUREG-1055, US NRC, May 1984
3. "Technical and Economic Aspects of Successful Nuclear Plant Construction Projects in the U.S. and Future Prospects," C Braun and FJ Rahn, American Power Conference, April 1986
4. "An Objective Approach to Explain the Growth of Nuclear Plant Costs," E Brabazon and G Kent, American Power Conference, April 1986
5. "Nuclear Follies," J Cook, Forbes Magazine, February 1985
6. "Results of Self-Initiated Evaluations", Construction Project Evaluation Program, Phase I, INPO, February 1983
7. Mark Gielecki and James Hewlett, Commercial Nuclear Power in the United States: Problems and Prospects, US Energy Information Administration, August 1994