Engineering the Future

Nuclear Construction Lessons Learned

Guidance on best practice: nuclear safety culture

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Foreword

Achievement of the UK government's challenging carbon reduction targets is directly related to the successful delivery of a fleet of new nuclear power stations. In support of this, *Engineering the Future*, following a request from the Department of Energy and Climate Change and the Office for Nuclear Development, set up a steering group to examine the lessons that could be learned from recent civil nuclear power plant construction projects. The project steering group was formed by representatives from relevant engineering institutions and bodies and considered both the lessons that could be learned and how they should be incorporated into the proposed UK new build programme. In October 2010 the project steering group delivered a report to Charles Hendry MP, Minister of State for Energy & Climate Change, on the construction lessons learned from six international nuclear new build projects.

The purpose was to help UK industry fully understand the issues that had led to delays, rework and redesign in past nuclear build projects in order to incorporate that learning into new build projects and thus reduce delays and increase investor confidence.

The *Nuclear Lessons Learned*[1] study examined experiences from six recent nuclear construction projects and established five general lessons:

1. Follow-on replica stations are cheaper than first of a kind.
2. The design must be mature and licensing issues resolved prior to start of construction.
3. A highly qualified team should be established to develop the design, secure the safety case, plan the procurement and build schedule in collaboration with the main contractors.
4. Sub-contractors should be of high quality and experienced in nuclear construction, or taught the necessary special skills and requirements for quality, traceability and documentation.
5. Good communications with the community local to the site should be established and maintained.

Once these general lessons were established, an industry stakeholder group meeting in November 2010 suggested to the steering group that a focus on specific areas of nuclear construction would be of particular use to industry. It was decided that the first three of these 'deep dives' would cover nuclear safety culture, welding and concrete. Working groups led by the most relevant professional engineering institutions took these topics forward, producing best practice guidance documents for each. Industry was widely consulted on the draft guidance documents, which were finalised following a workshop held on 19 September 2011.

The *Nuclear Safety Culture* best practice document presents an overarching view of safety culture in the context of a new nuclear build programme. The recommendations of this specific report apply to all aspects of nuclear construction.

The aim of these best practice guides is to provide accessible information to help those involved in nuclear construction projects to adopt behaviours conducive to successful project delivery. Although they are not intended to be standards, codes of practice or contract conditions, the members of the *Engineering the Future* alliance believes that following the recommendations will be beneficial to companies in terms of delivering new nuclear projects to cost and programme.

A consistent approach is important, given the degree of sub-contracting prevalent in the UK market, as the success of the project relies on all those involved throughout the supply chain.

The guidance documents are aimed at all those within the supply chain wishing to better understand the demanding requirements of nuclear construction. The documents are particularly relevant to those whose roles encompass the design, specification, tendering and bidding for work within nuclear construction projects, as well as those responsible for delivery. The recommendations should prove selectively useful for those developing business strategies through to those working on site.

Through these documents, *Engineering the Future* seeks to facilitate learning from previous construction projects to help create a strong and successful new nuclear build programme in the UK.

During the nuclear new build programme further lessons will surface, it will be important to ensure that an effective mechanism is in place to capture and disseminate this learning. This process will further contribute to the effective delivery of a fleet of new nuclear power stations.

1. Introduction

The publication of the *Nuclear Lessons Learned*[1] report in October 2010 was managed through a steering group. Following its publication, the steering group, coordinated by the Institution of Civil Engineers, convened an industry workshop to identify topics to be addressed from the conclusions of the report. At this workshop in November 2010, areas of learning were identified that could be applied to the forthcoming UK new build programme. The three most significant were: concrete quality, nuclear safety culture and pipe work welding. In February 2011, the steering group set up three working groups to produce guidance on best practice in these areas.

The Nuclear Institute was asked to chair the Nuclear Safety and Quality Culture working group with the aim of identifying issues in the original report where a lack of nuclear safety culture was a causal factor. The group could then make recommendations on actions to assist all participants in the UK new build programme, at all levels in the supply chain. This would then address the issues and so help prevent repeating identified problems. While this document looks predominantly at the construction period, establishing a good safety culture at that stage is fundamental to ensuring safe and continued operation during operation.

2. Why is nuclear different?

Successful delivery of a fleet of new low carbon electricity generation is vital to meeting the UK's energy policy and future energy security objectives. For the UK to deliver a new fleet of nuclear power stations in accordance with these objectives, the nuclear industry must demonstrate and maintain the highest possible standards of safety, quality and efficiency. These standards need to be appreciated and applied by every participant involved in the design, manufacture, construction and operation of new nuclear plants.

To assure safety, the industry has created strict standards for the design, engineering and construction of nuclear facilities, as well as strict quality regimes for all structures, systems and components. One of the fundamental design principles that contributes to assuring nuclear safety is the principle of 'Defence in Depth' (see example in figure 1). This strategy relies on multiple barriers to reinforce integrity and prevent unintended release of radioactivity. To this end, the construction industry has developed strict standards for all pre-operational processes as well as stringent quality regimes for every structure, system and component. The nuclear industry has a well-established process of peer review though the World Association of Nuclear Operators (WANO).[2]

However, for best practice, good design standards and quality regimes alone are not sufficient. It is crucial that a positive nuclear safety culture is developed and demonstrated by all organisations and individuals involved in the construction process. This calls for highly focused leadership committed to fostering the values and behaviours which place an overriding emphasis on safety.

It is essential that these values and behaviours are promoted throughout the supply chain so that every link in the chain is able to play a key role in ensuring that the highest standards are met throughout the construction process. For example, this will include developing a knowledgeable and competent workforce that has a good awareness of the importance of safety, in particular nuclear safety, and their own contribution to the overall safe delivery of a new fleet of power stations.

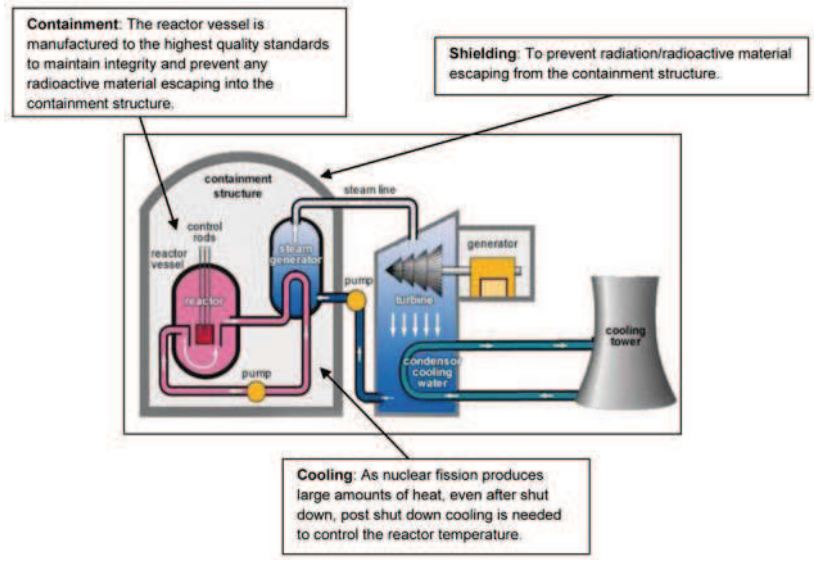

Figure 1: Defence in Depth Example – An example of a pressurised water reactor

3. Safety culture

Developing and maintaining an appropriate safety culture is a priority for nuclear site licensees. It underpins the way in which their organisations are designed and managed. An overriding priority on safety should govern the leadership, procedures and behaviours on site. This is reinforced by the ONR Safety Assessment Principles[3], which set clear regulatory expectations for effective leadership and management for safety. In the UK, the licensee's responsibility for nuclear safety extends through all levels of the delivery supply chain.

The International Nuclear Safety Advisory Group[4] (INSAG) defines safety culture as:

"...that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."

A Basic Nuclear Industry Behaviour standard has been created by the Safety Directors Forum via the UK Human Performance Forum (HuP) of which the National Skills Academy for Nuclear is a member[5].

Successfully translating the development of a nuclear safety culture into the construction of a new nuclear power station will be a key challenge. Supporting this challenge, *Principles for Excellence in Nuclear Project Construction*[6] published by the Institute of Nuclear Power Operators (INPO), sets out the essential principles and attributes of a healthy construction environment for organisations building new nuclear plants or other nuclear facilities.

Building on the INPO report, this document considers how the INPO's key principles can be applied beyond the construction of a single plant while also seeking to identify the wider benefits such principles will bring to the successful delivery of a fleet of nuclear power stations.

Using the nine key principles described in the INPO report, a series of bullet points are set out in the following section, which demonstrate elements of best practice that will support the development of a robust nuclear safety culture. Where relevant, recommendations are proposed that can either be applied in the delivery of a project or can support effective delivery of a fleet.

4. Demonstration by leaders of alignment on a commitment to excellence

The commitment to high-quality construction and personnel safety begins at the top of each organisation. The leadership across organisations must be aligned on the development, communication, demonstration and reinforcement of clear standards and common expectations for processes and behaviours that are essential to constructing a high-quality facility in a safe manner. In this context, 'the leadership' refers to executives and managers throughout the multiple organisations involved in the construction of a nuclear power plant or other nuclear facility.

Best practice

- Leaders of licensee organisations and their construction supply chain should share a single corporate vision, with safety as an overriding priority.
- Leaders should 'walk the talk' and demonstrate their commitment to their vision through their actions.
- Leaders should exhibit a strong commitment to establishing a 'learning organisation' that values learning from internal and external sources and commits to improving as a result of this learning.
- Leaders should ensure that they understand the safety performance of their organisation and take steps to maintain adequate oversight of safety.

Recommendation 1

Nuclear projects should establish a single Leadership Charter. This charter should embody the key principles, priorities and goals of the diverse range of stakeholders, setting out clear arrangements for communication and monitoring as well as ensuring 'sign on' by all parties.

Recommendation 2

All companies engaged in a programme of nuclear new build should work together to establish a leadership charter. This should embody the overarching principles that support effective fleet delivery based on INPO and IAEA standards of stakeholders, setting out clear arrangements for communication and monitoring as well as ensuring 'sign on' by all parties.

5. Focused front-line supervision is key to success

The completion of quality work and the maintenance of a safe work environment during construction depend significantly on the performance of front-line supervisors. These supervisors may be foremen, superintendents, field/construction engineers or others, depending on the organisational structure, in any of the organisations involved in the project. Supervisors are largely held accountable for work quality and personnel safety, along with the workers. Therefore, supervisors must possess both the technical and the management skills to understand the job content, coach workers on task conduct, implement the required work standards and processes, as well as address personnel performance issues.

Best practice

- Supervisors should have clearly defined roles that they understand and which they have been trained to perform effectively. These arrangements should reflect the special requirements of nuclear construction.
- Supervision should be provided for all those who work on-site and whose actions could potentially have safety implications.
- Supervisors should understand the importance of effective communication with the work team.

Recommendation 3

Role profiles should be established setting out the skills and knowledge required at different levels of supervision. All supervisors should undertake formal competency assessment against these role profiles. Use should be made of the Nuclear Skills Passport[7] and the Engineering Council standards of competence for professional engineers[8].

6. People are competent to carry out their jobs

Personnel must possess the skills to perform high-quality nuclear project construction safely. They should understand the expectations and demonstrate the behaviours necessary to achieve project requirements for construction quality and personnel safety. Workers should receive and value pre-job briefings, work mock-ups, just-in-time training or qualifications, and human performance (error prevention) techniques. They must understand the expectation to be self-critical of their work performance and to identify and report any quality or safety issues. The National Skills Academy for Nuclear's Triple Bar, Nuclear Industry Awareness Award and Certificate of Nuclear Professionalism can contribute to this culture.

Best practice

- All personnel taking part in construction operations should be suitably qualified and experienced to carry out their work.
- Role profiles should be provided for all personnel and training provided to support effective performance.
- Personnel performance standards should be defined and assured through suitable competence assessment and continued professional development.
- An expectation of high quality work and responsibility for individual safety must be shared by all personnel. Supervisors should verify levels of performance through regular on-site observation.
- A culture of zero tolerance towards any individual not abiding by set safety requirements is essential.

Recommendation 4

A systematic approach to training should be taken to provide confidence that all personnel are trained and competent. Commonly recognised qualifications and standards should be used where these have been established.

7. Schedules are realistic and understood

Effective project controls and detailed planning are key factors in the success of any large construction project. Unrealistic, uncoordinated, or obsolete schedules or insufficient resources can have a negative effect on construction quality and personnel safety, especially when inappropriate actions are taken to accelerate construction or reduce cost.

Best practice

- Schedules must be realistic and contain achievable timescales for all aspects of design, procurement, construction and handover. They should include major milestones, critical paths and logic ties.
- Schedules should explicitly allow time for personnel orientation and skills verification activities.
- Activities in the schedule should be risk-ranked, and additional oversight and contingency planning put in place where required.
- Robust arrangements must be in place to communicate the above throughout the supply chain to the appropriate level of detail.

8. Construction of a nuclear plant has special requirements

Construction of a nuclear plant requires rigorous implementation of programmes and procedures to ensure all requirements and regulations are met. Some of these additional requirements are not typically emphasised in commercial construction projects; therefore, some organisations and workers may not be familiar with them. Such requirements and regulations include: strict adherence to project policies, procedures, work documents and design specifications; quality control witness/hold points; extensive documentation; seismic, environmental, emergency response, and security requirements; verification of equipment configuration and construction quality, plus prompt reporting and correction of deficiencies and a thorough design control process to maintain conformance.

Best practice

- A quality assurance programme designed and implemented by trained personnel should be in place in each supply chain organisation.
- All managers and personnel in supply chain companies should understand how their work contributes to the effective and safe delivery of new nuclear plants.
- All parties to the supply chain must fully understand and implement agreed processes for Inspections, Tests, Analysis and Acceptance Criteria (ITAAC).

9. Personnel safety is highly valued

The safety of all employees is a high priority and should receive constant scrutiny. Through organisational and individual efforts, employees must have confidence that they will leave the site each day without injury. A strong personnel safety programme will address physical conditions at the site and individual behaviours, which combine to minimise personal risk.

Best practice

- All personnel must understand the requirement to take responsibility for their own safety and the safety of others.
- All projects should develop and monitor sets of leading indicators for safety, such as the percentage of personnel receiving safety refresher training, safety observations made in a period, safety communication briefings provided in a period, plus safety walks and interventions made by management or supervisors in a period.
- Managers and supervisors must ensure that personnel have the training, tools and equipment required for the creation and maintenance of a safe working environment.
- Planning must be in place for activities identified as carrying any risk of injury to individuals or the environment.

Recommendation 5

An agreed industry-wide framework for industrial safety should be developed covering expectations, rules, rewards and consequences to ensure consistent, predictable first-class safety performance on all projects. Cognisance should be taken of the advice given by HSE, RoSPA, IOSH and other similar bodies (see page 18 for definitions).

10. The plant is built as designed

Personnel should be systematic and rigorous in building the plant as designed. Decisions regarding deviations from design or specifications, as well as any changes in design margins, need to be made carefully, with involvement of the design authority. Managers and supervisors must understand the expectation, when faced with unexpected or uncertain conditions, to take actions that preclude unauthorised changes, deficient construction quality, or risk to workers. When faced with unusual or uncertain conditions, workers should stop and seek clarification before proceeding. Senior leaders should support and reinforce conservative decision-making.

Best practice

- Following the principles established through the Generic Design Assessment (GDA), the UK programme will deliver facilities based upon accepted generic designs. Site specific variations should be the exception and managed by change control.
- Variations during manufacture or construction should be carefully considered; their impact to the Generic Design understood and managed by change control.
- Personnel should not proceed if uncertain. In these circumstances clarification must always be sought.

Recommendation 6

If design changes are believed to be absolutely necessary, a formal system must be used to evaluate and sanction deviations from the original design, with appropriate oversight, record keeping and communications arrangements.

11. Deviations and concerns are identified, communicated and resolved

Personnel should be required to report issues that can have an adverse effect on construction quality or personnel safety. Such reports are highly valued and are recognised as a very important part of achieving success. Each issue must be resolved in a timely manner commensurate with its importance to quality and safety and resolution is communicated to those who raised the issue. The process should support and positively reinforce efficient upward communication of problems and downward communication of resolutions.

Best practice

- All companies working in the nuclear industry should recognise the benefits of learning from operational experience gained both within and outside their own organisations and commit to addressing learning points.
- Companies should foster a 'just' culture, which encourages workers to report safety concerns and errors[9].
- All safety concerns and deviations from expected processes and deliverables should be reviewed and the response tracked to satisfactory completion.
- In particular, safety incidents and near misses should be investigated thoroughly to understand the root cause and findings shared between all interested parties, including external bodies such as regulators and contractors.
- The use of appropriate performance indicators (both leading and lagging) should also be considered to monitor safety culture and capture longer term systemic changes in safety culture performance. The aim of such performance measures should be to enable companies to implement improvements prior to any degradation in safety culture being a precursor to an actual event.

Recommendation 7

Companies should put in place processes to learn from and act on, informed by operational experience gained both within their own organisations and elsewhere.

Recommendation 8

For each project, a just and open reporting system should be put in place, its use publicised, reports investigated and the overall system monitored.

12. The transition to plant operation is started early

Successful handover of systems, structures, and components, and of the completed plant for safe and reliable operation, are the result of a well-planned handover process, a fully functional and qualified operating plant staff and effective implementation of operational processes. Plant operations, maintenance, and engineering personnel are engaged during the construction phase in advance of handover activities, and therefore should establish plant familiarity and ownership of acceptance by testing results and equipment maintenance, as well as ensuring compliance with design requirements.

Best practice

- Operational posts and processes should be defined and populated as early as possible with shadow working in place, with a view to enable plant operational issues to be identified and resolved as soon as possible.
- A control room simulator should be in place at an early date to enable operators to conduct pre-start up and start up activities.
- A plan to manage the shift from construction through commissioning to operation should be in place at an early stage. The plan should acknowledge the change in mindset required by the operating organisation as it takes on responsibility for protecting the nuclear core and maintaining high operational standards required in a nuclear plant.

13. Conclusions

The key principles of Best Practice set out above describe the key activities that will help to deliver a strong nuclear safety culture. The eight recommendations set out additional activities that will help successful delivery at both project and fleet level.

Developing a robust nuclear safety culture is a key element to supporting successful delivery of a fleet of new low carbon nuclear power stations. This will require highly focused leadership, development of a highly skilled and motivated workforce and strong supporting processes at all levels of the delivery supply chain.

A culture should be encouraged to ensure individuals feel able to be open about any lack of competence or excessive pressure for the task or decision on hand.

Abbreviations and acronyms

HSE	Health and Safety Executive
HuP	Human Performance
IAEA	International Atomic Energy Agency
INPO	Institute of Nuclear Power Operations
INSAG	Internal Nuclear Security Advisory Group
ITAAC	Inspections, Tests, Analysis and Acceptance Criteria
NSA	National Skills Academy
ONR	Office for Nuclear Regulation
RoSPA	Royal Society for the Prevention of Accidents
SQEP	Suitably Qualified and Experienced Person
WANO	World Association of Nuclear Operators

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Engineering the Future:

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We provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy.

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