Legacy Facilities, Managing Through Life Safety

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INTRODUCTION

Dounreay, in the far north of Scotland, was the site of the UK's fast reactor development programme until the early 1990's, when a Government decision was made to cease further fast reactor development work; following this there was a programme of diversification during the 1990's where commercial work was sought until a decision to decommission the site was taken in 1998.

The Dounreay site is located on a former military airfield, adjacent to the far north coast of Scotland. Construction of a Materials Test Reactor (MTR), the Dounreay Fast Reactor (DFR, 15 MW(e)) and the associated fuel cycle facilities, waste plants and site infrastructure (drains, electrics etc) commenced in the early 1950's. DFR was used to successfully demonstrate the viability of fast reactor technology and to optimise the design of fuel until its closure in 1977. The Fuel Cycle Area (FCA) was built at the same time and consists of two reprocessing plants, numerous solid waste stores, liquid waste stores and associated experimental and laboratory facilities. The Prototype Fast Reactor (PFR, 250 MW(e)) was constructed during the early 1970's to demonstrate the technology at an industrial scale, and at the same time some of the FCA plants were upgraded to enable PFR fuel to be reprocessed.

This paper considers the challenges associated with decommissioning legacy facilities using real examples from the site's ongoing decommissioning programme.

EARLY DESIGN CONSIDERATIONS

The early fuel cycle plants at Dounreay were constructed using the design codes and engineering standards that prevailed at the time. Techniques and components originally developed by the shipbuilding industry were used extensively in the construction of several of the early plants at Dounreay, particularly DFR – hence the expression "built like a battleship".

Ageing and the effects of radiation on materials were given some consideration at the design stage but there was no concept of design substantiation or safety cases as we now know them, rather a rudimentary reference was made to materials choice, pressure withstand etc; large design margins were used to mitigate against uncertainties. The understanding of criticality and radiological protection was reasonably well developed and was included as part of the design process, however little thought was given to waste management considerations and the design process did not take account of how the plant would eventually be decommissioned.

During their lifetime, the effect of individual modifications to the original plant design was given detailed consideration, but the cumulative effect of modifications was not always fully considered and the standard of maintaining and updating as-built drawings and operational records was generally poor. Also, details of incidents such as leakage of contamination were not always well documented, which necessitates a precautionary approach to be taken during decommissioning.

DEVELOPMENT OF SAFETY CASES

UKAEA sites were not originally subject to independent regulation on the grounds of national security and crown immunity, they were instead regulated internally by a central safety directorate. However as a result of the changing nature of UKAEA's mission it was decided by HM Government that from 1990 UKAEA sites would need to meet the requirements of the Nuclear Installations Act 1965 and be independently regulated by the Nuclear Installations Inspectorate (NII) on behalf of the Health and Safety Executive. In the UK this entails the granting of a Site Licence which contains a set of 36 licence conditions that the site operator is required to meet – these conditions are non-prescriptive and the onus is on the licensee to put in place a set of management arrangements and systems to satisfy them.

NII Licence Condition 14 (Safety Documentation) places a requirement on licensees to produce and maintain safety cases consisting of documentation to justify safety during the design, construction, manufacture, commissioning, operating and decommissioning phases of the installation. Licence Condition 15 (Periodic Review) requires these safety cases to be subject to periodic and systematic review, and there are further licence conditions dealing with plant modifications and new plant design.

During the late 1980's the first generation of safety cases was produced for the fuel cycle plants at Dounreay in anticipation of them being subject to NII regulation. These safety cases were written against a tight deadline and used a probabilistic approach to demonstrate that risks presented by the plant were tolerable (i.e. less than "one in a million"). If this case could not be made, then modifications were made to the plant to reduce the risk to a tolerable level. Experience worldwide has since shown that this approach does not, on its own, prevent low probability/ high consequence events from occurring.

INTRODUCTION OF "MODERN STANDARD" SAFETY CASES

During the 1990's the mission of UKAEA changed and there was a programme of downsizing, divestment and the increased use of contractors as commercial work was sought to replace the previous government-funded fast reactor development work; at the same time, a number of redundant FCA plants were taken out of service and placed under a minimal "care and maintenance" regime pending their eventual decommissioning, as funding for decommissioning work was limited. This was a period where there was a lot of change happening at Dounreay, which caused the NII to become increasingly concerned over the material condition of the site and the level of competence of the licensee to manage safety. Following a loss of electrical power incident and an audit of the site in 1998, NII issued a "Direction" that halted all operations in the Fuel Cycle Area pending completion of the actions agreed to address these issues. This is one of the few cases in the UK when the NII has issued such a Direction, which reflects their level of concern at that time.

As part of its response to the NII safety audit, UKAEA was required to subject each of the FCA plant safety cases to periodic review and to seek re-approval before operations in that plant could resume. As there were shortcomings in the original safety cases, and best practice in safety case methodology had moved on during the 1990's, it was in effect necessary to start again from scratch.

The new generation of safety cases used a more deterministic approach with far greater emphasis on engineering considerations. In the case of existing plant, there was a requirement to include retrospective substantiation of the design, which included a review of the original design codes and consideration of the effects of aging on safety-significant systems. If shortcomings against modern standards were identified then an associated series of "reasonably practicable" plant improvements/ enhancements was defined to bridge the gap. In the case of some plants this approach showed that it was either not possible, not economic or not ALARP to bring the plant up to an acceptable safety standard; neither was it possible to remove, in the short term, the hazard present in that facility. In some instances, this led to a decision not to seek to resume operations and the plant was closed, but the hazard then remains until it is addressed during decommissioning. In several instances the hazard is as prevalent post shut-down as it was during operations, unlike the defuelling of a reactor where the major potential hazard is progressively removed.

APPLYING ENGINEERING SUBSTANTIATION TO EXISTING PLANT

For new plants, design substantiation is addressed from the outset as a means of ensuring that the plant is designed and built to the appropriate standard, taking into account the foreseeable effect of plant usage on the validity of that design. An operating envelope is set, a maintenance regime is defined to preserve the original design intent and arrangements are put in place for managing and controlling plant modifications.

The practicalities are much less straightforward when applying this concept to existing nuclear facilities, particularly those that were constructed several decades earlier. For many reasons, retrospective engineering substantiation can never be as effective as design substantiation and a degree of pragmatism is required to reach a sensible outcome. Whilst it is tempting for safety case writers, design engineers and regulators to seek to bring the plant up to today's standards, re-engineering existing plant is rarely straightforward, is always expensive and can entail not inconsiderable risks in itself. It is then necessary to determine which modifications and upgrades are reasonably practicable, taking into account the projected operational lifetime of the plant and the nature of the hazards – and agreeing on what is reasonably practicable entails a degree of subjectivity which can lead to some interesting discussions between operators and regulators.

For facilities that are already closed, there are other factors that come into play. Specifically, there is a need to make decisions on the extent of upgrades that need to be made before decommissioning work can commence. In doing this it has to be recognised that the funding available from government for site decommissioning programmes is often capped, so that in a given year money can either be spent on upgrades or on reducing hazards by decommissioning the plant using the existing infrastructure.

Practical experience at Dounreay has showed that in the early years after the NII Direction and audit of 1998, there are examples where too much emphasis was placed on upgrading plants having short remaining operational lifetimes rather than focusing on completing the operational programme and decommissioning the plant. This is much more evident with the benefit of hindsight than it was at the time, and is understandable in the context of the climate that prevailed at Dounreay at that time.

Probably the best example of this is the plant that was used to fabricate fuel elements for Materials Test Reactors. The plant itself was some forty years old, and only had a two year operational programme to complete before it was due to close and be decommissioned. The gloveboxes that formed the primary containment were in good condition and there was a functional filtered extract system, however the plant infrastructure did not meet modern standards. Following development of the new safety case, decisions were taken to replace parts of the electrical distribution system that contained vulcanised rubber insulation wiring, the criticality incident detection system was upgraded and the ventilation system underwent a significant modernisation programme to meet current best practice; this work took over two years to complete, longer than the remaining plant operational lifetime. Once operations finished, the plant was decommissioned in two years!

One shortcoming of using just the safety case as the basis for applying engineering substantiation to identify shortcomings/define improvements is that systems that do not fulfil a safety function do not come within the scope. This has led to some systems that fulfil an environmental or operational function being neglected, which became a cause of concern to SEPA, the site's environmental regulator. Environmental support files have since been produced for each plant in order to address this shortcoming; these define the systems that are essential in order to meet the requirements of the site's environmental authorisations and have been used as the basis for defining environmental improvement programmes. As an example, this showed that many of the Site's statutory sampling/monitoring systems were no longer meeting availability targets and as a result an upgrade programme was undertaken.

PRACTICAL EXPERIENCE OF AGEING EFFECTS AT DOUNREAY

Building Structures

Most of the FCA plants are constructed from a steel framework with outer cladding panels of corrugated steel or asbestos. Over the years much of the original cladding and roofing has been replaced as a result of ageing and weather damage. The structural steelwork has generally remained in good condition, an exception being the DFR engineering support building where widespread corrosion was found on the diagonal bracing as a result of water ingress over a long period. The ability to withstand an earthquake was not a consideration when most of the FCA plants were designed.

When applying substantiation retrospectively there is now a regulatory requirement to consider seismic response, taking into account the risks from the facility. Fortunately Dounreay is in a geologically stable area and in most cases it has been possible to either meet the 10,000 year design base earthquake criterion (0.14g peak acceleration) or else to make a consequence-based argument that a lower return frequency is applicable.

Shielded cells

Although some of the fuel cycle plants at Dounreay are now approaching fifty years of age, in most cases the primary containment has survived well. Shielded cells and cave lines are constructed from reinforced concrete and structural surveys have shown that they remain in good condition. Visibility into the cells was provided by large windows which used zinc bromide contained inside glass tanks as shielding, with an inner, separate layer of thick glass ("crash glass") to provide protection against mechanical damage. The windows in the former PFR fuel reprocessing plant have been subject to very high levels of radiation throughout their lifetime which has resulted in crazing of the inner glass, reducing visibility. Within the last ten years several of these windows have developed small leaks, probably as a result of building settlement combined with the effects of ageing on the sealant at the tank joints. This has necessitated the replacement of several windows with new ones manufactured from blocks of solid leaded glass, a complex operation costing around £500k per window.

Liquor Storage Tanks

In 2006, during a routine survey, around 5 litres of liquor was observed in a drip tray and on the floor below two small liquor storage tanks inside a shielded cell. The tanks were manufactured from 304L stainless steel and had contained dissolved high burn-up PFR fuel in nitric acid. The tanks had a drain valve and connecting pipework at their base. The drain valves are a three piece ball valve, socket welded with two sets of viton seals and o-rings. An investigation has shown that the most likely cause of the leakage is failed seals within the ball valve allowing liquor to pass through coupled with a failed weld allowing liquor to escape from the pipe work. The liquors have subsequently been encapsulated in cement.

In 2007, again during a routine survey, a small quantity of liquid and a crystalline deposit was noticed in a drip tray below a slab tank containing uranium oxide (U03) in an area that is normally inaccessible. The source of this was found to be a leak from a flanged rodding/inspection point, which has subsequently been replaced by an all-welded joint.

In both cases the fissile liquors had been stored in tanks for an extended period pending the availability of new conditioning plant and leakage had occurred from joints rather than from the tanks themselves, probably as a result of the joints drying out and shrinking, highlighting the need to eliminate such joints where possible and showing the value of routine surveys.

Electrical Issues

The Site's 11kV high voltage electrical distribution system was commissioned in 1956 and over the past decade the rate of failure has increased due to the effects of ageing. Several failures of cable joints have occurred at locations where the original system has been extended or repaired and a number of 11kV/415V distribution transformers have failed, one due to explosive failure of the associated HV cable box. The original air-break and oil filled switchgear has also become increasingly unreliable.

The Site has embarked upon a progressive upgrade programme to install modern vacuum circuit breakers, either as retrofit trucks or for those nodes of the network having a long projected lifetime, complete replacement of the switchboard. More recently a major review has shown that the system is now oversized for the site as presently configured and is thus expensive to maintain, and for this reason a project has been defined to reconfigure the entire distribution system to meet future needs.

Vulcanised rubber insulated wiring was used extensively for in-building low voltage electrical distribution. With time, this type of insulation becomes hard and eventually brittle as a result of ageing effects and is prone to failure, particularly when disturbed. As a result of this, a programme of rewiring has been undertaken in those facilities which have a long remaining lifetime. In the case of facilities which are already undergoing decommissioning then VRI wiring has generally been retained, subjected to an enhanced risk based inspection regime, and only replaced on failure.
For plants with a lot of redundant wiring, experience has shown that there are safety and cost benefits in installing a completely new, discrete distribution system to feed the equipment that is necessary for decommissioning and to isolate the legacy installation.

Instrumentation
The design of instrumentation and control systems has gone through several evolutions since the site was constructed, with the newer systems being much more reliable and easier to maintain. As a result, most of the original instrumentation has been replaced, sometimes on several occasions, as spares become increasingly difficult to obtain.

Human Factors
The raffinate storage facility at Dounreay will remain in service for at least another ten years until all of the stored liquors have been conditioned. Since this plant was first built it has been extended several times by the addition of new underground storage tanks and the raffinate transfer system became ever more complicated. Following two instances when raffinate was incorrectly routed a review by human factors experts showed that the plant control room mimics had become increasingly difficult to understand and the potential for human error was high. As a result, a new control room has been installed using computer consoles rather than large plant mimics, and improved instrumentation has been added to show the position of diverters. At the same time it was decided to use this control room as a central point for responding to alarms from other FCA plants during silent hours, enabling other local control rooms to be left unmanned and thereby reducing surveillance costs.

Contamination spread/legacy issues
During a planned survey of the below ground non-active drainage system in the vicinity of the redundant liquid effluent settling pits, radioactive contamination was found on a swab taken from inside a drainage inspection manhole. As this is a part of the site where there is known to be the potential for historic contamination to be present the risk assessment and method statement for doing the work took this into account. It has not been possible to establish with certainty the source of the material, although it was probably as a result of a historic spill in the vicinity of the effluent pits, carried to the manhole during a localised flash flood at Dounreay in autumn 2006.

This is one of numerous examples at Dounreay where radioactive contamination has been found in places where it should not be present. Whilst significant incidents are recorded in histories /archives, relatively small events with localised effects are often either not recorded or knowledge of them is not readily accessible. Realistically, the only way to cater for this is to adopt a conservative approach during decommissioning and land remediation work and plan for the unexpected until surveys have proved otherwise.

CONCLUSIONS

Experience in managing and decommissioning legacy facilities at Dounreay has shown that the primary containment systems such as glove-boxes, cells and vessels have stood the test of time well. Considering their age, this is a testament to the high quality of engineering of the 1950s/1960s. The associated infrastructure and systems have, however, suffered more from the effect of ageing, obsolescence and keeping pace with new standards and codes of practice. The advent of modern standard safety cases with the emphasis on engineering substantiation has provided a systematic methodology for determining whether such systems can safely remain in service or whether upgrade or replacement is needed.

It is inevitable that as nuclear plants age it will become progressively more difficult and hence expensive to meet contemporary standards of safety and environmental performance. It follows that adequate funds need to be made available to deal with legacy facilities in a timely manner in order to maintain high levels of safety and to minimise overall programme costs.