AGEING PROCESSES AND THEIR INFLUENCE ON SAFETY AND PERFORMANCE AT WYLFA

SUMMARY

This Review considers how ageing of the Magnox nuclear power station at Wylfa could be expected to influence performance and safety.

For the Wylfa reactors, the ageing processes apply to a diverse range of different materials and components. Some of these ageing processes are relatively straightforward and well understood; others are complex and have yet to be fully understood. As time passes, it becomes increasingly more difficult, if not more unreliable, to predict the types of age-related problems that are likely to be encountered now and in future years. In fact, as the reactors move well beyond the 20 to 25 year design life originally specified, a greater reliance has to be placed on inspection of in-reactor materials and components and, from this, the ageing effects deduced. The problem here is that the Wylfa reactors do not include features that enable ready access to all of the components susceptible to ageing.

Even once identified, it may be difficult to establish how the age-related degradations might apply to the plant overall during normal operation and, particularly, when the plant is under fault conditions. Indeed, ageing may introduce aspects of plant performance and response that were unforeseen by the plant's original designers and for which they provided no contingency.

Three specific ageing effects are examined. These are the cracking of the reactor pressure vessel steel liner closure plates in the vicinity of the vessel wall penetrations carrying the superheated steam tailpipes from each boiler; the corrosion of the internal steelwork of the reactors, particularly the core restraint garter; and the radiolytic oxidation (corrosion) or loss of volume of the graphite core. The Review examines how each of these ageing effects might contribute to reactor fault conditions, particularly where the simultaneous failure of a group of superheater tailpipes results in high pressure differentials within the reactor and which subjects the graphite core and its restraint system to excessive loading.

Excessive loading of the core structures could result in core misalignment. Once the core has been misaligned or damaged, the circumstances that could lead to localised overheating of fuel channels are examined in terms of the effectiveness of the primary circuit cooling plant to extract both the post trip decay heat and the release of heat from stored (Wigner) energy in the graphite core. For this case the detrimental influence of the steady build-up of carbonaceous dust over past years of operation, associated with graphite radiolysis, accumulating in and partially blocking the secondary and cross flow passages of the core is considered to contribute to localised overheating of the core. For the case where the pressure vessel containment has failed, for which the decay heat extraction must be completed with an open primary circuit with the core immersed in air, the additional contribution of Wigner energy, the increased chemical reactivity (burning) of the graphite and carbon dust are all considered to contribute to a deteriorating thermal situation,

resulting in fuel temperatures sufficiently high to prompt magnesium clad and fuel ignition.

Importantly, the ageing of critical and essentially non-serviceable components within the reactors at Wylfa determines how these components perform under fault conditions. The original designers of Wylfa did not foresee and account for this ageing so the outcome of the so called *Design Basis Accident* was based on certain components surviving unscathed during the then nominated worst case fault conditions. There is now considerable doubt that the graphite core could survive both rapid reactor depressurisation and steam intrusion fault conditions so the *Design Basis Accident* and its limited consequences, both of which continue to be adopted by the present operator and the regulator the Nuclear Installations Inspectorate (NII), are no longer valid.

Both reactors at Wylfa have been shut down since the discovery of the closure weld cracking in April 2000. Because the consequences of a single closure weld failure could present a *beyond design basis event* and trigger failure of the weakened core restraint system and distortion of the graphite core, BNFL Magnox's strategy of returning the reactors to power with an interim fix (see footnote 28) whilst the closure weld studies are underway, should be considered unacceptable because it continues to rely upon the integrity of the core restraint and core assembly system which, for the aged reactors at Wylfa cannot be stated with certainty.

The fact that there has been little modification to the fault conditions that make up the *Design Basis Accident* is particularly surprising since the NII has known of the deteriorating ageing conditions within the reactors since a year before Wylfa was first commissioned.

This is because two years before Wylfa was scheduled to start its nuclear reactors it was discovered that the steelwork internals of the other Magnox reactors, particularly at Dungeness and Bradwell, were corroding at an unacceptably high rate. In late 1970, less than year before criticality of the first of Wylfa's reactors, it was decided, at Cabinet Office level, that it would not be economic to rip out and replace the internal steelwork to inhibit corrosion but, instead and to slow the corrosion rate, the reactors would be temperature derated and the quality of the coolant gas modified. The effect of this latter modification was not fully understood at the time, particularly how the rate of graphite radiolysis increased markedly at the higher gas pressure of the Wylfa reactor circuits. The outcome was that, at the cost of slowing the steel corrosion rate, there resulted an increased rate of radiolytic loss (oxidation) of the graphite and a structural weakening of the graphite core assembly, both of which have significant safety implications.

The role of the NII is of interest in that it was criticised at the time of the discovery for its relationship with the then operator the CEGB (Central Electricity Generating Board) and that the problem had not been recognised as soon as it might have been. The NII has never acknowledged that the steel-graphite corrosion trade-off at Wylfa arose from its own recommendations of 1970 nor, in its reporting of subsequent years, has it indicated that the two processes are linked. Moreover, the NII has been slow to acknowledge the importance of loss of strength of the reactor cores due to graphite radiolysis linked to the deteriorating strength of the restraint garter. It was not until 1995 that it required the introduction of greater diversity in the reactor shut-down systems to cater for the greater potential of core distortion under its weakened condition, and as late as 1998 it noted that changes to material properties of the core at Oldbury power station were "subject to uncertainty", from which it might be assumed that the safety case for the core could never have been rigorously examined. The now abandoned proposal to deploy the enriched MagRox fuel at Wylfa, which was intended to compensate for the reduction in thermal moderation linked to graphite loss, also suggests that the NII had failed to grasp the extent by which this ageing process had depleted the moderating, and hence the strength of the reactor core.

In effect, when in 1971/2 the reactors at Wylfa were first brought into operation, there was considerable doubt and uncertainty about the future performance of crucial, in-reactor components as these aged. Put another way, if the basis of the design was that the reactor would survive the *Design Basis Accident*, then departure from the original design by unforeseen ageing processes would invalidate the *Design Basis Accident.*

Uniquely, Wylfa was a nuclear plant that was to be licensed in the knowledge that its safety margins would deteriorate over time in a manner and to an extent not foreseen by its designers. Thirty years after the commissioning of these reactors, the NII continues to express doubts as to the actual condition of the graphite core and its restraint garter and, in the view of the very limited inspection access, it continues to rely upon the operator to substantiate the safety case with further information drawn from ongoing studies. In this important respect the regulatory regime at Wylfa seems to be reactive rather than prescriptive.

Why the NII has chosen never to declare that it knew, from the onset, that there were serious ageing problems underway at Wylfa is baffling. The NII's Long Term Safety Review for Wylfa (1995) reports both steel and graphite corrosion in a matter of fact way, implying that the steel oxidation is 'well understood and managed". This is entirely in contrast with its startling discovery in 1969-70, which called for a decision on whether to strip out the incorrectly specified steels from both Wylfa reactors before their respective start ups which would render the reactors radioactive thus precluding any major modifications in future years. We now know that the reactors were started without modification and that this decision, taken at the highest political level, was in line with the NII's recommendation of that time.

Finally, the fact that the NII not only knew but, indeed, was instrumental in the 1970 decision to put Wylfa into service without modification puts a whole new light on the nuclear safety regulatory regime as then practised in the UK.

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