Radioactive Waste Management Directorate

Packaging of B38 Retrieved wastes at SDP at Sellafield – Response to Action Points for Conceptual Stage LoC (Conceptual stage)

Summary of Assessment Report

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Background

In 2005 British Nuclear Group Sellafield Ltd (BNGSL) made Conceptual stage proposals for retrieving wastes from the B38 Compartments at Sellafield and packaging for interim storage, long-term management and eventual disposal. Nirex undertook a detailed assessment of the proposals, and in March 2006 provided an Assessment Report and covering letter in response. It was concluded that in most respects the waste packages to be manufactured by the proposed Silos Direct encapsulation Plant (SDP) offered good promise and, subject to the satisfactory outcome of development work, should be able to meet disposability criteria as defined by Nirex packaging standards. However, three specific issues required resolution before a Conceptual stage Letter of Compliance could be issued.

At the time of previous interactions, active consideration was being given to two alternative packaging options:

- Option A – containerisation and high force compaction of the waste, and grouting of the compacted products into 500-litre drums;
- Option D – tumble mixing of the waste with cement grout and packaging into a standard 3m^3 Box.

In both options some large waste items would arise, which would be directly encapsulated in a 3m^3 Box using cement grout. During early 2006 BNGSL, in association with a broad set of stakeholders, undertook a Best Practicable Environmental Options study and used Multi-Attribute Decision Analysis techniques to de-select to a single preferred packaging process and package, Option D – the tumble mixed waste package.

Since that time BNGSL has also undertaken a considerable body of work towards addressing the three residual Conceptual stage issues raised by the Nirex assessment. A further submission was made to Nirex in 2006 and an assessment undertaken. This has led to production of this Assessment Report. The key findings are summarised below

Summary of Issues

Issue 1 - Waste Container

BNGSL are pursuing a square cornered box design based on the 'compact stillage' plan dimension of 1665mm. Nirex noted that the existing standard dimension for the 3m^3 Box of 1720mm would provide additional conditioned waste volume and maintain compliance with Nirex standards, but BNGSL advised that there are cost and programme drivers which dictate that the box should maintain consistency with existing stillages and facilities on the Sellafield site. Nirex has decided to revise its 3m^3 Box standard, which will now cover square cornered boxes with common stacking post/lifting points and square dimensions that fall within the plan dimension of 1720mm. This new standard will cover the dimensions of the

Sellafield Three Cubic Metre ILW Product Container, and hence the non-compliance is removed and the outstanding issue considered closed.

Nirex would now expect continued informal and formal dialogue with BNGSL as the details of the box design are progressed. As a risk mitigation measure it is recommended that once detailed box design, prototype manufacture and testing is complete, formal endorsement is sought prior to placement of contracts for large-scale manufacture.

Issue 2 - Physical Protection

In March 2006 there was concern that SDP products could require a higher level of physical protection than currently provided for within the Nirex disposal concept. However, Nirex has subsequently concluded that the specific choice of Option D, the tumble-mixed product, will result in a product where the nuclear material will be dispersed in the wasteform, either by the nature of much of the waste (sludge) or by the action of the tumble mixer, breaking up the majority of any enclosed cans. As a result, it is anticipated that the existing Phased Geological Repository Concept (PGRC) Security Plan, based on Category III physical protection standards, will cover the proposed SDP products. The outstanding issue regarding physical protection is therefore considered closed.

Issue 3 - Data Recording Methods

In response to the remaining issue associated with derivation and assignment of inventory and data records, BNGSL have submitted a series of reports covering data recording proposals, and have also provided other information, including details of radionuclide inventory data and corroboration and control proposals.

Fingerprints

BNGSL propose to generate 'fingerprints' for each broad waste type: 'swarf' (fuel, cladding and associated fuel furniture), or Miscellaneous Beta-Gamma Waste (MBGW). These would be generated from an analysis of the materials expected to be present in each Compartment, based upon records, which have been enhanced and are themselves based on measurement in a number of key instances.

Best Estimate Inventory

Wastes would be defined as swarf, MBGW or mixed waste (swarf/MBGW) during retrieval at B38, and the fingerprints would be scaled using some measured parameter (e.g. volume) and used to create a package inventory. This would be the best estimate package inventory.

The method of deriving the fingerprint for swarf has already been developed in detail, and is based on a combination of historical records (e.g. fuel burn-up records and uranium carryover in wastes tipped to the Compartments) combined with FISPIN calculations. Nirex considers these to be broadly acceptable, although further work is required, in particular on the method to be applied for Compartments 19 to 22, due to the partial removal of stored wastes which has already occurred.

We recognise that much work has been undertaken to retrieve information from records on MBGW. The work required to generate MBGW fingerprints has not yet been undertaken, and would represent a significant task as the project progresses.

At SDP it is expected that a small proportion of the wastes, the oversize MBGW, will be retained on a 350mm grid. Much of this will be contaminated with sludge. The proposals for oversize data recording are not well developed at this stage. These will need to be described in detail as part of finalised data recording proposals, and aspects such as how sludge carryover on oversize items will be assigned will need to be addressed. In principle, it should be possible to generate a package inventory using information linked to an operator "pick list" of oversize items, with estimated contributions from sludge carryover. For MBGW which has passed through the screen to the undersize stream, BNGSL have developed proposals for inventory assignment but will need to set these down in further detail.

Limiting Inventory

It is also proposed to generate a limiting, or maximum, package inventory for undersize and for oversize wastes. The contents of the filled transfer skip would be limited by weight to 2,750kg. This limit is derived from the skip hoist weight limit. The SDP project is assuming that skips sent to SDP would contain at least 200kg of cover water, permitting a maximum waste content of 2,550kg. The limiting case inventories for undersize swarf are based on conservative calculations, for example by assuming the 2,550kg of waste per skip will comprise a mixture of corroded fuel and some water. BNGSL has illustrated this limiting inventory for Pu-239. BNGSL will need to extend this proposal to cover all other significant radionuclides associated with swarf.

There are currently no proposals to generate a limiting package inventory for MBGW. Nirex estimated a bounding inventory for common items of irradiated MBGW (e.g. steel and graphite) in 2005 for assessment purposes. BNGSL also need to generate a limiting inventory or inventories for MBGW, once a best estimate fingerprint has been generated. Nirex has given some consideration to the implications of enriched uranium and unusual items that may arise in MBGW, and believes further work is required on the records to identify and assess such unusual items. Ultimately, it is possible that quality checks will be required on manufactured packages, to cover the potential presence of any large radiation sources or materials generating significant quantities of radioactive gases, at the time of transport to a repository.

Realistic Worst-Case Inventory

BNGSL also propose to generate realistic worst-case package inventories, intended to bound the majority, but not all, waste packages. This would be based on historic records information as for the best estimate inventory, plus uncertainties. This inventory would be derived from a composite distribution of the systematic and random uncertainties which BNGSL believe affect the uranium inventory of skips. This inventory estimate has a useful function, in that it illustrates the expected frequency of packages arising below and above any given inventory. For example, it has been illustrated for swarf, that the majority of packages (e.g. 99.5%) will have an inventory of swarf-related radionuclides which are only a small fraction of the limiting case inventories. Also, the best estimate package inventory for Pu-239 for wastes arising from B38 Compartments 13 to 18 is nearly 20 times smaller than the limiting package Pu-239 inventory. Indeed, estimates of inter-package variability provided by BNGSL suggest only one package from Compartments 16 to 18, the source of the most challenging B38 wastes, would be likely to exceed a Pu-239 inventory of 5 times the best estimate package Pu-239 inventory.

Impact of Uncertainties

It should be noted that although these data recording proposals appear workable, they will result in very large uncertainties in individual package inventories. The uncertainties are a result of the nature of the waste and the packaging process, and are even larger than those which were assessed previously. The large uncertainties in package inventory implied by the limiting cases will lead to pessimistic safety assessments. The consequences of this are discussed further below.

Nirex recommends that BNGSL continues to consider whether the limiting case inventories can be reduced, either by improving process control at B38 or SDP to restrict potential fuel loadings per skip, by re-visiting the conservatisms within the methodology used to generate the limiting inventory on a Compartment by Compartment basis, and by exploring corroboration techniques.

Corroboration

Some measures for package inventory corroboration are being explored by BNGSL, and commitment to continue this work is welcomed. At this stage, corroboration is proposed mainly to rely on gamma dose rate measurements on the B38 retrieval machine grabs, although there are doubts within BNGSL about the likelihood of success. BNGSL are urged to continue to pursue development of inventory corroboration proposals, particularly with the aim of identifying any unusually high inventory waste packages. This may enable limiting case inventories to be reduced after packaging is complete and open up specific management options for a minority of problematic packages.

Safety Assessments

The present Assessment has tested the waste package inventories (including the limiting case, extended to consider all radionuclides of significance) against waste packaging standards and safety assessments that underpin the Phased Geological Repository Concept. It is concluded that although the radionuclide inventory of most SDP waste packages should not challenge the PGRC, the potential for some more extreme and challenging SDP package inventories cannot be excluded. The criteria which could be exceeded are the:

- $3m^3$ package limit on total activity of 105 A_2 multiples at the time of transport;
- $3m^3$ package limit on heat output of 200W at the time of transport;
- fissile material limits identified in the Design Safety Report for a transport package;
- the dose limit for workers as a result of design basis operational faults;
- package limit on heat output of 150W at the time of vault backfilling;
- Upper Screening Level of 2.8kg U-235 equivalent per $3m^3$ Box for the post-closure stack-collapse criticality scenario.

Transport

The first two criteria listed above, relating to limits on activity and heat output, derive from the IAEA Transport Regulations and the design basis for the Standard Waste Transport Container (SWTC). Nirex has been designing the PGRC, including the transport system, to manage ILW within an anticipated range of activities. The limiting case package inventories proposed by SDP, which may not arise in practice, exceed that previously expected of ILW and thus the existing justifications for the SWTC design.

The bounding capabilities of the SWTC have not been fully explored at this stage. For example, the regulations impose a surface temperature limit of 85ºC on Type B(U) packages if transported under ‘exclusive use’. Thermal analyses for the Re-useable Shielded Transport Container (RSTC), the forerunner to the developing SWTC, predicted an external body temperature of 57ºC at the 200W limit. For the limiting inventory the heat output at the time of transport is predicted to exceed 200W, however it would appear that some margin is available before the 85ºC temperature limit is reached. Further work would be required to establish the bounds of the SWTC’s capability with respect to surface temperature and other related aspects.

The limit on total activity is applied to Type B transport packages which have not been qualified to comply with the requirements of an ‘enhanced water immersion test’. The need to comply with this requirement was not included in the scope of the SWTC design, since it was not expected to be required for intermediate level wastes. Nevertheless, Nirex believes there are good prospects for developing the SWTC design to meet the requirements of the enhanced water immersion test if considered necessary.

Only the best estimate package inventories are expected to fall inside the generic criticality cases defined in the current Design Safety Report for the RSTC. The scenarios modelled are very conservative, intended to cover a wide range of intermediate level wastes, and do not take credit for the specific design and contents of SDP packages. Nirex believes that a criticality safety case can be made for storage of SDP packages, even at the limiting case inventory, and that the transport case need be no more restrictive. A case will need to be produced by Nirex in co-operation with BNGSL to cover SDP packages, and would require new, less conservative approaches.

Operational Safety

The Design Basis Accident analysis (DBA) undertaken in support of the assessment reported in March 2006, identified that repository workers would be subjected to unacceptable doses as a consequence of accident scenarios. The operational safety toolkit used by Nirex makes conservative bounding assumptions on accident scenarios, release fractions and exposure routes. The very high radionuclide inventory of B38 waste packages requires a more realistic analysis of accident consequences that cannot be provided using the tools that are currently available. This aspect of the assessment is under development and future updates will provide less conservative data on the consequences of fire and impact accidents in the repository. Other information relating to the design and accident performance of B38 silo waste packages is expected to be provided by British Nuclear Group as development work proceeds towards the Interim stage LoC. These factors will be taken into account when more detailed assessments are undertaken in support of future LoC stages, and it is expected by Nirex that this more detailed analysis stage will show that DBA limits can be satisfied with margins of safety.

Thermal modelling of back-filled vaults has shown that heat output equivalent to an individual $3m^3$ Box waste package producing up to approximately 150W, distributed with other packages near the average heat output of just under $1Wm^{-3}$, results in temperatures less than the long-term target for the repository of 50ºC. The predictions for SDP packages for swarf, suggest that a few packages will exceed 150W at 2090. If packages are produced that exceed the limit, the consequences may not be serious, if this can be demonstrated to be a low frequency event. Further work is necessary to address this and to develop technologies which will permit identification of waste packages with high radiogenic heat output for specific management post-manufacture.

Post-Closure Safety

Under the new approach to criticality assessments, Nirex is developing screening levels for four generic fissile material groupings: natural uranium, low-enriched uranium, high-enriched uranium and separated plutonium. For each waste grouping Nirex is determining upper and lower screening levels (LSL and USL) taking account, where appropriate, of radioactive decay and the time required for redistribution of fissile materials into potentially more reactive configurations within packages. The lower levels are based on conservative assumptions with regard to the likely evolution of the system post-closure, and the upper levels are based on a realistic or less pessimistic expected evolution scenario. Two types of stylised post-closure scenarios are considered, package-scale and stack-scale.

All predicted SDP package inventories fall within the Upper Screening Level for the post-closure package-scale scenario. The limiting case inventories and the realistic worst-case inventory for Compartments 13 to 18 fall outside the Upper Screening Level for the post-closure stack-collapse scenario, suggesting significant numbers of packages containing wastes from Compartments 13 to 18 could be non-compliant.

The stylised stack-collapse scenario is an extremely unlikely scenario, and may even be argued to be incredible in the future. The scenario is based on generic assumptions that do not account for the robust nature of the double-skinned annular SDP packages. More significantly, it should also be noted that only a small proportion of SDP packages

(specifically some of those arising from Compartments 13 to 18) out of the total of 10,000 SDP packages are likely to exceed the Upper Screening Level for this scenario, and thus it is very unlikely that the scenario-basis of a stack of seven packages above this level will arise in practice. It may be possible to manage packages during emplacement to ensure those arising from packaging the highest uranium content wastes, are inter-stacked with less demanding packages, for example those arising from packaging Compartments 1 to 12 wastes. Finally, the consequences of a post-closure criticality after repository closure will be less severe than during operations or transport, since direct exposure of workers or the public to radiation will not be possible. A criticality safety assessment specific to SDP packages will be required, with more consideration by Nirex of the likelihood of post-closure criticality scenarios.

Conclusions

BNGSL have made significant efforts to address concerns raised by Nirex in March 2006, in particular to develop data recording proposals and to provide estimates of likely inter-package radionuclide variability. The uncertainties in package inventory remain large, and as a consequence a number of PGRC criteria for waste transport and disposal could be breached by packages of B38 wastes packaged at SDP. The main reason why these criteria are being challenged relates to the large uncertainty in the maximum package inventories, with the consequence that these significantly exceed limiting inventories previously anticipated for intermediate level wastes.

Nirex judges that these challenges can be overcome. Nirex supports BNGSL and the SDP project, and recommends continuation of the proposed waste retrieval and packaging solution. At this time Nirex cannot issue a Conceptual stage Letter of Compliance. A Letter of Compliance would indicate that the proposed waste package would in principle be compliant with packaging standards and specifications and with the concept design and underlying safety assessments. As discussed above, there remain areas where compliance has yet to be demonstrated and further work is required to address the transport and disposal system, through a ‘due process’ of change control, to confirm that the transport and disposal system design can be modified to accommodate the proposed packages. This process may take a considerable time to complete.

It is recognised that the packaging solution proposed for these wastes may not produce the “best” waste package but the hazard presented by this legacy requires that a pragmatic solution be adopted. As described in the Assessment Report, Nirex supports BNGSL proposals for remediation of B38 and can see that the packaging proposals are heading in the direction that should enable them to meet Nirex packaging and disposability criteria. The report highlights that BNGSL need to work at reducing the limiting inventories ascribed to waste packages and develop workable corroboration techniques.