Permission for installation of equipment in the Vaporisation Facility of the Tails Management Facility

Project Assessment Report ONR-DFW-PAR-15-002
Revision 1
2 December 2015

Published 06/16

EXECUTIVE SUMMARY

Title

Permission for installation of equipment in the Vaporisation Facility of the Tails Management Facility at Capenhurst.

Permission Requested

UUK Limited has requested, under its arrangements made under Licence Condition 19, acknowledgement of receipt of the Pre-Commencement Safety Report (PCSR) for the Vaporisation Facility. The effect of this acknowledgement will be to grant permission for the installation of the equipment in the plant.

Background

The main business of Urenco UK Ltd (UUK), the holders of the nuclear site licence at Capenhurst, is the enrichment of uranium. A by-product of uranium enrichment is known as tails, depleted uranium stored as uranium hexafluoride (UF_6, or hex) in steel transport cylinders. Hex represents a potential chemotoxic and radiological hazard both to workers on the site and the public: a faulty or damaged cylinder may release gaseous UF_6, which is radioactive, and can readily form hydrogen fluoride (HF), which is highly toxic. A major new plant, the Tails Management Facility (TMF), is therefore being constructed at Capenhurst to convert these tails to an oxide of uranium, a chemical form more suitable for long-term storage.

Tails have accumulated at Capenhurst since the 1950s and there is now a stockpile of uranium in the form of hex. To bound the potential hazard, ONR and the licensee agreed a limit for this stockpile. In the short term TMF is needed to ensure that UUK can continue to comply with this limit without reducing its production of enriched uranium. Thereafter, one function of TMF will be to reduce the stockpile of hex at Capenhurst; in due course TMF is intended to perform this same chemical conversion on tails accumulated by Urenco in Germany and the Netherlands.

TMF is being constructed by, and will be operated by, Urenco Chemical Plants Ltd (UCP), a tenant on the Capenhurst nuclear licensed site.

The TMF consists of a number of interrelated facilities; in 2010-11 ONR gave permission, in the form of Licence Instruments 518, 520, 521, and 522, for both construction and installation, and construction began in 2011. By then, however, there had been extensive changes to some features of the design described in the safety cases (PCSRs). ONR and UUK therefore agreed that the permissions ONR had already given would be regarded as covering only construction, and that UUK would seek new permissions for installation, the applications being supported by new PCSRs. These were submitted in 2013–14. Only the three facilities in the highest safety category (broadly those in which some faults had radiological consequences to operators estimated as more than 1mSv) required a new permission.

ONR chose not to reassess the PCSRs for two of these; accordingly, ONR issued LIs 534 and 535 in 2014, giving permission for installation to commence in those facilities.

Assessment and inspection work carried out by ONR in consideration of this request

ONR decided to conduct an assessment of the Vaporisation and Deconversion Facilities because: they contained the dominant radiological and chemotoxic faults; the Deconversion

Facility was to use hydrogen to drive the oxidation reaction, a technique used at only one other facility in the UK that introduces additional deflagration faults.

The management of hydrogen within the Deconversion Facility was identified by ONR as entailing significant potential faults. In particular it was clear that the choice to operate the kilns with flammable concentrations of hydrogen would need a strong justification. ONR assessors visited the Springfields site to determine how the licensee there ensured the safety of its kilns, particularly as regards hydrogen.

In the course of the assessment ONR held a number of meetings with the licensee on specific topics; they were often attended by representatives of the Environment Agency and the Health and Safety Executive. Of particular note were early discussions on the proposed content of operating instructions and on Leadership and Management for Safety, which identified issues with UCP's intended staffing structure.

Early assessments of the new PCSRs led ONR to conclude that some central elements of the design, engineering substantiation, and safety assessment were still incomplete and supporting documents were not available. General findings from the ONR assessment work were that the new PCSRs were inadequate, and that the primary reason for this was that the arrangements for the production of safety documentation were inadequate in some key areas. In particular the arrangements were not aligned with some of ONR's safety assessment principles (SAPs), notably in the areas of Design Basis Accident Analysis (DBAA), the categorisation of safety functions, and the classification of safety systems. A common finding of the assessment work since 2013, albeit one reached with difficulty, has been that TMF stands in a better position relative to the SAPs than can be deduced from the PCSRs.

Six assessment reports were completed in support of this request; they are summarised in the report.

Matters arising from ONR's work

These assessments raised a number of issues which extend beyond the principal purpose of this report. They are:

- the delays and extra costs attributable to features of the design being uncertain even when the second set of PCSRs was submitted, and the underpinning documentation therefore being incomplete
- the arrangements for the production and assessment of safety documentation not being compatible with the SAPs, particularly for the assessment and treatment of DBAA (which contributed to ONR initially concluding that there was a shortfall in the engineering associated with TMF and an over-reliance on administrative controls); also, the radiological consequences of faults being expressed in a way that lead initially to significant overestimates and necessitated the completion by the licensee of an explanatory paper
- the SAPs not providing clear guidance on the analysis of faults that have both radiological and chemotoxic consequences
- ONR's assessment having implications for similar autoclaves both at Capenhurst and Springfields.

Work has already begun aimed at addressing the wider implications of these issues.

Conclusions

ONR concludes that the licensee has demonstrated that the risks associated with operation of the TMF are at least tolerable. However, for a new plant like TMF ONR would expect risks to be near the levels known in SAPs as Basic Safety Objectives.

Initially, ONR judged that risks to workers had not been reduced so far as is reasonably practicable. After much further discussion, and the submission of a paper on the need for workers to have access to the area around kilns while they are operating, ONR has accepted the arguments on this question, subject to the recommendations listed in this report.

ONR has raised a number of other regulatory issues during its assessment of the safety of TMF. These will next be set out in letters from ONR to UCP and the licensee. ONR has already stated that these will require to be addressed to ONR's satisfaction before any request for permission to commence active commissioning is made.

Recommendations

This report recommends that ONR grants the permission requested, namely to install equipment in the Vaporisation Facility associated with the Tails Management Facility at Capenhurst. In accordance with the arrangements made by the licensee under condition 19(1) attached to its nuclear site licence, this permission should be in the form of a Licence Instrument acknowledging receipt of the PCSR for the facility.

The recommendations identified during ONR's assessment process should be formally communicated to the licensee and UCP by means of letters that should follow the licence instrument. Thereafter those issues should be pursued without delay, and brought to a conclusion satisfactory to ONR before ONR grants permission for active commissioning of TMF.

Additionally, ONR should examine the records of commissioning, and the Pre-Active Commissioning Safety Reports, for the Vaporisation and Deconversion Facilities, as part of its work in deciding whether to give permission for the TMF to commence active commissioning.

OFFICIAL

LIST OF ABBREVIATIONS

ALARP	As low as reasonably practicable
BSL	Basic Safety level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
C&I	Control and Instrumentation
CHF	Cylinder Handling Facility
CIDAS	Criticality Incident Detection and Alarm System
COMAH	Control of Major Accident Hazards Regulations
COSER	Continued Operations Safety and Environmental Report
CWF	Cylinder Wash Facility
DBAA	Design Basis Accident Analysis
DJR	Design justification Report
DMF	Decontamination and Maintenance Facility
EA	Environment Agency
EC&I	Electrical, Control and Instrumentation
EMC	Electromagnetic Compatibility
ESR	Engineering Substantiation Report
ETP	Effluent Treatment Plant
FSG	Fault Sequence Group
HAZAN	Hazard Analysis
Hex	Uranium hexafluoride
HF	Hydrogen fluoride/ Hydrofluoric acid
HOW2	(Office for Nuclear Regulation) Business Management System
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ICSR	Inactive Commissioning Safety Report
LCF	Legacy Cylinder Facility
LI	Licence Instrument
LMfS	Leadership and Management for Safety
LOPA	Layers of Protection Analysis
MHSWR-99	Management of Health and Safety at Work Regulations 1999
NDA	Nuclear Decommissioning Authority
ONR	Office for Nuclear Regulation
PACSR	Pre-Active Commissioning Safety Report
PCSR	Pre-Commencement Safety Report
PPE	Personal Protective Equipment
PSA	Probabilistic Safety Assessment

PSR	Preliminary Safety Report
R2P2	Reducing Risks, Protecting People (HSE)
RGP	Relevant Good Practice
RRF	Residue Recovery Facility
SAP	Safety Assessment Principle(s) (HSE)
SFAIRP	So far as is reasonably practicable
SLOD	Significant Likelihood of Death
SSC	System, Structure and Component
Sv	sievert
TAG	(ONR) Technical Assessment Guide
TDP	Tails Deconversion Plant
TMF	Tails Management Facility
UCP	Urenco Chemical Plants Limited
UOS	Uranium Oxide Store
UUK	Urenco UK Limited

OFFICIAL

TABLE OF CONTENTS

1 PERMISSION REQUESTED

1. The licensee has requested ONR's permission to install equipment in the Vaporisation Facility associated with the Tails Management Facility. It has done so in accordance with the arrangements it has made under condition 19 attached to its nuclear site licence, the subject of that condition being the control of construction or installation of new plants. The usual form of that permission envisaged by those arrangements is an acknowledgement by ONR of the receipt of a Pre-Commencement Safety Report (PCSR) for the facility.

2. The request for permission is contained in two letters from the licensee. The original request, dated 16 October 2013 [Ref 1] was accompanied by the PCSR whose acknowledgement it requested. That letter was recently supplemented, on 26 November 2015 [Ref 2], to make clear that the permission sought does not also constitute permission to commission the facility.

2 BACKGROUND

3. The main business of Urenco UK Ltd (UUK), the holders of the nuclear site licence at Capenhurst, is the enrichment of uranium. A by-product of uranium enrichment is known as tails, depleted uranium stored as uranium hexafluoride (UF_6, or hex) in steel transport cylinders. Urenco regards tails not as waste but as a reserve of uranium, already in the chemical form required for input to the enrichment process, ready to be utilised if economic conditions become favourable.

4. However, hex represents a potential chemotoxic and radiological hazard both to workers on the site and the public: a faulty or damaged cylinder may release gaseous UF_6, which is radioactive; and can readily form hydrogen fluoride (HF), which is highly toxic.

5. A major new plant, the Tails Management Facility (TMF), is therefore being constructed at Capenhurst to convert these tails to an oxide of uranium (U_3O_8), a chemical form more suitable for long-term storage.

6. Tails have accumulated at Capenhurst since the 1950s and there is now a stockpile of uranium in the form of hex. A fixed portion of this is managed on behalf of the NDA. The other portion, now owned by UUK, is continuously augmented as a consequence of enrichment activities. To bound the potential hazard, ONR and the licensee agreed a limit for this latter portion [Ref 3]. In the short term TMF is needed to ensure that UUK can continue to comply with this limit without reducing its production of enriched uranium; thereafter, one function of TMF will be to reduce the stockpile of hex at Capenhurst.

7. Another function of TMF will be to perform this same chemical conversion on tails accumulated by Urenco in Germany and the Netherlands, with the oxide being returned to the country of origin. A subsidiary function is the preparation, for sale commercially, of the hydrofluoric acid produced by the process. TMF is being constructed in a way that allows its throughput to be increased by the installation of extra process lines.

8. TMF is being constructed by, and will be operated by, Urenco Chemical Plants Ltd (UCP), a tenant on the Capenhurst site. TMF is intended to employ technology that,

largely, is already used at the Capenhurst and Springfields sites. The design of the TMF is based on a plant in Pierrelatte, France, that has been operated by AREVA since the 1980s.

9. The TMF consists of a number of interrelated facilities:

- the Cylinder Handling Facility (CHF), where hex is received in transport cylinders (Type 48Y only) and cylinders are stored temporarily, and from where emptied cylinders are dispatched.
- the Tails Deconversion Plant (TDP), where the UF_6 is converted into U_3O_8. First, in a vaporisation plant, the solid UF_6 is heated in an autoclave and sublimes. The associated increase in pressure pushes the UF_6 vapour into a kiln where it reacts with steam and hydrogen to form U_3O_8 and by-products.
- the Hydrogen Fluoride Processing and Storage Facility, which will receive hydrofluoric acid solution from the deconversion plant, process and store it for dispatch.
- the Cylinder Wash Facility (CWF), where cylinders are washed to remove residual quantities of uranium (heels) and are certified for reuse (or sentenced as scrap).
- the Residue Recovery Facility (RRF), which will receive and treat solid and liquid arisings from the TMF (primarily from the CWF), separate recyclable materials, and immobilise or otherwise condition wastes for authorised disposal.
- the Uranium Oxide Store (UOS), which will receive, store, and dispatch the oxide, in DV70 mild-steel containers. The UOS is intended to store the UK's U_3O_8 for up to 100 years, pending either reuse of disposal to the GDF; oxide for return to Germany or Holland will be stored in the UOS temporarily, to await transport.
- the Decontamination and Maintenance Facility (DMF), which will provide these functions to all of the TMF.

10. The licensee submitted a series of Pre-Construction Safety Reports in 2009–10 [Ref 4] in support of applications for permission to construct the principal facilities and install equipment in them. ONR assessed those PCSRs, primarily focussing on the radiological controls, doses associated with the store, and control and instrumentation across TMF. Although the assessment did not identify any significant regulatory issues, ONR found that in some areas there was insufficient information to make a full judgement. In particular, the C&I report [Ref 5] concluded that, although there was no reason to withhold regulatory permission to construct and install, the licensee should be advised that, given the lack of design detail, C&I installation would entail a commercial risk: if ONR subsequently suggested changes for regulatory reasons, ONR would not take account of the costs of removing and replacing equipment when assessing any ALARP case that might seek to resist its suggestion.

11. Four permissions, in the form of licence instruments, were issued:

12. LI518 acknowledged receipt of the PCSR associated with the Cylinder Handling Facility.

13. LI520 acknowledged receipt of the PCSR associated with the Tails Deconversion Plant (which comprises the Deconversion and Vaporisation facilities). ONR completed a limited assessment of this PCSR and concluded that the design was insufficiently developed to permit a final regulatory judgement. ONR noted that the case appeared to rely heavily on administrative controls and that these would require substantiation by means of a Human Factors Analysis. The control of criticality was identified as a significant issue yet to be fully analysed; ONR said it would be looking for engineered as well as administrative controls for this hazard [Ref 6].

14. LI522 acknowledged receipt of the PCSR associated with the Residue Recovery Facility (RRF) and the Effluent Treatment Plant (ETP).

15. LI521 agreed to the construction and installation of equipment in the Uranium Oxide Storage (UOS) Facility, (an Agreement being an alternative form of permission). In its assessment ONR suggested a number of necessary conditions, which the licensee promised to implement [Ref 5] including:

    - DV70 containers to be delivered to UUK in a controlled manner
    - DV70s to be stored under cover to prevent corrosion
    - inspections to be made to ensure the containers are dry before use
    - an inspection regime to be developed, to include humidity monitoring in the UOS.

16. ONR had thus given the permissions sought, in the form of Licence Instruments, and in Q3 2011 construction began. By then, however, there had been extensive changes to some features of the design described in the PCSRs. ONR and UUK therefore agreed that the permissions ONR had already given would be regarded as covering only construction, and that UUK would seek new permissions for installation, the applications being supported by new PCSRs. These were submitted in 2013–14.

17. The structure of this new suite of PCSRs was set out in a generic PCSR [Ref 8]. This was supported by six PCSRs for individual facilities [Refs 9-14]:

    - Cylinder Handling Facility (A)
    - Hydrogen Fluoride Processing and Storage Facility (A)
    - Vaporisation Facility (A)
    - Deconversion Facility (B)
    - Uranium Oxide Storage (C)
    - DMF, CWF, RRF (C)

18. With the exception of the generic PCSR these seven PCSRs were assigned a safety category by the licensee, based on the estimated consequences of faults. This is shown in brackets. Those in Category A represent parts of the TMF in which some faults had radiological consequences to operators estimated as more than 1mSv. The licensee's arrangements made under condition 19(1) of the nuclear site licence say that construction or installation of a Category A proposal cannot commence without the permission of ONR.

19. ONR chose not to assess the PCSRs associated with the Cylinder Handling Facility and HF Processing and Storage, on the grounds that (a) these facilities had lesser radiological significance and (b) in the case of HF Processing and Storage it would be examined by ONR (through HSE–HID) under COMAH regulations, and by EA under the permitting regulations. Accordingly, ONR issued LIs (respectively LI 534 and LI 535) acknowledging receipt of these PCSRs, thus giving permission for installation to commence in those facilities.

20. ONR decided to conduct an assessment of the Deconversion and Vaporisation Facilities because:

- they contained the dominant radiological (and chemotoxic) faults
- they formed the heart of the TMF
- the deconversion facility was to use hydrogen to drive the oxidation reaction, a novel technique for the UK that introduces additional deflagration faults.

21. The assessment was to take the form of a small number of deep slices, which were intended to decide whether there were any significant concerns as to the safety of future TMF operations and highlight any generic issues associated with the design or safety cases [Ref 15].

3 ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST

22. Many of the faults analysed in the deconversion and vaporisation PCSRs had both chemotoxic and radiological consequences. Moreover, in many instances the chemotoxic consequence—from the inhalation of or immersion in HF—would be an operator fatality so rapid that the radiological consequence would be trivial.

23. The management of hydrogen within the deconversion facility was identified by ONR as having significant potential faults [Ref 16]. In particular it was apparent that the deconversion kilns would operate with flammable concentrations of hydrogen, and that a strong ALARP case would be required to justify this choice of reagent, a view subsequently communicated to the licensee on 17 December 2013 [Ref 17]. On 8 January 2014 ONR invited the licensee to give a detailed presentation on the approach to the management of hydrogen, in particular the ALARP arguments underpinning its proposed use [Refs 18,19].

24. In the course of the assessment ONR held a number of meetings with the licensee on specific topics; they were often attended by representatives of EA and HSE HID. Of particular note were early discussions on the proposed content of operating instructions (styled standard operating procedures, SOP) [Ref 20] and LMfS [Ref 21], which identified issues with UCP's intended staffing structure.

25. ONR assessors visited the Springfields site to determine how the licensee there ensured the safety of its kilns, particularly as regards hydrogen [Ref22].

26. Early assessments of the new PCSRs led ONR to conclude that some central elements of the design, engineering substantiation, and safety assessment were still incomplete; supporting documents, such as HAZANs, Engineering Substantiation Reports (ESRs) and DJRs were not available. ONR therefore suspended its

assessment in January 2014, and considered whether to defer it until the licensee submitted its PACSRs prior to the commencement of active commissioning, a later regulatory hold-point. ONR decided against deferral because: it had identified the same deficiencies during its assessment of the first set of PCSRs; a central question remained to be answered, namely whether the risk from TMF was tolerable; once the plant was built the opportunity to influence improvements would be reduced; the cost of improvements, in both money and time, would be greater the later they were made.

27. General findings from the ONR assessment work were that the PCSRs submitted in 2013 were inadequate, and that the primary reason for this was that the arrangements for the production of safety documentation were inadequate in some key areas. In particular the arrangements were not aligned with some of the SAPs, particularly in the areas of DBAA, the categorisation of safety functions, and the classification of safety systems. One result of these findings was that UCP withdrew its estimates of worst-case consequences, and presented consequence estimates afresh in what it termed a bridging paper [Ref 23].

28. A common finding of the assessment work since 2013 has been that TMF stands in a better position relative to the SAPs than can be deduced from the PCSRs. However, ONR has had to work hard to extract the information that has led to this finding, and the assessment overall has taken much more time than was expected or allocated, largely because of this.

29. Six assessment reports were completed in support of this request; they are summarised below.

3.1 CHEMISTRY

30. ONR's assessment [Ref 24] focussed on the hazards of the chemical reactions at the heart of the process by which the hex is converted to oxide. The assessment concludes that although the TMF will be the first of its kind in the UK, UCP has the benefit of being able to draw on the considerable operating experience of the plant in France. In addition, the main chemical reaction is commonly employed in the UK's fuel cycle, and worldwide. The assessment highlighted the need for ONR to consider further the proposed use of hydrogen; this was done in the chemical engineering assessment (see Section 3.4).

3.2 FAULT STUDIES

31. ONR's assessment [Ref 25] focussed on Fault Sequence Groups (FSGs) in the Vaporisation and Deconversion Facilities associated with loss of process control that could result in a radiological and chemotoxic release into rooms where workers are located, specifically:

- Vaporisation facility: FSG 8C - the autoclave door opened in error when the autoclave contains UF6 as the result of a leak within
- Deconversion facility: FSG K01 - over-pressure faults following loss of steam to the kiln; K05 - Pressure increase within the autoclaves leading to releases of UF6 and HF in the Deconversion facility.

32. This assessment was informed by ONR's Safety Assessment Principles (SAPs), the Management of Health and Safety at Work Regulations (MHSWR-99), and discussions with HID to ensure consistency in the assessment of chemotoxic hazards. Regulators agreed that the basic risk criteria are the same and that the individual risk criterion in HSE's guidance document Reducing Risk Protecting People (R2P2) of $1x10^{-3}$ per year

applies to all causes. Hence, recognising the need to account for normal operational risk on a nuclear facility, an accident risk Basic Safety Level (BSL) of $1x10^{-4}$ per year should be used for both conventional and nuclear risk.

33. ONR's assessment of TMF was challenging because of the complexities of assessing a facility with faults that would result in both radiological and chemotoxic consequences.

34. UCP assessed radiological hazards using a Design Basis type approach. Consequences to workers were initially predicted to be very high. ONR raised concerns early on in the assessment process over the consequence modelling, various aspects of the plant design, the adequacy of the safety systems claimed to reduce risks, and the application of the UUK's safety assessment methodologies.

35. Following lengthy engagements, including a presentation from ONR on interpretation of the SAPs (categorisation of safety functions and classification of safety systems), a number of fault sequences were re-evaluated, resulting in a significant reduction in the predicted radiological consequences. The results were later presented in the bridging paper.

36. Although some uncertainties remain, ONR judges that the risk to workers from a radioactive release is small compared to that presented by a chemotoxic release. UCP assessed chemotoxic hazards using a Layers of Protection Analysis (LOPA). This is a simple probabilistic approach often used in the chemical process industry to analyse fault sequences and identify the requirement for safety provisions.

37. ONR raised concerns over the modifying factors used in the LOPA analysis, notably when considering time spent in the kiln room when a release could occur. Entry is said to be necessary to monitor plant both visually and aurally. ONR questioned the use of arguments based on time at risk, and on rapid evacuation. The modifying factors are used to reduce the requirements placed on engineered safety systems, often with limited or no underpinning evidence.

38. ONR considers that to undertake certain activities an increase in risk may be acceptable in the short term, if risk can be demonstrated to be ALARP for long-term operation, and providing adequate controls are in place. However, ONR is of the opinion that LOPA relies too much on administrative controls and evacuation in preference to engineered prevention/protection. ONR considers that the claims on evacuation are not justifiable because exposure to HF/UF_6 for a very short period of time would be fatal.

39. If credit for evacuation is removed, the risk to these workers is likely to reside close to the upper level of the tolerable region. It is assumed that work will be undertaken under a rota system, therefore some account can be taken of risk-sharing, which is reasonable in the circumstances. However, ONR would normally expect new plants to be closer to the broadly acceptable level and therefore the current situation is far from ideal, hence the requirement for a robust demonstration of ALARP.

40. In response to a request from ONR for additional evidence to demonstrate that this risk has been reduced ALARP, a short paper [Ref 26] was submitted arguing that routine entry by workers to the kiln room satisfies this principle. Although the paper provides a more coherent view, ONR considers that it does not provide sufficient evidence to conclude that the risk to the workers has been reduced ALARP; ONR considers it to be reasonably practicable to do more. ONR would expect a high gross disproportion to be used and, given the questionable quality of evidence behind the LOPA, some appropriate sensitivity analysis to be undertaken.

41. A number of recommendations for improvement are made below, which need to be addressed prior to active commissioning of TMF to demonstrate that the risk to workers has been reduced ALARP.

- Access to the kiln room needs to be adequately controlled through engineered interlocks and procedural arrangements, and monitored to underpin the time-at-risk arguments used.
- It needs to be demonstrated that workers in the kiln room are capable of detecting changes to the plant by ear, against the background noise, to support the argument that entry is essential and acoustic monitoring is not practical.
- Further consideration needs to be given to use of Personal Protective Equipment (PPE) when entering the kiln room to undertake visual and aural inspections.
- Whether workers are in PPE or not, controls need to be put in place to ensure that before they enter the kiln room when kilns are on, all relevant external indicators have been checked and there is no indication of an abnormal plant condition.
- Further consideration needs to be given to the use of operator aids to monitor plant conditions and assist in the detection and decision-making process.
- Alarms/indications identified as forewarning of a release, prompting the operator to evacuate (or take other safety action) need to be claimed in the safety case, adequately substantiated, and demonstrated to deliver their safety function.

42. On the assumption that these recommendations will be satisfactorily addressed, the ONR Fault Studies assessor is content to conclude that it is adequate to stipulate Class 2 for the relevant safety systems on the kiln. However, if the recommendations are not addressed, then a higher classification may be warranted, in addition to other risk reduction measures.

3.3 ELECTRICAL, CONTROL AND INSTRUMENTATION (EC&I)

43. The assessment of the original PCSRs identified a number of regulatory issues that required follow-up work. In particular there was a general lack of clarity on the categorisation of safety functions, the classification of safety systems, and the effective use of smart instruments when delivering safety functions.

44. However, the licensee did generally respond positively to initial ONR criticism and provided additional supporting documentation when requested. It became clear that more documented evidence of the suitability of the engineered protection existed than was suggested by the 2013 PCSRs.

45. ONR's fault studies assessment of the TMF made recommendations that must be satisfactorily addressed by the licensee and tenant prior to active commissioning. On that premise, the fault studies assessor concluded that it was adequate to stipulate Class 2 for the safety systems sampled in the EC&I assessment, namely: FSG K01 - over-pressure faults following loss of steam to the kiln; FSG 8C - the autoclave door opened in error when the autoclave contains UF6 as the result of a leak within.

46. The basis of the EC&I assessment [Ref 7] was to establish whether the safety systems sampled were capable of meeting ONR's expectations for Class 2 safety systems.

47. ONR concluded that the proposed EC&I safety systems that it sampled are consistent with Class 2 safety systems. The arrangements in the design of the TMF for segregation are generally acceptable.

48. Although the licensee has begun activities aimed at providing increased confidence in the performance and reliability of the proposed safety systems, the assessment concludes that, if they are to be substantiated to Class 2, more work is required to demonstrate that the potential for common-cause failures in smart devices has been minimised.

49. The assessment has identified areas of regulatory concern in relation to the ability of the TMF design to fail in a safe state. Though a number of meetings, and the provision of additional documentation, have gone some way to increase regulatory confidence that safety system failures will be detected, it is recommended that the licensee produces a comprehensive demonstration during inactive commissioning that safety systems fail safe and potential failure modes have been adequately identified.

50. There is a lack of information on the detailed plans for EMC testing and maintenance, which ONR would expect to be available at this stage in the design. In addition, ONR has been unable to assess the reliability of TMF's external electrical supply, which will need to be addressed before active commissioning.

51. The assessment generated five regulatory issues, which have been translated into recommendations:

- Dependency analysis should be undertaken to provide confidence that the use of smart instruments has not given rise to common-cause failures within the safety systems. This analysis should consider the diversity of design in the operational platform and manufacturing of the smart devices and may call on the results of the tests performed on the protection systems as part of the inactive commissioning. This analysis should be made available to ONR prior to the submission of the pre-active commissioning safety report for TMF.

- The licensee should produce a comprehensive demonstration during inactive commissioning that C&I safety systems have been designed to be inherently safe or to fail in a safe manner or to ensure that operators are alerted to any failures that do not fail to safe state. The demonstration should include the consideration of reliability of operator alarms following any failure. This demonstration should be made available to ONR prior to the submission of the pre-active commissioning safety report for TMF.

- The licensee should provide detailed plans for EMC tests to be carried out where applicable, in accordance with established standards. The results of those tests should be made available to ONR prior to the submission of the pre-active commissioning safety report for TMF.

- The licensee should provide ONR with detailed arrangements for examination, inspection, maintenance and testing, prior to the submission of the pre-active commissioning safety report for TMF. This should include arrangements to detect systematic errors where tests are not conducted end-to-end.

- The licensee should provide an assessment of the reliability of the electrical supply. In addition, during the inactive commissioning stage the licensee should compile evidence for presentation to ONR on the following:

- the strategy to protect against the propagation and potential escalation of faults in the electrical supply;
- confirmation, using data collected during commissioning, that the electrical load of the TMF and the load distribution are as predicted;
- the impact of variations in voltage and the loss of a phase within the electrical supply, and whether monitoring needs to be implemented in the TMF.

52. ONR will expect these issues to be resolved to an adequate standard before a request is made by the licensee for permission to commence active commissioning.

3.4 CHEMICAL ENGINEERING—HYDROGEN MANAGEMENT

53. ONR focussed its Chemical Engineering assessment [Ref 27] on the UF_6 to U_3O_8 reaction within the kiln, and the justification and potential consequences of the use of hydrogen therein. In addition, ONR assessed aspects of the long-term storage of the U_3O_8. A key supporting safety submission was 'The Development of the approach for the Management of Hydrogen within TDP' [Ref 28].

54. An excess of hydrogen within the kiln will lead to an exothermic reaction, U_3O_8 producing UO_2 and steam; therefore the flow of hydrogen into the kiln must be controlled in order to minimise this potential. Operating experience from France indicates that some hydrogen is carried over from the kiln, and therefore the potential exists for deflagration within the kiln and downstream vessels. The justification for the use of hydrogen is that it drives the oxidation reaction towards completion, reducing the potential for fluoride corrosion of the DV70 containers.

55. Within the kiln the licensee considered alternatives to hydrogen, such as methane and ethane, but concluded that they would lead to the production of fluorocarbon greenhouse gases such as CF_4 and CHF_3. The licensee argued that to change the French design would add significant cost and time to the project, and that none of the potential alternatives would lead to a significant reduction in deflagration risk, but may in fact have undesirable consequences such as greenhouse gas generation.

56. Two further arguments were that: if hydrogen were not used additional vaporisation and deconversion units would be needed to achieve the same throughput, increasing the overall risk; the use of hydrogen results in a higher quality product, with a longer storage life.

57. The licensee's safety case is based on ensuring that the hydrogen concentration in the off gas system is kept to below 1% during normal operation and 15% during fault conditions, and designing the off-gas system to withstand the overpressure generated during a deflagration. ONR had initial concerns relating to the 15% hydrogen concentration during a fault, and the Dangerous Substances and Explosive Atmosphere Regulations imply that this operating regime would only be acceptable if there were no alternative. In this instance a significant by-product from the deconversion kiln is HF, which is intended for sale. If this option were not available then ONR judges that a large and complex additional plant would be required to treat and neutralise the HF, which would add significant risk. ONR judges that this increase in risk would exceed any reduction from eliminating the risk of hydrogen deflagrations in fault conditions. Taking all of these arguments into account, therefore, ONR judges that the use of hydrogen is ALARP in this instance.

58. This assessment concluded that the intention to allow workers routine, managed access to the deconversion facility is not in accordance with the SAPs, partly because

it relies on inadmissible time-at-risk arguments. On that basis this assessment concluded that the licensee should be required to give additional justification for such an operational approach, which must clearly demonstrate why the entry is required and why it cannot be replaced by remote operation and monitoring.

59. The assessment concluded that the proposed approach to inactive commissioning of systems designed to manage hydrogen appeared sensible and in line with relevant good practice. It recommended that ONR examines the PACSRs before radioactive materials and hazardous chemicals are introduced, in order to ensure that the associated safety systems have been robustly tested.

3.5 MECHANICAL ENGINEERING

60. Like the assessment reported above under Fault Studies, ONR's assessment of mechanical engineering [Ref 36] examined Fault Sequence Groups 8C, K01, and K05 in detail. In addition it examined FSG 14, the overheating of a hex cylinder in an autoclave, causing the cylinder to leak and, in the worst case, the autoclave to rupture.

61. It resulted in four recommendations, which ONR will require to be satisfactorily resolved before giving permission for radioactive materials to be introduced to TMF. The following are to be submitted to ONR for its assessment:

- the procedure for inspecting Type 48Y cylinders on entry to TMF, before they are accepted into the cylinder store
- the substantiation reports demonstrating the integrity of the autoclaves
- arrangements for training technicians who will work on the operation and maintenance of the autoclaves
- the valve reliability data together with associated analysis demonstrating that the valves fulfil their safety functional requirements.

3.6 RADIOLOGICAL AND CHEMOTOXIC CONSEQUENCE

62. A principal purpose of ONR's assessment in this area [Ref 35] was to provide guidance to ONR's assessors in other specialisms. ONR was initially presented with a series of PCSRs in which many faults had a radiological consequence estimated as greater than 1Sv, from inhalation of uranic material following a release of UF_6. In calculating these figures an evacuation time of 30 seconds had been assumed for the operators; but, if evacuation was not made within 30 seconds, it was considered likely that the operator would be overcome by the HF associated with the UF_6.

63. The assessment concludes that to assume 30 seconds for an evacuation time is not conservative. It further concludes that following a release of UF_6 from the Deconversion or Vaporisation facilities the chemotoxic consequence of many fault sequences exceeds the level termed the SLOD (significant likelihood of death), even on the assumption of evacuation in 30 seconds.

64. ONR's SAPs define numerical levels of risk: the Basic Safety Limit (BSL) and Basic Safety Objective (BSO) provide guidance as to the level of risk that is broadly tolerable. However, these levels are specified in terms of radiation dose only, without a direct link to chemotoxic consequence. This assessment had therefore to consider this difficulty. It recommends the use of risk criteria derived directly from two of the documents that formed the basis of risk guidance in SAPs. The documents 'Reducing Risks, Protecting People' (R2P2) and 'The Tolerability of Risks from Nuclear Power

Stations' provide a framework for judging the tolerability of risk, deriving numerical targets for tolerable and broadly acceptable risks to workers of 1 in 10,000/y and 1 in 1,000,000/y respectively for the sum of the assessed risks.

65. This assessment went on to recommend that the risks from all fault sequences in TMF should be summed, assuming worst-case occupancy factors, and that the ALARP case should show that the protection on the plant complies with the principles set out in Regulation 4 and Schedule 1 of the Management of Health and Safety at Work Regulations (MHSWR-99).

66. The conclusions and recommendations of this assessment [Ref 35] were utilised by the authors of other ONR assessments summarised here.

3.7 CRITICALITY

67. The generic PCSR [Ref 8] stated that criticality is not considered to be a credible hazard in the TMF. This statement was based on the assumption that TMF would not take material with a U^{235} concentration greater than that of natural uranium, with the potential exception of heels in containers that had been used for hex derived from reprocessed uranium, which the licensee said may reach 1% U^{235} but which could not credibly form a critical array. The PCSR acknowledged that the receipt in error of enriched material at TMF would constitute a hazard: there are Type 48 cylinders containing this material at up to 6% enrichment. It gave arguments that such an error would be rare, and on that basis TMF did not initially incorporate any control measures designed to prevent criticality.

68. The licensee generated an accompanying CIDAS omission case; this was not submitted to ONR as the licensee received advice from its nuclear safety committee that the argument relating to CIDAS was not robust and that such a case should be built upon an assessment of the criticality risk.

69. ONR has discussed the criticality safety management associated with the 'W' plant at Pierrelatte [Ref 29]. The criticality safety case for the 'W' plant is based upon enrichment monitoring of all material before import to the plant, colour-coding and different valve configuration for those containers containing enriched material, and administrative controls associated with the movement of enriched material.

70. ONR agreed that a criticality event within TMF was incredible if it always received only the feed material it was designed for; however, it judged there were credible initiating events that could lead to the accidental import of enriched material into TMF. The licensee has undertaken to produce a criticality safety case before commencement of inactive commissioning.

71. To increase ONR's confidence that it would be reasonable to issue the requested permission in advance of receiving a criticality safety case, the licensee summarised its intentions in a document [Ref 30]. ONR has accepted this as providing the necessary reassurance.

3.8 CONTROL OF MAJOR ACCIDENT HAZARDS REGULATIONS (COMAH)

72. When safety documents were submitted to ONR in 2009 a Pre-Construction Safety Report was submitted to HSE–HID under COMAH. HSE–HID judged that the Pre-Construction Safety Report was incomplete in many areas, emergency response and ALARP for example, but pursuit of these deficiencies was deferred until the next stage of the COMAH assessment process. A second Pre-Construction Safety Report was submitted to HSE–HID in 2014.

73. When ONR was created as a statutory body by the 2013 Energy Act it became a joint competent authority under COMAH for nuclear licensed sites. To support ONR a number of HSE–HID inspectors (who were given ONR warrants) carried out an assessment of this second COMAH Pre-Construction Safety Report. ONR–HID judged that the Pre-Construction Safety Report did not comply with regulation 7(1) of COMAH in that there was not a suitable and sufficient ALARP demonstration. The dutyholder (UCP) was notified [Ref 31] that this and other deficiencies must be resolved before the submission of its Pre-Operation Safety Report, which is required before COMAH substances can be introduced in the quantities prescribed.

3.9 OTHER GOVERNMENT DEPARTMENTS

74. In accordance with the memorandum of understanding between them ONR has consulted the Environment Agency, which has indicated that it is content for ONR to grant the requested permission [Ref 32].

4 MATTERS ARISING FROM ONR'S WORK

75. It should be apparent from the foregoing that this assessment has raised a number of issues whose import and resolution extend beyond the principal purpose of this report, which is to make a recommendation on whether ONR should give permission for equipment to be installed in the vaporisation facility. They are:

- Even when the second set of PCSRs was submitted the majority of the underpinning supporting documentation such as HAZANs, design justification reports, and engineering substantiation had not been completed. In addition, there were features of the design that had yet to be decided. This was only revealed after ONR had started its assessment, and introduced significant delay and consequential cost.

- The arrangements for the production and assessment of safety documentation did accord with the guidance contained within the SAPs, particularly for the assessment and treatment of DBAA. This contributed to ONR initially concluding that there was a shortfall in the engineering associated with TMF and an over-reliance on administrative controls. The radiological consequences of faults were expressed in a way that lead initially to significant overestimates and necessitated the completion by the licensee of a bridging paper [Ref 23] to provide an explanation and further justification.

- The SAPs do not provide clear guidance on the analysis of faults that have both radiological and chemotoxic consequences. ONR had intended to use the SAPs to judge the safety and tolerability of the design, but found that all of the dominant faults associated with the operation of the TMF have both chemotoxic and radiological consequences. The chemotoxic effects dominate in that they very quickly—within 30 seconds—overpower and disable anyone within the area. After much internal deliberation ONR focussed on judging the tolerability of risk based on R2P2.

- It is clear that similar autoclaves both at Capenhurst and Springfields are associated with the same potential faults and significant chemotoxic and radiological consequences as have been assessed in respect of TMF. In the light of ONR's feedback on the TMF PCSRs the licensee has delayed the

COSER for E23. In an inspection at Capenhurst [Ref 33] the ONR inspector discussed deficiencies associated with the protection systems on autoclaves that the licensee stated were to be reviewed as part of the COSER process.

76. Work has already begun aimed at addressing the wider implications of these issues. As part of this, ONR has discussed holding a workshop with UUK and UCP in 2016 to consider the lessons of the regulation of this project up to this stage.

5 CONCLUSIONS

77. ONR concludes that the licensee has demonstrated that the risks associated with operation of the TMF are tolerable. However, for a new plant like TMF ONR would expect levels of risk to be near the levels known as BSOs.

78. Initially, ONR judged that risks to workers had not been reduced so far as is reasonably practicable. After much further discussion, and the submission of a paper on access to operating kilns, ONR has accepted the arguments on this question, subject to the recommendations in section 3.2.

79. ONR has raised a number of other regulatory issues during its assessment of the TMF PCSRs. These will next be set out in letters from ONR to UCP and the licensee. ONR has already made clear that these will require to be addressed to ONR's satisfaction before any request for permission to commence active commissioning is made.

80. ONR's assessors have indicated that they are content for the permission requested to be given, as have the EA.

6 RECOMMENDATIONS

81. This report recommends that ONR grants the permission requested, namely to install equipment in the Vaporisation Facility associated with the Tails Management Facility at Capenhurst. In accordance with the arrangements made by the licensee under condition 19(1) attached to its nuclear site licence, this permission should be in the form of a Licence Instrument acknowledging receipt of the PCSR for the facility.

82. The recommendations identified during ONR's assessment process should be formally communicated to the licensee and UCP by means of letters that should follow the licence instrument. Thereafter those issues should be pursued without delay, and brought to a conclusion satisfactory to ONR before ONR grants permission for active commissioning of TMF.

83. Additionally, ONR should examine the records of commissioning, and the Pre-Active Commissioning Safety Reports, for the Vaporisation and Deconversion Facilities, as part of its work in deciding whether to give permission for the TMF to commence active commissioning.

7 REFERENCES

1. Urenco UK Ltd. Letter to ONR, referenced ONR/2013/28R and dated 16 October 2013.

2. Urenco UK Ltd. Letter to ONR, referenced ONR/2015/45N and dated 26 November 2015.

3. Urenco UK Limited. *Uranium Hexafluoride Tails Policy*. June 2012

4. Urenco UK Limited. Original PCSRs.

5. *Tails Management Facility Pre-Commencement Safety Report: Control & Instrumentation (C&I) Assessment (Short report.)* 9 March 2010.

6. ONR Contact Report. Visit to Capenhurst on 4 May 2010.

7. Control and Instrumentation Assessment of the Tails Management Facility Generic Pre-Commencement Safety Report UUK6036139 Revision 7.

8. Urenco CP Ltd. *Tails Management Facility Generic Pre-Commencement Safety Report*, referenced UUK6036139, Revision 07, 16 October 2013.

9. Urenco CP Ltd. *Tails Management Facility Cylinder Handling Facility Pre-Commencement Safety Report*, referenced UUK6036143, Revision 08, 10 January

10. Urenco CP Ltd. *Tails Management Facility HF Processing and Storage Facility Pre-Commencement Safety Report*, referenced UUK6036144, Revision 09, 8 April 2014.

11. Urenco CP Ltd. *Tails Management Facility Vaporisation Facility Pre-Commencement Safety Report*, referenced UUK6036141, Revision 07, 14 October 2013.

12. Urenco CP Ltd. *Tails Management Facility Deconversion Pre-Commencement Safety Report*, referenced UUK6036145, Revision 08, 17 October 2013.

13. Urenco CP Ltd. *Tails Management Facility Uranium Oxide Store Pre-Commencement Safety Report*, referenced UUK6036142, Revision 6, 29 May 2014.

14. Urenco CP Ltd. *Tails Management Facility Cylinder Wash Facility/Decontamination and Maintenance Facility/ Residue Recovery Facility Pre-Commencement Safety Report*, referenced UUK6036140, Revision 05, 22 May 2013.

15. ONR. Internal email.

16. ONR. Internal email. 20 November 2013.

17. ONR. email to UUK. 13 December 2013. 2013/465774

18. UCP. Presentation on the Management of Hydrogen in TMF on 8 January 2014.

19. ONR Contact report of UCP's presentation on the management of hydrogen in TMF on 8 January 2014.

20. UCP. Presentation on the preparation of Standard Operating Procedures. 6 December 2013.

21. Letter ONR to Urenco CP Ltd. *Organisational Capability*. 19 December 2013.

22. Westinghouse. Notes for a visit to Springfields by ONR inspectors on 6 January 2014.

23. Urenco CP Ltd. *Tails Management Facility Review and Justification of Safety Case Methodology*, referenced UCP8000133, Revision 3, 27 April 2015.

24. ONR. *Assessment of the Chemistry Aspects of the Tails Management Facility at Capenhurst*. ONR-DFW-AR-14-014 Revision 0.

25. ONR. *TMF—Fault Studies Assessment of PCSR—Summary of Recommendations.* 3 November 2015.

26. Urenco CP Ltd. *Tails Management Facility Demonstration that Routine Entry by Workers into the Kiln Room satisfies the ALARP Principle*, referenced UCP8000485, Revision 3, 2 September 2015.

27. ONR. *Tails Management Facility Deconversion PCSR Hydrogen Safety Assessment*. ONR-DFW-AR-14-013 11 December 2014.

28. Urenco CP Ltd. *Tails Management Facility— Development of the approach for the Management of Hydrogen within TDP.* referenced UUK6025565, Revision 4, 9 May 2014.

29. ONR Contact Report. *Discussion with ASN—French perspective in the regulation of the 'W' tails plant.* 8 April 2015. ONR-DFW-CR-15-001.

30. Urenco UK Ltd. *Tails Management Facility Criticality Safety Assessment.* Letter to ONR, referenced ONR/2015/24N and dated 14 July 2015.

31. ONR–HID. Letter to Urenco CP Ltd, referenced SVC4281187, dated 29 July 2014.

32. EA. E-mail to ONR 16 November 2015.

33. ONR Intervention Record. *Systems-Based Inspection of Materials Containment at UUK Capenhurst*. 19 March 2015. ONR-DFW-CR-15-001.

34. Systems Based Inspection (SBI) of Materials Containment at UUK Capenhurst.

35. ONR. Radiological and Chemotoxic Consequences Assessment of TMF Pre-Commencement Safety Reports. ONR-DFW-AR-15-004 Revision 0.

36. ONR. *Mechanical Assessment of the Tails Management Facility Deconversion Kilns*. ONR-DFW-AR-15-006 Revision 0.