REPORT OF THE CONCLUSIONS OF THE HEALTH AND SAFETY EXECUTIVE (HSE), NUCLEAR INSTALLATIONS INSPECTORATE (NII), REVIEW OF THE FIRST PERIODIC SAFETY REVIEW FOR THE IMPERIAL COLLEGE CONSORT REACTOR

SUMMARY

This project assessment report summarises the NII assessment of the first Periodic Safety Review (PSR) for CONSORT research reactor at Imperial College Silwood Park, Ascot. It provides the background and justification for our conclusions on the acceptability for continued operation for a further 10 years.

As a result of our assessment, we are generally satisfied that the CONSORT reactor at Imperial College, Silwood Park, Ascot is adequately safe. The analysis of the reactor operation using the PARET computer modelling code has enabled the licensee to carry out a detailed fault analysis and refine the claims made in previous safety reports, for safety systems. The licensee has also had a level 1 PSA (Probabilistic Safety Assessment) carried out to further support the assertions made in the deterministic analysis as to the adequacy of the existing provisions. In addition the licensee has instigated further improvements to bring the reactor into line with modern standards.

As part of the PSR, a detailed component level PSA has been produced by Electrowatt-Ekono on behalf of Imperial College. The analysis, which has been carried out using linked event trees/ fault trees using a modern code is consistent with current PSA practice and is acceptable for the PSR.

However, Imperial College needs to carry out further work to integrate the PSA into the safety case produced for the PSR and to carry out improvements to the design and operation of the facility in the areas identified from the PSA. This includes improvements to the reactor building, the operating procedures and instructions, administrative controls and training, providing additional automatic reactor trips, a diverse means of shutting down the reactor and separate power supplies to diverse warning circuits.

In the longer term, Imperial College needs to review the screening/ grouping process used and revise the PSA accordingly, consider whether the analysis could be simplified and provide better justification for/ documentation of the calculations of the radiological doses to workers, students and members of the public for the fault sequences identified in the analysis.

Imperial College has given a commitment to maintaining the PSA as a living PSA and to set up a system for the collection of component failure data for use in future updates of the PSA.

NII assessment of the review submissions has identified a number of minor areas where ALARP improvements could be made in the future. The licensee also highlighted these findings, and has put forward a programme indicating the stages of refurbishment or replacement, and when these improvements will be included. This work is being undertaken in accordance with agreed programmes and the licensee has responded to all identified issues. On this basis, the safety case for the CONSORT reactor is judged to be adequate for a further ten years of operation, until the next review in 2010.

Continued operation is therefore accepted on the basis that any agreed further analysis, improvements and inspections are completed and the formal annual regulatory reviews continue to give satisfactory results.

INTRODUCTION

1. The Imperial College research reactor is the last remaining operational civil research reactor in the UK. The licensee, Imperial College, provides further education at degree and postgraduate level. The licensed site comprises a research reactor located at Silwood Park, Ascot. The reactor was first licensed on 20 December 1962, and was completed by February 1963. The current site licence is numbered 7B and was originally granted to Imperial College as part of the University of London. In 1983 Imperial College based at South Kensington, London, became sole owner, operator and licensee.

2. The reactor is housed in a purpose built hall adjacent to the T H Huxley School of Environment, Earth Sciences and Engineering. The "Consort 2" design research reactor is a pool type reactor with a thermal power rating of 100 kW. The fuel is uranium / aluminium alloy clad in aluminium, similar to that used in other UK research reactors. The reactor facility provides teaching, research, material irradiation, neutron detector calibration and support for environmental analysis.

3. The reactor operates on a daily basis, normally shutdown in a safe state at weekends and silent hours. The reactor is also shutdown over the Christmas period and there is a major annual shutdown each year during the summer when routine maintenance and inspections are carried out. There are 24 fuel elements in the core, and 6 irradiated elements in the below core storage location. There are small quantities of low level waste (LLW) stored in the active store, less than 200 litres as of August 2000. The LLW is made up mainly of clothing such as gloves. There are currently two irradiated ladder jigs used to hold samples in the reactor. LLW is routinely disposed of to Drigg via Harwell. There is no radioactive contamination of the general licensed site areas.

4. Gaseous and liquid radioactive discharges from site are Argon 41 to atmosphere and tritiated water, which is stored on site in a holding tank and eventually disposed of to Ascot Sewerage Treatment Works on an annual basis. All discharges are subject to Authorisations granted by the Environment Agency (EA). The Discharge Authorisations (DAs) are currently being reviewed by the EA. The site does not envisage any operational problems as a result of this review and there is currently no set date by which the revised DAs will be completed.

5. NSD has held discussions with the site about the Quinquennial Review. This is a five yearly review, which looks at the operation of the site, plans for decommissioning, and financial provisions over the life of the site. An HSE report on the Quinquennial Review of the Imperial College CONSORT reactor is available on the HSE Internet site, http://www.hse.gov.uk/nuclear/qqreview/icqqr.htm

THE PSR PROGRAMME

6. The safety case for a nuclear licensed site is a point-in-time representation. As modifications to the plant are made over the years, the safety case inevitably becomes more complex, difficult to identify and potentially out of date. The safety case should be a "living" document, which is continually referred to during the life of the facility. Licence Condition 15 requires licensees to undertake

periodic and systematic reviews, and carry out reassessment of the safety case. NII has a particular interpretation of the requirements for a periodic safety report, in that not only is it an updating of the safety case documentation, but also a comparison of the safety case against modern standards, an analysis of ageing and life limiting features, and a justification of adequacy of safety for a future period of operation.

THE LICENSEE'S FINDINGS

7. PSR improvements

PSR improvements identified by the licensee are detailed in document entitled "CONSORT Periodic Safety Case Review: A summary of Imperial College's Findings" referenced ICRC 190/02/08/33 Issue 2. In addition to these findings, the licensee has agreed to develop a diverse secondary shutdown system. This decision is based on deterministic criteria adopted for other reactors and good practice within the nuclear industry. This system will help in further reducing the initiating frequency of reactivity faults.

8. Hazards

The primary risks identified are from fire or spillage of radioactive materials within the building.

9. Review of Operations

The reactor is currently operating some 200 days per year, with significant signs of the workload increasing. The operating profile of the reactor has changed quite significantly throughout the previous operating period, from mainly full power operation with the production of radioactive samples, to a mixture with low power operation for teaching, training and instrument calibration purposes. Annual reactor utilisations have varied between 100 and 156 MW hours over the period.

10. Reactor Core

The current fuel approaches 38 years in wet conditions in some cases, although examination has caused no suspicions to be raised of loss of clad integrity. The residual reactivity lifetime of the current fuel charge is some 8 years. Discussions have been taking place with UKAEA and others on the back-end route and lack of replacement fuel. Two projects will be set up to take the initial work forward on both areas. The College remains committed to keeping options open to refuel, with a decision being taken to continue with sourcing fresh fuel to be made shortly. The analysis and fuel behaviour aspects of the PSR submissions, and further correspondence, demonstrates a large safety margin before the integrity of the fuel plates may be challenged under all relevant fault conditions. The protection system, whilst to the original design, is not critical to the inherent safety of the core. The licensee has agreed that at an opportune moment it should be upgraded and further lines of protection provided. This is in line with the PSA recommendation for high dose rate and low reactor tank level trips. Following on from the PSR, the licensee has purchased in core video camera equipment. This equipment has been used successfully to examine the core and parts of the reactor tank. The licensee has been able to confirm that the core conforms to the PSR safety case. During inspection it was found that some of the fuel elements were slightly misaligned and this has now been rectified.

11. Human Factors.

The PSA did identify a potential over-reliance on operator response. This is being addressed through involvement of the operators in decision processes, procedural changes, and training based upon PSA findings. Two additional trip mechanisms will be assessed: area radiation monitoring, and coolant level low. Because of the reliance for operator action detailed in the PSA the need to carry out additional training of operators has been identified. Retraining will also be needed for operators and other reactor centre staff (DAPs and SQEPs) to broaden their knowledge of the safety case.

12. Fault Studies.

Capability needs to be maintained in fault studies. This will take place through continued student projects, and training for a member of Imperial College staff to take over responsibility for the PARET code.

13. Probabilistic Safety Assessment.

The College has seen the benefits of producing a PSA based upon current industry standard approaches. There are minor amendments to be incorporated in the PSA report produced by the College's contractor. These will take on board comments identified by NII during assessment of the PSA. The college is also pursuing the purchase of the PSA code (RISK Spectrum) and maintaining a live PSA, as recommended by NII.

NII ASSESSMENT

14. In order that NII's assessment effort is used efficiently, areas of the PSR were targeted for assessment, taking into account the overall risk from the facility compared to other nuclear licensed facilities in the UK. The targeting is based on knowledge of the site through regular inspections and previous assessments of safety submissions.

15. Based on this knowledge and experience, three areas of assessment were identified. These were; fault analysis, fuel behaviour, and the electrical/ control and instrumentation systems. No detailed assessment was carried out by NII of the civil structure as no claims are made by the licensee in mitigating the consequences of any release.

16. During the assessments in these areas, concerns arose which required the licensee to provide additional justification of adequacy, demonstration of options studies, and in certain cases the submission of additional supporting work.

17. A major area of additional work requested of the licensee was the production of a level 1 probabilistic safety assessment (PSA). NII considered that this was an essential piece of supporting work to the deterministic safety case and would provide an indication of "goodness" and balance of the overall reactor design including the safety system.

18. This additional work was a major resource commitment by the licensee, who employed external consultants experienced in such probabilistic assessments, to carry out the work

NII FINDINGS

19. The NII assessment of the Transient Analysis and Fuel Behaviour aspects of the PSR submission, supplemented by additional correspondence and reports, concluded that the submissions are now adequately detailed and demonstrate the existence of a large safety margin before the integrity of

the fuel plates may be challenged under all relevant fault conditions. Accordingly, the NII assessor recommended that NII should accept the Imperial College of Science and Technology Periodic Safety Review for the CONSORT reactor.

20. NII carried out an assessment of control, instrumentation and electrical submissions in the PSR. This identified that the controls and instrumentation are predominantly those provided as part of the original design in the 1960s. However, the equipment continues to be serviceable. Segregation of the protection system in the control room area could be improved, and this should be pursued when there is a major refurbishment of the control and protection panels. The present equipment is considered to be adequate. This is supported by the fault analysis and PSA, which indicate that safe operation can be achieved with only a limited protection system. This is due to the design characteristics of this reactor.

21. The C&I assessment also noted the level of reliance on operator action identified in the PSA carried out by Electrowatt. As a consequence the provision of automatic trips on high area gamma and low reactor tank level should be pursued at the earliest convenient time as an ALARP measure for reducing potential radiation dose to the operators.

22. As for the C&I systems, the design of the reactor places no additional demands on electrical services. There is no post trip cooling requirement. Failure of electrical supplies is fail safe resulting in reactor shutdown. Monitoring of status can be maintained by battery powered equipment. Self-contained emergency lighting is provided and the fire and security alarms have self-contained supplies.

23. It was noted that the safety case has been made for continued operation for a further 10 years. The age and design of the instrumentation is a concern but this is judged to be an operability rather than safety issue.

24. The NII assessment concluded that although the C&I system falls below modern standards, it is nevertheless judged to be adequate. This is because the reactor design and analysis of the fuel behaviour have shown that only modest claims need to be made for the protection system. However, reasonable improvements can be made and should be pursued as and when the opportunity arises.

25. No life limiting features have been identified other than potential obsolescence of the equipment, which will result in reactor operability problems. The characteristics and design of the reactor do not require a high integrity of electrical supply. Essential instrumentation, monitoring, and emergency lighting are provided with battery backed supplies.

26. Also the licensee has contracts are in place for routine inspection and maintenance of the electrical switch gear and distribution system.

27. Although the instrumentation and protection systems are of late 1960s vintage, the licensee can demonstrate adequate reliability and ability to maintain the equipment. Failures are predominantly fail safe and lead to operability rather than safety concerns.

28. The independent PSA carried out by Electrowatt indicates a balanced design. The possibilities of improving areas dependent on human action have been identified, though these are desirable rather than essential. The licensee has prepared a programme identifying appropriate stages in when these improvements can be addressed.

29. The licensee has gone further than the analysis would indicate, by proposing the addition of a diverse method of reactor shutdown.

30. The PSA in the electrical, and C&I should be accepted as a justification of adequate safety.

31. Improvements in the segregation of the protection system in the control room should be pursued when refurbishment of the equipment is planned. The option for incorporating desirable features, as identified in the PSA, should be pursued with the licensee.

32. Maintenance and testing of the protection and control technology, and spurious operations should be monitored by NII to confirm continued suitability of the equipment.

33. The Fault Schedule produced by Imperial College is judged to be sufficiently comprehensive to form the basis for the PSR PSA. However, in the longer term, Imperial College needs to give further consideration to the initiating events that have been screened out and to the grouping process to determine if they are acceptable.

34. NII agrees that the event tree analysis is acceptable, as is the fault tree analysis carried out for some initiating events and nodes on the event trees.

35. The initiating event frequencies used in the PSA are acceptable at this stage. However, in the longer term, Imperial College needs to carry out further analysis to assign frequencies to those initiating events where no failure events have occurred for CONSORT.

36. The generic component failure data used for the quantification of PSA is acceptable for this current PSR. However, Imperial College should set up a scheme for collecting plant specific data that is in a form that could be used in a future update of the PSA.

37. Although the judgements made appear to be reasonable, no justification is given for the way that the levels of defence have been determined in the Common Cause Failure analysis (CCF).

38. One of NII's requirements for the revised PSA was that it needed to model equipment failures and human errors explicitly and this has been achieved. However, the modelling of the dependencies between the human errors modelled in the analysis is not discussed in the documentation provided for the PSA.

39. A modern PSA code has been used for the construction and quantification of the PSA. This has generated all the information that is required for the analysis to be used to determine whether there are weaknesses in the design and operation of the reactor – that is, cut-set frequencies, consequence frequencies, importance functions, sensitivity analysis, etc.

40. The quantification of the PSA has generated all the numerical information that would be expected from a modern PSA code. Errors noted in some of the data will need to be corrected and the PSA re-quantified before it is integrated into the safety case.

41. It is judged that the radiological doses assigned to the endpoints of the event trees are acceptable at this stage. However, it was not possible to trace the radiological consequences assigned to the end points of the event trees back to a calculation which sets out the methods used and the assumptions made.

42. The current PSA is presented as a stand-alone analysis. This needs to be combined with the consequence information that was generated for the earlier PSA and a comparison made with the probabilistic SAPs.

43. Electrowatt-Ekono has used the PSA in a systematic way to identify weaknesses in the design and operation of the CONSORT reactor. Areas where improvements need to be made have been

identified. These have been accepted by Imperial College, which has agreed to make improvements in all these areas. These improvements will be progressed by NII as part of the programme of work following on from the PSR.

CONCLUSIONS

44. The conclusion of our assessment is that we are generally satisfied that Imperial College has conducted a wide-ranging and satisfactory Periodic Safety Review of the CONSORT nuclear reactor at Silwood Park, Ascot.

45. We conclude that the licensee has;

i) extended the general applicability of the existing safety case for a further 10 years,

ii) identified and is implementing reasonably practicable improvements to plant and procedures,

iii) carried out a systematic review of age-related degradation phenomena and ensured that suitable monitoring and surveillance schemes are in place, and

iv) reviewed the safety case reflecting the current plant configuration, and made arrangements to present a newly documented and updated safety case.

46. Arising from this review, the licensee has identified modifications, procedural changes, inspection and additional analysis to further enhance the safety of the reactor. Programmes of work are underway to implement these improvements and we are monitoring the progress, which has been adequate to date.

47. FOLLOW-UP WORK PROGRAMMES

From the periodic safety casework, Imperial College has put together a table of work against nuclear licence conditions, ICRC190/02/08/33P. The main points in this table are;

i) Refresher training for Duly Authorised Persons and Suitably Qualified and Experienced Persons.

ii) Revised and reissue the PSA, with aim of maintaining it as a living PSA.

iii) Implement extended radiological protection surveillance programme.

iv) Implement segregation and fire protection of cabling for safety systems when practicable.

v) Review additional trip facilities.

Specific areas for future work have also been identified by NII. These are in the areas of; LC6, document schedule required; LC 17, introduce peer review process and improve traceability of working calculation records, particularly important as Imperial College relies on contractors and consultants for specialist assessment work; LC 27, condition monitoring and defect records needed. This will be important in justifying the data for next PSR. To support the existing case Imperial College are encouraged to backfit historical data for the last 5 years. Also work should be followed up to combine the PSA with the consequence information, and a comparison made with the probabilistic SAPs.

REFERENCES

1. A review by the Health and Safety Executive's Nuclear Installations Inspectorate of the strategy of Imperial College of Science, Technology and Medicine for the decommissioning of its nuclear site. http://www.hse.gov.uk/nuclear/qqreview/icqqr.htm