

**Report of the investigation into the leak of
dissolver product liquor at the Thermal Oxide
Reprocessing Plant (THORP), Sellafield, notified
to HSE on 20 April 2005**

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Foreword

This report covers the investigation by HSE into the circumstances of the leak of highly radioactive product liquor inside a cell of the THORP plant at Sellafield. The leak was reported to us on 20 April 2005.

The report includes a description of the investigation, its findings and the causes. It provides major lessons for both the operator of the Sellafield site, British Nuclear Group Sellafield Limited, and the nuclear industry generally.

Our extensive investigation into the events in THORP has shown that the operator fell significantly short of the required standards for such nuclear facilities for a considerable period of time before the leak was discovered. Although we stress that there is no evidence of any harm to workers or the public, the leak being contained within a stainless steel lined, heavily shielded cell, there had been a significant prolonged reduction in attention to the high standards demanded for the unique nature of nuclear operations, something we are not prepared to tolerate.

THORP was Sellafield's flagship and built to high standards. It must also be operated, maintained and managed to the high standards we insist on, and the public expect from the nuclear industry.

For the wider nuclear industry, my message is clear: high standards are expected of the nuclear industry, this means continued vigilance and close attention to maintaining each and every one of the multiple physical and administrative barriers put in place to protect people and society from highly radioactive material.

It is not acceptable to let any of these barriers degrade or weaken, relying on the existence of other barriers to secure continued protection. Industry must continue to embrace high standards of design, construction, operation and maintenance and vigorously seek to monitor, review and maintain them at all times.

This requires, especially during times of change, that the leaders and managers of the industry instil an open challenging, questioning culture that continuously strives for sustained excellence in operation. This is especially important for older nuclear facilities that may not have been built to modern standards.

There are also lessons for us as regulators, ones that I am determined to embrace in seeking to serve the people of Britain to the best of our ability. We will push further in directing our available resources to regulating on the basis of hazard potential as well as risk, and maintain an appropriate balance between day to day regulation and strategic issues. We will also further embed inspection based on the safety management requirements of nuclear site licence conditions targeted on the engineering and other barriers highlighted by the safety case. But regulating compliance is not enough; our challenge is to use the most effective way or leverage to secure the standards expected, especially in influencing the safety culture required for the continued safe operation of the nuclear industry.

HSE will ensure that the lessons learnt from this event are applied right across the nuclear industry and also, where relevant, for other major hazard industries. The public have a right to expect no less.

Dr Mike Weightman
HM Chief Inspector of Nuclear Installations

Summary

1 On 20 April 2005 British Nuclear Group Sellafield Limited (BNGSL) discovered a leak from a pipe that supplied highly radioactive liquor to an accountancy tank in a part of the Thermal Oxide Reprocessing Plant (THORP) at Sellafield, known as the 'feed clarification cell'. The incident was categorised by BNGSL as '3' on the International Nuclear Event Scale.

2 In total, approximately 83 000 litres of dissolver product liquor, containing approximately 22 000 kilograms of nuclear fuel (mostly uranium incorporating around 160 kilograms of plutonium), had leaked onto the floor of the cell. That leak had begun prior to 28 August 2004 and had remained undiscovered until 20 April 2005. It is likely that the leak was relatively small until January 2005.

3 Video evidence indicated that the leak came from a pipe, identified as nozzle N5, which had completely severed at a point just above where it enters accountancy tank B (HEAT B - Head End accountancy tank V2217B). The most likely cause was fatigue failure from the swinging or swaying motion of the suspended tank, which occurred during agitation of the tank contents as part of normal operation. The motion occurred because of design inconsistencies in the later stages of the design process and during construction, together with a modification to the operational mode of the vessel around 1997, which inadequately considered the impact on pipework. The change process overlooked the effects of the tanks swinging on their suspension rods during agitation of liquor, leading to pipework fatigue.

4 The leak remained undetected for a period of some eight months for two reasons: a failure to ensure that leak detection equipment was in effective working order, and a failure to follow key operating instructions. These failures were not identified due to inadequate monitoring arrangements and management oversight.

5 All indications suggest that the leaked liquor was contained within the cell and it is accepted that there was no possibility of a criticality from the incident. The leaked liquor was successfully returned to primary containment.

6 The HM Nuclear Installations Inspectorate conducted an investigation into the circumstances surrounding this incident. That investigation revealed shortcomings at the Sellafield site and made 55 recommendations for improvement, which were communicated to BNGSL during the course of the investigation. Two Improvement Notices were also issued.

7 The investigation identified that the company had been in breach of nuclear site licence conditions at the Sellafield site (see www.hse.gov.uk/nuclear/silicon.pdf for more details on nuclear site conditions). Three of these breaches can be demonstrated to have been serious, to have continued over a prolonged period of time and to have directly contributed to the incident. The company fell well below the standard required by the licence conditions and these breaches amounted to serious offences.

8 As a result, the company was charged with three offences alleging breaches of nuclear site licence conditions. BNGSL pleaded guilty to these offences in the Whitehaven Magistrates Court and the case was committed to Carlisle Crown Court for sentencing. On 16 October 2006 the company was fined a total of £500 000 with costs of £67 959 awarded to HSE.

9 THORP was shut down following the incident and required a Consent from HSE before being allowed to begin reprocessing operations again. Consent was granted on 9 January 2007.

Regulatory framework

10 The operators of nuclear plants in the UK, like their counterparts in other industries and places of work in general, are required to comply with the Health and Safety at Work etc Act 1974 (the HSW Act). The HSW Act places a fundamental duty on employers to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all their employees. It also imposes a duty to ensure, so far as is reasonably practicable, that people not in their employment are not exposed to risks to their health or safety as a result of the activities undertaken.

11 Earlier nuclear industry specific legislation, the Nuclear Installations Act 1965 (as amended) (NIA65), is also applicable and establishes a stringent nuclear licensing regime. Those sections of NIA65 relating to the licensing and inspection of nuclear installations are relevant statutory provisions of the HSW Act.

12 In particular, Section 1 of NIA65, together with regulations made under the powers provided by Section 1, prescribe the types of activity that may be undertaken only on a licensed site. Under this Act, apart from certain exceptions, no site may be used for the purpose of installing or operating any nuclear installation unless HSE has granted a licence. Additionally, Section 4 of NIA65 enables HSE to attach conditions to a licence in the interests of safety or with respect to the handling, treatment and disposal of nuclear matter. HSE has developed a standard set of 36 conditions which are attached to all nuclear site licences. A nuclear site licence can only be granted to a corporate body.

13 Some licence conditions impose specific duties, others require the licensee to devise and implement adequate arrangements for particular issues. The issues covered range from arrangements for ensuring the safety of plant and for controlling operations to management issues such as the supervision and training of staff. Taken together the licence conditions define important areas of nuclear safety to ensure safe operation of nuclear installations.

14 Her Majesty's Nuclear Installations Inspectorate (NII) is that part of the Health and Safety Executive's (HSE) Nuclear Safety Directorate (NSD) with responsibility for regulating the safety of nuclear installations in Great Britain under the HSW Act and its relevant statutory provisions.

The company

15 British Nuclear Group Sellafield Limited (BNGSL) is part of British Nuclear Group (BNG), which in turn is part of British Nuclear Fuels plc (BNFL). At the time of the incident, BNFL group comprised three self-standing business groups: British Nuclear Group, Nexia Solutions and Westinghouse. Westinghouse is no longer part of the Group.

16 Sellafield is located on the West Cumbrian coast just north of the village of Seascale and covers an area of approximately four square kilometres. From 1971 until 2005, BNFL owned, managed and operated the plants on the Sellafield site and held the nuclear site licence. The site comprises more than 200 nuclear facilities and provides work for over 10 000 people.

17 BNG's site management business is responsible for plant operations and delivering clean up solutions at Sellafield and various UK reactor sites. Since 1 April 2005, the Sellafield site has been managed and operated by BNGSL and BNGSL is also the holder of the nuclear site licence (Licence Number 31G). The site is owned

by the Nuclear Decommissioning Authority (NDA), a non-departmental public body set up in April 2005 under the Energy Act 2004 to take strategic responsibility for the UK's nuclear legacy. NDA's objective is to ensure that the 20 civil public sector nuclear sites under its ownership are decommissioned and cleaned up safely, securely, cost effectively and in ways that protect the environment.

THORP

18 Sellafield activities include decommissioning and clean up of the historic legacy. The site is also home to the THORP and Magnox spent fuel reprocessing plants, the Sellafield MOX fuel production plant and a range of waste management and effluent treatment facilities.

19 The Sellafield site is split into several operating units (OUs), one of which is THORP. The THORP OU contains several ponds and plants that reprocess fuel from nuclear power plants. THORP started reprocessing operations in 1994.

20 Used (irradiated) nuclear fuel from reactors (mainly advanced gas-cooled reactors and light water reactors) is transported to one of the THORP ponds for cooling and storage. Once sufficiently cooled, the fuel is moved to another of THORP's ponds for marshalling immediately prior to reprocessing. The used nuclear fuel is then moved in customer specific batches to the THORP Head End plant, where it is sheared (chopped up into small chunks), dissolved in nitric acid (to form dissolver product liquor), centrifuged (to clarify the dissolver product liquor) and 'accounted' (for customer product allocation and international safeguarding). Once accountancy is completed, the clarified dissolver product liquor is fed forward into the chemical separation area and other downstream areas within THORP. There the dissolver product liquor is separated into broadly three streams: uranium, plutonium and highly radioactive liquid waste effluent.

21 THORP contains various cells. One of these cells, Cell 220 - the feed clarification cell (FCC), is the part of the Head End Chemical (HEC) plant where the dissolver product liquor is clarified and accounted. Tanks within the FCC accept the dissolver product liquor from upstream plants. Within the FCC are many vessels, the main ones are:

- a centrifuge feed tank;
- two centrifuges (which spin the dissolver product liquor in order to separate out the clarified liquor from undissolved solids such as fuel cladding);
- two diverters (that take the liquor from the centrifuges and can feed either accountancy tank);
- two head end accountancy tanks (or HEATs – vessels V2217A and V2217B respectively); and
- three buffer storage tanks (or BSTs) that hold the accounted clarified liquor prior to feeding forward into chemical separation.

22 The HEATs are 23 m³ vessels that are suspended from the roof of the FCC to allow weighing by load cells for accountancy reasons. Both vessels have a diameter of about 2.4 m and an overall height of about 6.3 m. The vessels and pipework are made from a nitric acid grade (NAG) stainless steel, which is especially resistant to attack by nitric acid.

23 The liquor in the HEATs is sampled for isotopic content and weighed. This enables an accurate account of the amount of uranium and plutonium to be determined. The fractured pipe was identified as Nozzle N5 of HEAT B, part of the pipework that feeds liquor from centrifuge B via diverter B (see Figure 1). Nozzle N5

is a set through nozzle with its axis vertical, an inside diameter of about 40 mm and a wall thickness of about 5 mm. The liquor in the HEATs can be agitated using a pulse jet agitation system. The design provides for liquor agitation in order to blend/homogenise different batches of dissolved fuel.

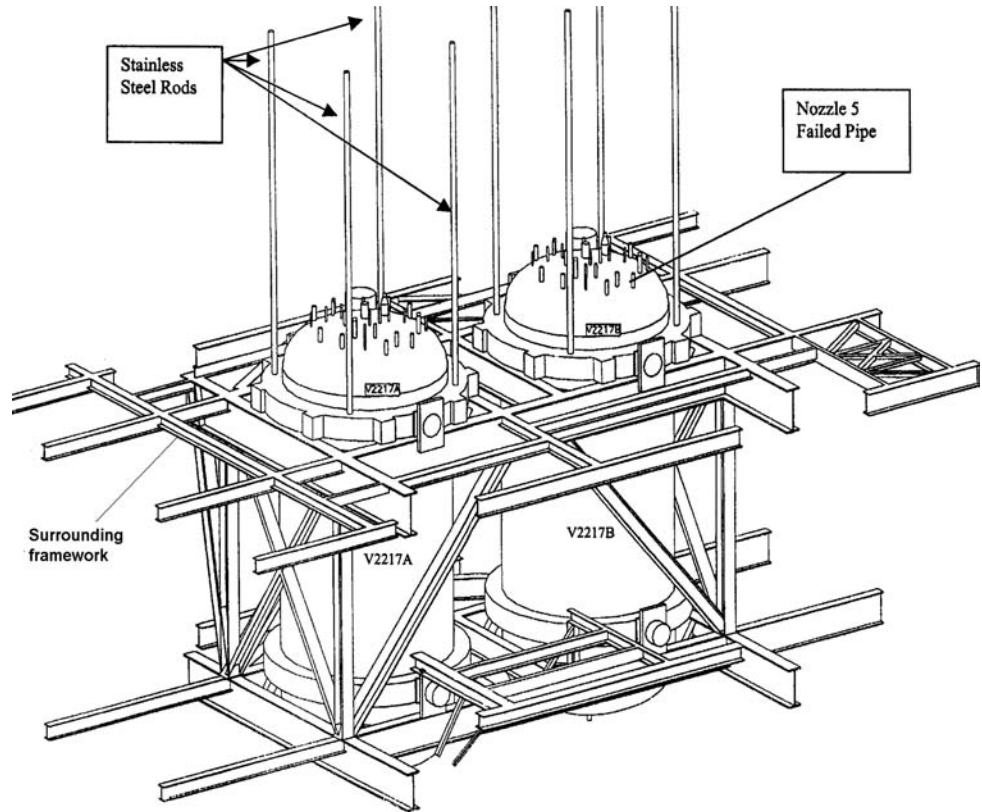


Figure 1 Line drawing of accountancy tanks V2217A and V2217B, hanger rods and surrounding framework

24 The FCC is of substantial construction in order to shield workers from the high radiation levels within the cell. The walls are approximately 1.5 m thick barytes concrete. The cell is 36.5 m long, 21 m high and a maximum of 14.5 m wide. The floor of the cell is lined with stainless steel, as are the walls of the cell from the floor, to a height of around 1.5 m. This lining, together with the substantial wall and roof thicknesses, form a secondary containment in order to contain and marshal any leaks from the many tanks and long lengths of pipework within the FCC.

25 Although the FCC is one cell, the floor area is divided into two by a small wall the same height as the lining. The centrifuges and diverters are above one floor area – the feed clarification area (commonly known as the ‘feed clari’). The accountancy tanks and the buffer storage tanks are above the other floor area – the buffer area.

26 Each of the floor areas slope down into stainless steel gulleys running around the edges of the floor areas. These gulleys slope down to two sump areas (one sump in each side of the FCC – the feed clarification sump and the buffer sump). The sumps are at low points in the cell floor lining to collect any leaked liquor, provide both areas with a means of determining the nature of the leak and to allow recovery of any leaks to safe primary containment. Within each sump is a level detection system known as a pneumaticator, and a means of emptying the sumps called an ejector. These sumps should always be primed with a small amount (about 0.3 m depth) of clean acid in order for the pneumaticators to work and to avoid cross contamination of the FCC ventilation systems (via exposure of the feed pipe to the ejector).

Leak detection

27 A pneumericator is a commonly used means to measure depth of liquor. Such a device is installed to detect any changes in the level of liquor in the sump resulting from leakage and is required by the safety case. Significant changes in liquor level detected by the pneumericator should initiate an alarm in the control room.

Note: A safety case is the means by which a licensee demonstrates a plant is safe to operate.

28 The pneumericator comprises two pipes known as 'dip legs'. One pipe is open to the FCC atmosphere while the other is open near to the bottom of the sump and is normally immersed in a known volume of clean acid. A constant flow of air is pumped down each pipe via a rotameter that measures the airflow. A higher pressure of air is required to be pumped through the immersed pipe than is required to pump air through the other pipe. This is because the air has to flow against the head of liquid within the sump and the pressure will vary in proportion to the depth of liquid present. The difference in air pressure between the two pipes is measured by a pressure transducer that sends a signal to the THORP distributed control system (DCS) which translates the signal into a depth of liquid in the sump and is displayed in metres on a display in the THORP control room. (The DCS is a computer-based system through which the plant control room receives plant state information, including alarms, and it controls the plant remotely.)

29 The pneumericator has four alarms, low low, low, high and high high. The low and low low levels indicate the need to reprime the sump levels with clean acid. The high and high high alarms indicate that liquor has entered the sumps, for example by a leak from the primary containment. Too high a level of dissolver product liquor in the sump could, in some circumstances, increase the potential for a criticality. Too low a level poses a risk of cross contamination between ventilation systems.

30 The operational arrangements for THORP state that the sump should be sampled upon an unexpected level rise or high alarm. High alarm occurs at 98 litres in the buffer sump and high high at 113 litres. Since the normal level in the sump is 83 litres, then if the pneumericator was operating effectively, a leak of 15 litres into the sump should activate the high alarm. A leak of 30 litres should activate the high high alarm.

31 In addition, although not required by the safety case, the operational arrangements for the FCC require routine samples from the sumps to be taken every three months and analysed for the presence of uranium. Any uranium present in the sump is a strong indicator that a leak from a FCC tank or pipe has occurred. The samples are transferred remotely to Analytical Services for analysis. The feed clarification sump sampler works automatically, but the buffer sump sample needs the intervention of the HEC plant operator (from the control room desk) to suck the sample (using an ejector) from the sump to the collection point for sampling and transfer to the analytical facility.

The HSE investigation

32 After being informed of the event, the initial priority for HSE was to support the immediate operations required to recover the liquor safely. The initial HSE investigation was undertaken between 16 and 25 May 2005, in parallel to these safety recovery operations. Further investigations were undertaken between 12 July and 14 October 2005.

Discovery of the leak

33 The HSE investigation found that it was not the installed leak detection systems that led to the discovery of the leak. It was the analysis of nuclear materials accountancy (NMA) discrepancies at the end of several fuel shearing campaigns that led to the detailed investigations by BNGSL on the plant, and subsequently to the discovery of the leak.

34 THORP is designed such that the HEATs are the first and prime point at which accurate figures for material going through the plant are determined. Prior to this the fuel suppliers (the 'shipper') give an estimate of the in-feed to the plant. The 'received' amount of material is measured in the accountancy tank, by weight, volume and density, and content sampling. For a campaign, the data from each HEAT batch is added up. There is an end of campaign stocktake and the difference between what is notionally received, what is measured in the HEATs and the location of in-line and storage stocks is calculated. This is termed the Shipper Receiver Difference (SRD) and is an accountancy measure for international safeguards purposes. The SRD figure is measured as a percentage and has an upper limit of 0.45% difference, above which an internal investigation should be initiated.

35 Problems with the SRD have historically been traced to incorrect sender information, incorrect measurements, documentation errors etc. The HEAT information is used as an accurate measure of what is fed forward to the chemical separation plant. It is not part of the plant safety monitoring system. It is a requirement of Euratom safeguards (non-proliferation) and customer contracts. The four most recent campaigns that were conducted within THORP were:

- A campaign ending 30 Jan 2005, with an SRD of 3.5%.
- A short campaign ending 25 Feb 2005, with an SRD of 3.9%.
- A campaign ending 29 March 2005, with an SRD of 10.03%.
- An interrupted campaign when the leak was found with an SRD of approx 10.03%.

36 While these figures may seem to obviously indicate a problem at the time, the figures take three to six weeks to emerge because of waiting for sample results and the relatively complex calculations. The campaign ending in January 2005 was a long one and SRD information only started to emerge in mid March 2005. Acting on this result, a BNGSL investigation was undertaken. Part of this was to quickly look at the next campaign data.

37 This initial inquiry did not identify a loss of material as the cause and so it was thought that the problem was supplier or paperwork related, especially as the volume lost during the first campaign appeared to be about the same volume as in one accountancy tank. Subsequently, the SRD for the campaign ending in February 2005 was confirmed and BNGSL's Nuclear Materials Custodian (NMC) for this area of the plant began to consider that there was something physically wrong with the plant around early April. Prompt analysis of the campaign ending in March 2005 also supported this view.

38 On 14 April 2005, during the investigation into the elevated SRD, THORP staff noticed that the routine feed clarification sump sample results from November 2004 and February 2005 indicated the presence of uranium in the feed clarification sump. This led them to believe the problem was on the feed clarification side of the FCC.

39 A meeting of THORP Fuel Services (the part of THORP that oversees Head End operations) staff was held on Friday 15 April 2005 to discuss these findings,

including the estimate using the SRD data that about 83 000 litres containing approximately 22 000 kg of uranium had been lost. A plan of action to insert cameras into the cell was drawn up for work over the weekend of 16-17 April. This plan did not include the immediate shutdown of THORP operations although it was acknowledged that liquor movements within the FCC would have to stop when cameras were to be placed into the cell.

40 Over the weekend, concerns were raised that the placement of cameras was too great a task for weekend shift staff and the decision was made to defer the camera inspections until after the weekend. Preparations for the camera inspections resumed on Monday 18 April 2005. THORP remained operating over the weekend. The decision to remain operating is of concern to HSE as the prudent decision, given the SRD results, would have been to shut down immediately.

41 Another meeting took place on Monday 18 April 2005 when estimates of the amount of liquor lost were confirmed by other means. The decision was taken to shut THORP down following this meeting.

42 Camera inspections within the FCC took place on 19 April 2005. As explained above, inspections took place in the feed clarification side. These inspections found no evidence of a leak or fracture.

43 On 20 April 2005, at approximately 2 pm, a camera inspection took place on the accountancy/buffer storage side of the FCC which showed a fractured pipe on the top of accountancy tank B, together with staining due to leaked liquor on the side of the tank, severe corrosion of in-cell mild steelwork and a large volume of liquor on the floor of the buffer side of the FCC. (A sump sample was taken from the buffer sump on the 26 April 2005. The results from this sample showed the liquor on the floor of the cell was dissolver product liquor.)

44 The THORP Incident Control Centre was manned. HSE was notified at 5 pm on 20 April 2005 at a meeting between the Head of THORP and the HSE/NII THORP site inspector, who happened to be on site at the time.

45 The HSE investigation found no evidence of excessive delay by the NMC in responding to the NMA information, since in the early stages there was some uncertainty about whether there was a problem on the campaign ending in February 2005. Although it could be argued that the response could have been quicker, given past history of resolving such data mismatches, from documentation or measurement errors, then it may be understandable why there was a delay.

46 Earlier SRD figures, for the campaigns ending during August and September 2004, show a slightly elevated SRD of around 0.6%. This SRD was investigated by BNGSL and mistakenly explained as not being outside of THORP operational experience. This adds weight to the earlier finding from the sump sampling that a leak occurred prior to 28 August 2004.

Why was the leak not discovered earlier?

47 The HSE investigation revealed that the leak of dissolver product liquor into the cell went undetected from August 2004 until April 2005. It is likely that the complete failure of the nozzle occurred in January 2005 and eventually it was only the rate of volume of material that was lost into the cell sump that led to the discovery of the leak. The reasons for the delay in recognising that a leak had occurred are discussed below.

Level detection

48 As noted above (see paragraph 27) a liquor level rise in the sump should be detected by the pneumericator. On 22 April 2005, an instrument mechanic was sent as part of BNGSL's investigation into the leak, to look at why the pneumericator was still not recording a significant level rise even though there was some 83 000 litres of liquor on the floor of the cell.

49 The instrument mechanic noted that the flow indication to the buffer sump pneumericator was correct but that initial movement of the needle control valve was as if it were shut off or nearly shut. He returned the flow to the normal setting of 300 ml/min but noticed that the rotameter float was sticking in a position that indicated the flow was in the operational range even if the flow was lowered below this. Tapping the float tube cured the indication fault. The instrument was returned to operation showing a high sump level of 1.8 m.

50 The HSE investigation revealed that the pneumericator in the buffer sump had not been working properly. It had been in low alarm or producing an erratic output for some considerable time and it did not therefore respond to the level rise during the period of the leak.

51 Examination of the instrument records back to January 2000 shows that the output was both erratic and had been below the low alarm setting of 0.2 m for over 85% of the operating period (often falling below the low low alarm setting of 0.15 m).

52 The records are quite different from those for the feed clarification sump pneumericator, although the equipment is apparently identical. The investigating team concluded that the buffer sump level measurement instrument was routinely left in low and low low alarm. This evidence shows the problem was not confined to individuals or individual shifts but was a systemic problem.

53 The HSE investigation revealed that much of the breakdown maintenance of instrumentation (and similar activities by other craft personnel) was done without raising a job card but in response to a verbal request, and that these requests were often routed verbally directly to the craft personnel, rather than through their line management. Some BNGSL staff suggested during interviews that this had increasingly come about since staff levels were reduced, so making it not always possible to raise the paper trail and do the work. One consequence of this mode of working is that a systematic check of the plant behaviour and conditions cannot be undertaken.

Pneumericator maintenance

54 The lack of operational detail within the maintenance instruction (MI), the instruction used by the craftsman who is maintaining the piece of equipment as the procedure for carrying out the work, means maintenance relied heavily on the craft skills of the craftsman. The MI did not require any check or adjustment of the rotameter and none was made. This was because the MI was limited to calibration of the differential pressure transducer and confirmation of the correct response of the DCS to the application of a differential pressure to the pressure transmitter, rather than with proving correct operation of the instrument as a whole. Since the incident, BNGSL has improved the MI to include checks of the rotameter.

55 When the time came for maintenance and proof testing of the pneumericators, it was unusual for the people doing the work to look at the historical instrument trend to see if it showed any inconsistency (as the buffer cell sump readout trend clearly did). As the historical data is readily available, the HSE investigation team

was unable to determine why assessment of this was not a mandatory part of the maintenance procedure.

56 Witnesses also told the HSE team that a number of instrument maintainers were 'cross trained' electricians, who did not receive the same level of instrument mechanic training as a fully trained instrument mechanic. This may have been a contributing factor that prevented the maintainers of the FCC sump pneumericator from identifying that there was a problem with the instrument over a protracted period of time.

57 Proof testing of these instruments was carried out by a combination of maintainers and operators. The maintainers did the 'hands on' instrument maintenance and the operators, who run the plant, did the part of the testing which involved filling the sump with acid and draining/ejecting it and then refilling, to show that the high and low alarms were working correctly. This method of working may mean that there was lack of oversight for the whole task and delivery of a fully working, tested instrument.

58 As part of the HSE investigation, the records for the period of the last proof test of the FCC buffer sump pneumericator (on 1 July 2004) and the FCC clarification sump pneumericator (on 28 June 2004) were examined in detail.

59 In the case of the buffer sump, it would appear that the final steps to return the sump to its normal level were not completed since the subsequent records show that the level reading would have left the instrument in low alarm. While the individual actions of maintainers may have seemed appropriate at the time the work was done, the outcome was that the instrument was left not working properly and unable to carry out its safety function. BNGSL admit that the instrument was left in low alarm because it was 'only just' in low alarm and the proof tester knew it was difficult to reprime the sump to the correct level.

60 The pneumericator has the designation 'safety-related equipment' (SRE). The HSE investigation team had reservations about the way that SRE was treated in the maintenance schedule in THORP. The pneumericator maintenance is recorded within the computer maintenance system as 'normal plant', while the proof test is in the 'plant maintenance schedule' for SRE. One outcome of this separation is that there can be significant delay between the maintenance and proof test activities. These should ideally be carried out at the same time, since the equipment cannot be regarded as working correctly after maintenance until the proof test is completed satisfactorily.

61 The investigating team concluded that there were significant deficiencies in the scope, content and implementation of the instructions for the maintenance and proof testing of sump pneumericators. The maintenance and proof test procedures were inadequate and only tested part (the part from the pressure transducer within the pneumericator to the DCS output screen in the control room) of the pneumericator system. The complete system was not tested to show that the air flow to each dip leg was set up correctly and in addition, levels were not topped up with a known volume of liquid to produce the correct level rise on the instrument display. Therefore, there was no assurance that the instrument would do what was intended to fulfill its safety function, ie detect leaks from primary containment to the sump.

Response to and management of alarms

62 As noted above (paragraph 50) the buffer sump pneumericator had been behaving erratically for some time and had been below both the low alarm and the low low alarm setting for extended periods. The investigation concluded that the pneumericator was routinely left in low alarm.

63 There was an operating instruction covering the action to take in response to a low alarm, and this involved the addition of clean acid to the sump. Interviews with the HEC operators revealed that, from time to time, attempts were made to restore the instrument to service by following the operating instruction, ie by adding acid to the sump.

64 One such attempt was made in early December 2004. On this occasion, acid was added to the sump when the indicated sump level had fallen to zero. There was no response to the addition of acid and an instrument mechanic was asked to look into the matter. Entries were found in the HEC plant log that showed that the desk operator presumed the dip leg was blocked – a common problem with pneumericators that blowing through the pneumericator could solve. The instrument continued to behave erratically including periods of being in alarm for the remainder of December 2004 and there is no record of any further action.

65 The means of ‘topping up’ the sump with acid was difficult and considered to be inadequately engineered. As a result, operators and supervisors had significant difficulty in adjusting the sump level to the required depth so that the pneumericator level instrument could operate between the low and high alarm levels (ie ‘normal’ operating conditions). As a result, supervisors routinely allowed the instrument to operate in low alarm.

66 Supervisors also did not regard low level alarms as being as important as high alarms, so they were not always responded to. This may in part be due to the fact that the safety case did not recognise a low sump alarm as being significant, but it did for a high alarm. In the low alarm case, the safety case appears inadequate and this is thought to have had an influence on the level of attention of supervisors.

67 The HSE investigation team found that there were significant operational problems with the management of a vast number of alarms in THORP, resulting in important alarms being missed.

68 The DCS alarm screen collects all the plant alarms and displays them with a priority colour coding (eg low and high = amber, low low and high high = red). Unless an alarm resets itself (by returning within the acceptable parameters) it will stay on the alarm screen. This would have occurred with the FCC sump level alarms. However, as more alarms from elsewhere on plant were displayed, the sump level alarm would have been pushed down the page. The situation is exacerbated by a number of alarms and data presentations on the THORP HEC Plant control desk screens that are not associated with that part of the plant (eg alarms associated with feed pond), which could give data overload to the operators.

69 Eventually, if not reset or returning within the acceptable parameters, the alarm would be pushed back many pages and so disappear from the operator’s immediate consciousness. As a result, a long-standing sump alarm was likely to be left unattended to, unless it was dealt with when it first occurred.

70 The THORP HEC Plant was operated in a culture that seemed to allow instruments to operate in alarm mode rather than questioning the alarm and rectifying the relevant fault. The large number of alarms, and it being left to the supervisor to make a judgement on what was a priority, may have exacerbated this alarm-tolerant culture. This also meant that the alarm response instructions were not being followed, leading to the conclusion that the culture also condoned non-compliance with instructions and fault tolerance.

71 There was no formal log of standing alarms and thus no audit trail for rectification follow-up. If one had been put in place, the information could have been passed from one shift to another and the faults rectified and closed out. The fact that the plant had deliberately been operating for some time in alarm mode, and was therefore non-compliant with instructions, raises concerns about control and supervision as well as the effectiveness of the safety management system and safety culture existing in the plant at the time of the leak.

72 There is a site project dealing with alarm management improvements and an associated site code of practice (CoP) for the format of alarm response instructions. It appeared that THORP had been given internal dispensation from the alarm response instruction (ARI) format code of practice. It was unclear why this dispensation occurred and whether the lack of compliance with this CoP contributed to the inadequacy of the ARIs for alarms associated with this event.

Sump sampling arrangements

73 As noted in paragraphs 30 and 31, the THORP operational arrangements require a sample to be taken from the sump in the event of a high alarm from the pneumercator in addition to the regular three-monthly checks. Only dilute nitric acid primer should be present in the sump, so the presence of uranium would be a strong indicator of a leak from primary containment. The HSE investigating team concluded that if the sump sampling (in particular, the buffer sump) had been properly carried out, and the results assessed, this would have identified the event much earlier.

74 It appeared that the requirement for sump sampling at three-monthly intervals had been changed some years ago from a monthly interval. The reason for this change of frequency could not be established.

75 The investigation found that positive uranium sample results were not acted upon and that there were apparent difficulties in getting samples from the buffer sump, resulting in several nil volume samples (a liquid sample not successfully taken) in the autosample records. The investigation team was satisfied that the autosampling team in Analytical Services was requesting samples to be taken in accordance with the schedule and reporting the nil volume samples to the HEC team. In most cases, HEC staff did not follow this through. There is some evidence that the nil volume sample problem had been going on since 1995.

76 There was evidence that the routine buffer sump samples had frequently not been successfully taken. There were no results between mid Nov 2003 and mid August 2004 and mid Aug 2004 and April 2005 (the 28 Aug 2004 result was the only one in the 2004 calendar year). The feed clarification sump samples were mainly reliable, with only one nil volume (Aug 2004) in the last three years.

77 The pneumercator output was analysed by the HSE investigation team. It was obvious when the buffer sump samples were successfully taken as the level in the buffer sump was seen to drop at the same time as the feed clarification sump was seen to rise. On or around the days when the nil volumes were 'obtained', there was no change in levels of the FCC sumps. There is only one reason for this: the ejector was not lifting liquor from the buffer sump and draining it into the feed clarification sump as intended.

78 This could happen for various reasons, including a blockage in the ejector, or a lack of steam driving the ejector. However, the nil volume problem has been ongoing for many years, and the ejector should not block in clean acid (the ejector also worked during the incident recovery phase). It can only be concluded therefore that the HEC staff have not been firing the ejectors when prompted by the Autosampling staff.

79 The HSE team saw evidence of samples from both sumps that had not been acted upon:

- Buffer sump result of 50g/l uranium on 28 August 2004.
- Feed clarification sump result of 9g/l uranium on 26 November 2004.
- Feed clarification sump result of 60g/l uranium on 24 February 2005.

Note: If appropriate response had been made to these results then the leak could have been spotted at that time. These sample results indicate that the leak started prior to 28 August 2004.

80 On 24 February 2005, a routine sump sample was requested from the two FCC sumps. The feed clarification sump detected 60g/l uranium. The buffer sump sample failed and was not repeated. It is assumed that operators did not perceive the importance of this result as no further action was taken. The level of uranium measured in the sump was probably not due to the method in which the buffer sump samples were taken (liquor is ejected from the buffer sump and emptied into a small pot which drains into the feed clarification sump) as the uranium level had increased from the November 2004 sample without having any liquor from the buffer sump ejected into it. Although it has not been proved, it is assumed that the level of uranium in the feed clarification sump was due to leaked liquor from the accountancy tank B fractured feed pipe. No other mechanism for causing uranium to be present in the feed clarification sump has been identified. It is most probable that the leaked liquor either splashed or ran off in-cell steelwork into the feed clarification side. This hypothesis would also explain the rise in the level of liquor within the feed clarification sump from mid January 2005.

81 It has already been mentioned that the liquor level within the feed clarification sump started to rise from mid January 2005. This rise continued and the feed clarification pneumercator went into high alarm on 14 March 2005, and high high alarm on 23 March 2005. The output of the feed clarification pneumercator shows that the rate of the level rise slowed from 27 March 2005. This was because the sump would have been full (0.6 m) and the level rise would have been slowed by the increase in surface area as the liquor was now flooding the cell floor. The sump was drained on 30 March 2005 without any sample being requested (a breach of an operating instruction) or any explanation given in the operational logs.

82 The feed clarification sump sampler works automatically and regular three-month results have been obtained. The buffer sump sample needs the intervention of the HEC Operator, and has been hit and miss, with more failures (ie nil volume in the sample pot) than successes over the last few years.

83 It was apparent from discussions with some HEC shift team managers (STMs) that such infrequent routine samples are not high on their list of priorities. Operational samples needed to keep the plant processing appear to be the priority. There seems to be a split of responsibilities between autosampling personnel, whose job is to take samples to the schedule, and the HEC STMs, who appear to be responsible for assessing and responding to the sample result. The HEC STMs did not know the sampling schedule.

84 For these infrequent samples, the HSE team concluded that there was no process for closing the loop, ie to ensure that samples were properly taken to the schedule and analysed, that results were received, assessed, put into perspective and checked against limits, and that trends were monitored and appropriate action taken. Various people thought that this was the HEC STMs' role. The HEC STMs indicated that the manufacturing support team did this on day shifts. Therefore, there was confusion between the manufacturing team and the manufacturing support team as to who was responsible for what aspects of plant monitoring and trending of plant safety data, and what data should be trended.

85 In addition, a number of staff that could have monitored plant data trends were unable to do so as they had not been trained to use 'Process Explorer', a program to enable interpretation of data from the DCS. It appeared that those who could use this program had taught themselves how to do so.

86 The need for clarity of responsibility was a finding of BNFL's own investigation in 1998 of a similar event in the Head End Dissolver cell when pipework had eroded through and leaked a small quantity of diluted dissolver product liquor into the sump. The resulting Management Investigation Report (MIR) (Management Investigation Report MIR/98/028, IER SE 4842 and SE 4855) made some 28 recommendations, two thirds of which included recommendations concerning sump monitoring, pneumercaters and sump sampling, and required improvements in BNGSL's existing arrangements including:

- 'MIR rec 16 – the THORP production support managers should ensure that, where relevant and appropriate, procedures are put in place requiring that all cell sump analyses results are recorded and trended by shift team managers (STMs) as soon as practicable following receipt.
- MIR rec 17 – the THORP production support managers should ensure that, where relevant and appropriate, procedures are put in place requiring that cell sump analyses result trends are reviewed by production support personnel on a regular basis.'

87 It is HSE's view that these recommendations were directly relevant to, and transferable to, what was discovered in the investigation of the 2004/05 leak. It is apparent that in 1998 the plant suffered a similar but less serious event, which should have resulted in recommended arrangements being put in place to improve leak detection and monitoring at Head End.

88 BNGSL had no formal record of how or to what extent THORP Head End implemented all of the 1998 recommendations. It is the opinion of HSE that few of the older recommendations had been effectively implemented, otherwise it is likely that this leak would have been detected much earlier.

89 There are a large number of samples taken and results produced from across THORP every day. These are fed back from the labs onto the chemical plant information computer (CPIC). Results appear online on the HEC STM's computer and the infrequent sample results can easily be missed among the large number of other sample results. A specific sample every three months is an easy one to miss, especially on shifts, unless there is a proper system for monitoring.

90 The front screen of the CPIC only lists the samples taken and does not show the sample results. The results of each sample only appear when each sample line is selected and opened. CPIC does not have limits with the result – only providing the answer following interrogation – eg uranium in g/l, so this has to be put in perspective by the HEC STM. There were no means of flagging whether the result is within or outside specification, nor were there any procedures to tell STMs how to respond to sample results.

91 The HEC STM's job scope and range of duties and responsibilities appeared to the HSE team to be more demanding than other THORP STMs (eg they had additional safe systems of work duties). It is HSE's opinion that this pressure may have contributed to plant monitoring not being carried out sufficiently rigorously.

92 An earlier event in February 2005 (BoI Report – IER 9738, BN05020118, Personal contamination during thermocouple replacement, 13/02/2005) identified that 'the shift management structure within Head End can be confusing and that

control and supervision arrangements are often unclear among the workforce’.

93 Maintenance and breakdown repair resource during silent hours was not under HEC STMs’ control but was delivered from Head End Mechanical Plant. This required the HEC STM to be off-plant – chasing up jobs and resolving issues. Therefore, clarity of job role and minimisation of conflicting activities was lacking.

94 In the investigating team’s view, this lack of management oversight and consequent lack of proper ongoing proactive monitoring and audit was one of the principal reasons why this event proceeded for as long as it did.

Other indications of a leak which went unheeded

95 At the beginning of 2005, the volume flows changed. HEC staff noticed it was taking more feed from a constant volume feeder (CVF) to fill the accountancy tanks. Calibration checks were made on the CVF to confirm this was not the problem. However, these discrepancies were mistakenly explained at the time as the CVF being inaccurate. HEC staff also noticed that it was taking approximately 8% more dissolver batches to fill the buffer storage tanks. This was also mistakenly explained at the time as being due to uncertainty over the amount of dilutants added during the process.

96 On 6 January 2005, banging noises were reported coming from the FCC. These banging noises were investigated by BNGSL and explained away as normal pipework creaking. In hindsight, though it would have been highly unlikely to be recognised at the time, it is now believed possible that this noise could have been caused when the pipework failed over its whole cross section and the noise was the tank and pipework banging together.

97 Records show that the temperature within the buffer sump started to rise from 15 January 2005. This temperature rise was probably due to an increased leakage rate into the sump, whereas a slow leak and low volume would have been cooled to ambient temperature shortly after hitting any surface (eg tank, floor, steelwork). The level of liquor within the feed clarification sump also began to rise on 15 January 2005 (probably due to leaked liquor splashing or running off into the feed clarification side – as discussed in paragraph 80). The above evidence suggests the pipework fractured to allow significant liquor loss sometime early in January 2005.

Why did the leak occur?

98 The HSE investigation concluded that leakage of process liquor from the primary containment in THORP FCC occurred from a failure of nozzle N5 in the top of HEAT B (V2217B). The cross section of nozzle N5 was completely severed at a point just above where it enters the HEAT (see Figure 2) The most likely type of failure of nozzle N5 of HEAT B is fatigue failure due to the motion of the vessel on its rods during certain conditions of operation. HSE also concluded that initially the breach area would have been small and would only have grown to a complete guillotine failure in the later stages.

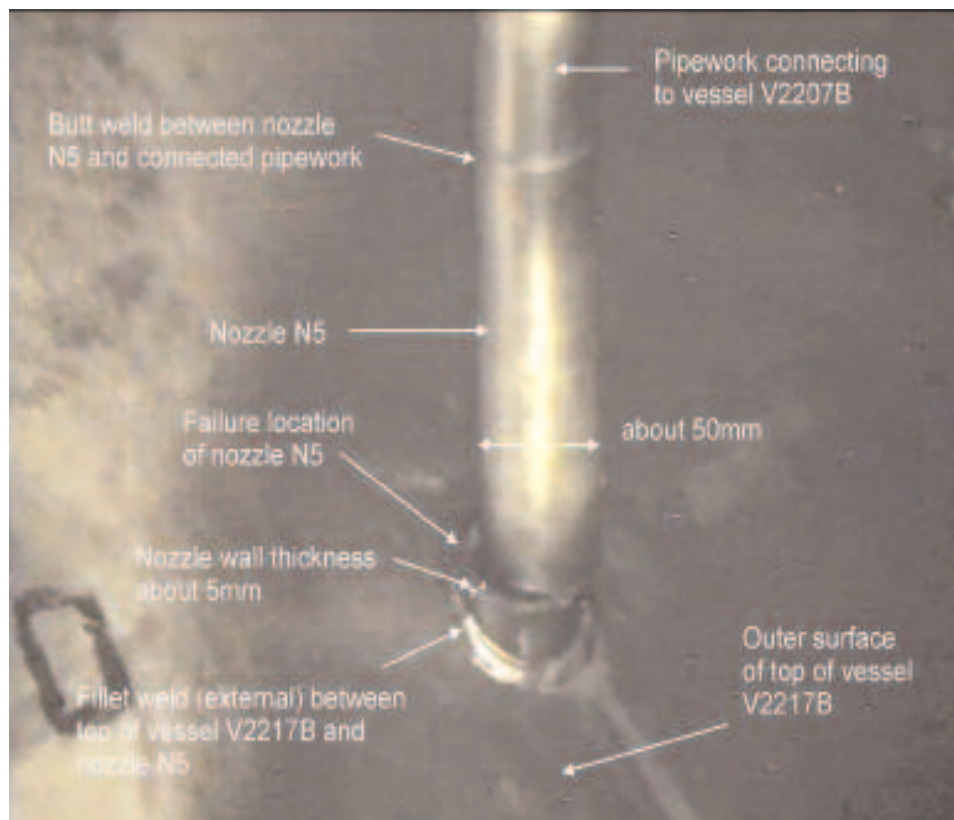


Figure 2 Failed nozzle 5 on HEAT B

99 The support arrangement (see Figure 1, paragraph 23) for each of the accountancy vessels V2217A and B consists of four rods which at their top ends connect to a weigh table in a room above Cell 220. The lower ends of the rods connect to a support ring, which is part of the vessel fabrication. The support ring is located about 1.2 m below the top-most point of the vessel (the crown of the top of the vessel). It is important to note that although the accountancy vessels are surrounded by a substantial mild steel framework (Figure 1), in normal operation the vessels are not supported by this framework.

100 BNGSL realised during its investigations following the failure that under certain operational conditions the accountancy vessels can move in a horizontal direction, ie they can swing or sway on the support rods. In effect, the rods and vessel form a rotational pendulum. The operational conditions arise when the accountancy vessel has liquor in it and the liquor is being agitated, or agitated and emptied. The agitation is required in normal operation to homogenise the liquor to obtain accurate accountancy results and also to prevent solids settling out. The method of agitation involves several small vessels within the accountancy vessels being alternately filled and emptied. Changes in fluid flow momentum during these processes cause overall motion in the accountancy vessel.

101 A video of the behaviour of HEAT accountancy vessel A taken as part of the BNGSL investigation showed that there is imperceptible movement when the vessel is full but very visible and large movements of the vessel in the horizontal plane when it is half full. This horizontal movement of the vessel can be seen to move the connections to it, including nozzle 4, that nozzle that has the same function as the failed nozzle 5 on HEAT B.

102 During periods when the accountancy vessels are swinging, the nozzles and immediately connected pipework move with the vessel. The pipework is anchored to support features in the cell some distance from the vessels, and at these points

the pipework does not move. The pipework between the nozzles and the fixed support points has some flexibility. But in order for the pipework to move with the vessel where it is connected to the nozzle, stresses must be induced in the pipework to make its shape accommodate the changing positions of its extremities (the nozzle on the vessel at one extreme and the fixed support point at the other extreme).

103 The stresses in the pipework during the swinging motion of the vessel are likely to be mainly bending stresses imposed on the pipework by motion of the vessel, acting through the nozzle. The nozzle is relatively stiff to bending where it attaches to the vessel. In this situation, stresses in the nozzle where it connects to the vessel, due to the swinging of the vessel, are likely to be quite high.

104 The purpose of HEATs is to provide a means of accurate Safeguards accounting for fissile material. Prior to THORP coming into operation, accounting of this sort had been achieved at other plants at Sellafield by measuring the volume of liquor in a vessel. However, for THORP it was decided at an early stage to consider accounting by weighing as a means of providing greater accuracy. Such a method requires that the vessel is as unconstrained as possible, particularly in the vertical plane.

105 Early in the design process, concerns were raised by BNFL engineers regarding the need to minimise or to assess the effects of, horizontal movement. As the method of accountancy had not been finally determined, two methods of accountancy (by volume and by weight) were designed for in parallel. Accountancy by volume would have resulted in the HEAT being located onto the framework, with horizontal movement limited by shear blocks welded to the framework. However, late in the design stage, accountancy by weight was chosen and therefore shear blocks were not fitted.

106 The HSE investigation established that the agitation arrangements for the contents of the HEATs changed during 1997. In the original sequence logic that was implemented during commissioning, the agitation of the tanks was limited to a maximum of three hours in a tank cycle. In addition the expectation was that the agitation was for a full tank that required sampling, although the sequence logic allowed the tank to be agitated even if the liquid in the tank was very low. The original sequence was automatic but it had a halt following agitation that required specific operator interaction to progress it beyond that point. The operator instruction guidance at this time (1994) was that the agitation always took place on a full tank before a sample was taken.

107 A BNGSL report of a 1997 investigation concluded that if the tank was operated cold (less than 35 °C) some of the uranium material could crystallise or solidify as small particles in the tank. There were two concerns from crystallisation if it should occur: namely, poor accountancy and line blockages from the solids. The report recommended changing the agitation regime by extending agitation timescale until all sampling was complete, and continuing agitation during transfer while the HEATs were being emptied.

108 These two changes to the operation of the agitation system, which were subsequently introduced, led to opportunities to agitate the HEAT contents for prolonged periods, and to agitate the tanks continuously when less than full. This would take the tanks through what is now known to be the most vulnerable point for vibration and resulted in large horizontal movements of the tanks.

109 The HSE investigation could find no BNGSL procedures for auditing how these decisions were made. The approval process for the Job Definition Document was not followed correctly in that the implementation did not match the design review, and the

full implications of the change appear not to have been considered. It became apparent during the HSE investigation that during the original commissioning of the vessels, insufficient work was undertaken to comprehensively describe or evaluate the behaviour of the tanks under agitation such that excessive movement at low levels was not observed.

Recovery of the leaked liquor

110 Following discovery of the leak, BNGSL utilised the installed sump ejector system to transfer the spilled liquor in batches into the buffer storage tanks. Lifting of liquor from the floor began on 23 May 2005 and continued to 14 June 2005. Between ejection steps, the in-cell wash ring system was used to lightly spray dilute nitric acid around the walls of the cell stainless steel liner, to try to flush off any residual material that remained.

111 On completion of the liquor removal, there remained a thin layer of silt (presumed to be highly radioactive) on some areas of the cell floor. The buffer cell sump was left primed with dilute nitric acid and with the sump level monitoring pneumercator operational. The cell is currently safe with all the mobile leaked material within the primary containment of the buffer storage tanks. A proposal for how to continue to process this material, which is contaminated with iron constituents from corroded steel components within the cell, has now been developed.

Hazards posed by loss of primary containment

112 The pipework and accountancy tanks are the primary containment of the highly radioactive liquor. Any loss from this containment results in liquor spilling onto the floor of the feed clarification cell. The last line of defence between the liquor and the building's foundations was the stainless steel feed clarification cell lining. The THORP foundations, although extremely substantial, are porous. Any leak through the floor could result in highly radioactive liquor seeping into the ground and, in such circumstances, could possibly be detected over the course of time by the sampling of the ground through boreholes.

113 The THORP safety case assumes that leaks of dissolver product liquor in the feed clarification cell would be detected and recovered 'certainly within a few days'. Examination of the results of a sample taken from the buffer side sump on 28 August 2004 demonstrates that the leak from the pipework of highly radioactive liquor had begun prior to that date. It was not until June 2005 that recovery from the floor of the bulk of the estimated 83 000 litres of this liquor was accomplished. To date, borehole testing of the ground around the feed clarification cell has not produced any evidence of an actual leak to ground from the cell.

114 Calculations based on values within the THORP safety case indicate that losing the line of defence afforded by the pipework significantly increased the likelihood of a leak to the ground during the incident from one expressed as having a probability of occurring once in every 40 000 years to once in 250 years.

115 Using the worst credible leak to ground, as presented in the extant safety case, an HSE specialist has estimated that the most affected person (ie a person who lives next to the site and lives off the land) could not have received a level of radiation sufficient to cause a possible serious health effect nor one above the maximum stated as the legal limit for doses to public from normal operations.

Criticality risks

116 HSE considers that a criticality incident would not have been possible with the particular concentration of leaked liquor involved in this incident.

117 A criticality accident occurs when a nuclear chain reaction unintentionally occurs in fissile material, such as enriched uranium or plutonium. This releases neutron radiation, which poses a great hazard to personnel and equipment. The purpose of nuclear criticality safety is to prevent a nuclear chain reaction in operations with fissile material outside a nuclear reactor.

118 The company's criticality safety case for the accountancy tanks in Cell 220 allows the processing of fuel, enriched up to 4% by weight of ²³⁵U (ie the proportion of a fissionable form of uranium, namely ²³⁵U, in the total amount of uranium is 4% by weight), and covers a number of accident conditions, although a major leak onto the cell floor was regarded as unlikely. HSE considers that the effectiveness of some of the measures in place to prevent criticality could not be guaranteed during the incident due to the large volume leaked onto the cell floor and the amount of time that the liquor lay undetected.

119 Administrative controls on upstream blending of liquors and the maximum enrichment of fuel reprocessed to date, means the probability of a leak of the type that occurred in this incident incorporating fuel of a sufficient enrichment capable of causing a criticality was extremely low. Had the incident occurred with liquor containing ²³⁵U at the highest enrichment level allowed by this safety case, then HSE considers that although still possible, the likelihood of criticality would still be low.

120 HSE estimates that should a criticality occur in the cell then this could result in doses of between 10 mSv and 100 mSv to people in the corridor adjacent to the cell: the substantial walls of the feed clarification cell would have provided significant shielding. To put this in context, the legally permitted dose limit to radiation workers is 100 mSv in a 5-year period. 100 mSv is well below the level at which deterministic health effects would occur and well below the 'fatality' limit.

HSE enforcement action

121 The initial HSE investigation undertaken between 16 and 25 May 2005 resulted in an interim investigation report with various recommendations, including the need for further investigations. These early recommendations were passed to BNGSL to ensure early safety improvements. In addition, the initial investigation also provided sufficient evidence of deficiencies in the licensee's compliance with a number of licence conditions to warrant serving two Improvement Notices specifically relating to operation of the THORP feed clarification cell. This was to ensure that BNGSL took prompt action to prevent similar events recurring. The Notices did not preclude further enforcement action. The two Notices required correction of deficiencies in compliance with:

- Licence Conditions 34(2) (to ensure that no leak or escape of radioactive material can occur without being detected) and 28(1) (to make and implement adequate arrangements for the regular and systematic examination, inspection, maintenance and testing of all plant which may affect safety); and
- Licence Conditions 24(1) (to ensure that all operations, which may affect safety, are carried out in accordance with written instructions) and 25(1) (to ensure that adequate records are made of the operation, inspection and maintenance of any plant, which may affect safety).

122 Further investigations were undertaken between 12 July and 14 October 2005. A summary and details of all those findings and recommendations are contained in Appendix 1. These were communicated to the licensee as soon as they became available so that work in the interests of safety could start as soon as possible.

123 As a result of these investigations and consideration of the Health and Safety Commission's Enforcement Policy Statement (see www.hse.gov.uk/pubns/hsc15.pdf), BNGSL were subsequently charged with three offences under the Nuclear Installations Act 1965 (as amended), namely being a person granted nuclear site licence that BNGSL:

- did on days between 27th day of August 2004 and 18th day of April 2005 contravene Licence Condition 24, in that BNGSL failed to ensure that all operations which may affect safety in particular the operation of the sumps in the feed clarification cell 220 in the Thermal Oxide Reprocessing Plant at Sellafield was carried out in accordance with written instructions and
- did on days between 31st day of December 2000 and 18th day of April 2005 contravene Licence Condition 27, in that BNGSL did operate plant namely vessels within the buffer area of the feed clarification cell 220 in the Thermal Oxide Reprocessing Plant at Sellafield when suitable and sufficient safety mechanisms, devices and circuits, namely the pneumercator number LIJ 2596 in the feed clarification cell 220 was not in good working order and
- did on days between 28th day of August 2004 and 18th day of April 2005 contravene Licence Condition 34, in that BNGSL failed to ensure so far as was reasonably practicable that radioactive material in the pipework connected to nozzle N5 of Head End accountancy tank V2217B in the feed clarification cell 220 in the Thermal Oxide Reprocessing plant at Sellafield did not leak or otherwise escape from the said pipework and BNGSL did fail to ensure so far as was reasonably practicable that no such leak or escape of radioactive material can occur without being detected.

124 At the initial hearing at Whitehaven Magistrates court on 8 June 2006 BNGSL pleaded guilty to these three offences and the case was committed to the Crown Court for sentencing. On 16 October 2006 at Carlisle Crown Court BNGSL was fined £300 000 for the breach of Licence Condition 27, £100 000 for the breach of Licence Condition 24 and £100 000 for the breach of Licence Condition 34. Costs of £67 959 were awarded to HSE.

125 THORP remained shut down following the incident and HSE issued a Notification under Licence Condition 21(8) notifying BNGSL that they must submit the safety case for the modified THORP and not commence movement of fuel from the feed pond to the shear cave without a Consent from HSE. Consent was granted on 9 January 2007 following Nil assessment and inspection of the modifications to the plant and BNGSL's response to the 55 recommendations made following the investigation.

Lessons for the company and the industry

126 The recommendations to BNGSL arising from the HSE investigation are detailed in Appendix 1. However, there are some general lessons which emerge.

127 The technical origins of the leak lay in design inconsistencies in the later stages of the design process and during construction, together with a modification to the operational mode of the vessel that inadequately considered the impact on the pipework. The incident has again highlighted the experience in the major

hazards industries across the world where ill conceived or inadequately executed changes to design, plant, procedures, process or organisational arrangements have resulted in incidents. It is essential that changes, even those that are apparently minor, are carried out with appropriate assessment of their potential impact by people who understand their safety significance in relation to the original design intent of the plant or processes to be changed.

128 The leak went undetected for a period of some eight months, albeit it appears to have been a small leak for the period up to January 2005. An underlying cause was the culture within the plant that condoned the ignoring of alarms, the non-compliance with some key operating instructions, and safety-related equipment which was not kept in effective working order for some time, so this became the norm. In addition, there appeared to be an absence of a questioning attitude, for example, even where the evidence from the accountancy data was indicating something untoward, the possibility of a leak did not appear to be considered as a credible explanation until the evidence of a leak was incontrovertible.

129 The IAEA has published guidance on issues to be addressed in strengthening the safety culture of an organisation and they have relevance here. The importance of a questioning attitude towards potential safety issues and the need to encourage challenge are aspects of culture that need to be instilled and demonstrated by the most senior managers. They need to lead by example in this respect.

130 Similarly there is a need to encourage a culture where shortcomings in working practices and plant conditions are challenged by the workforce through a system of open reporting, effective follow-up of the concerns raised and feedback. The workforce needs to understand the key precautions, which are necessary to ensure nuclear safety and the rules and procedures which support these. This promotes an understanding of why such rules and procedures are necessary and relevant, and reduces the likelihood that short cuts or workarounds will emerge over time.

131 The fact that there were some long-standing failings in some key safety arrangements and uncertainties in roles and responsibilities raises questions about the effectiveness of the company's arrangements for monitoring, audit and review. There need to be effective arrangements to provide assurance that those controls to ensure safety which are intended to be in place actually are in place, and are working effectively. Senior managers cannot rely on the absence of incidents as an indicator that everything is as it should be or as they would wish. This reinforces the importance of a questioning attitude and a challenge culture.

132 Another feature of this incident, and others in the nuclear and other major hazard industries, is that the failure to learn from previous events is a contributory factor. An effective system for organisational learning is a feature of high performance organisations. The lessons derived from learning should be embedded through a structured system for implementing corrective actions in a timely manner that is rigorously applied and actively followed up to completion. Effectiveness reviews should be undertaken to confirm that the changes have delivered the desired improvements.

Appendix 1

Recommendations to BNGSL following completion of the HSE investigation – communicated to BNGSL by letter on 13 December 2005

Recommendation 1 – BNGSL should examine the arrangements in existence during the THORP cell 220 design and installation for the control of the interfaces between the licensee and their design and construction contractors. BNGSL should also consider how lessons to be learned could be applied to current arrangements with multi-disciplinary design houses (MDDHs).

Recommendation 2 – BNGSL should review the issues raised by this incident and make necessary revisions to the THORP plant design and the design, commissioning and change control processes.

Recommendation 3 – BNGSL should reassess the change effected in 1997 which allowed longer agitation, and agitation during emptying, of the contents of the THORP HEATs. BNGSL should also review the PMP and any other design change processes to ensure an improved auditable trail of decision making associated with complex systems.

Recommendation 4 – BNGSL should provide adequate arrangements to ensure that any instrumentation installed to detect leaks of radioactive material into secondary containment in the THORP facility is appropriately designated (see Recommendation 5 below), and regularly and systematically examined, inspected, maintained and tested. This should include testing using known volumes of liquor.

Recommendation 5 – BNGSL should review the THORP safety case with respect to the SM/SRE designation of secondary containment sump level instrument systems and make any necessary improvements to the plant.

Recommendation 6 – BNGSL should identify and where practical implement diverse means of continuous/regular monitoring for the integrity of primary containment (eg via in-cell camera or sump sampling) in the THORP facility.

Recommendation 7 – BNGSL should review the THORP safety case with respect to claims made for intra-cell bund walls and make any necessary improvements to the plant.

Recommendation 8 – BNGSL should review the THORP safety case with respect to the uranium 235 enrichment to take into account the criticality limits for all fault conditions and make any necessary improvements to the plant.

Recommendation 9 – BNGSL should review how the decision was made to give dispensation to THORP from the alarm response instruction format in the CoP, and review and revise the alarm response instructions for THORP to comply with the site-wide code of practice for their format.

Recommendation 10 – BNGSL should review the history and progress of delivery of the 'Alarm Management Project' and the extent to which the site-wide approach is effective in making improvements to the number and frequency of alarms in THORP. This should include whether any additional measures are appropriate and whether improvement implementation timescales should be reduced.

Recommendation 11 – BNGSL should provide adequate engineered means for topping up cell sumps throughout THORP and adequate means for recording such work.

Recommendation 12 – BNGSL should ensure that there is adequate control, supervision and monitoring to ensure that the responses to sump alarms and sump operations in THORP are carried out in accordance with the instructions and that personnel understand the requirements and carry them out.

Recommendation 13 – BNGSL should ensure that the safety management system in THORP includes effective provision to control, supervise, monitor and audit compliance with key safety arrangements. Management should review the results of such monitoring and auditing to ensure that arrangements for ensuring safety are, and remain, effective.

Recommendation 14 – BNGSL should review the THORP safety case with respect to cell sump low level pneumatic alarms, derive any perceived requirements for the alarm and incorporate these into the operating, maintenance and training arrangements.

Recommendation 15 – BNGSL should review the way in which THORP standing alarms are dealt with and cleared from the DCS, and review logging arrangements so that there is an audit trail for investigating, prioritising, rectifying and return to service of standing alarms.

Recommendation 16 – BNGSL should review the alarms and indications that appear on the THORP HEC Plant DCS screens and implement appropriate changes so that only those pertinent to the control and supervision of this plant are displayed. BNGSL should also review the other alarm screens in THORP to ensure this problem is not widespread.

Recommendation 17 – BNGSL should review the frequency of sump sampling in THORP to ensure that it is effective, taking into account the consideration that the plant is getting older and the original sampling frequency may no longer be appropriate.

Recommendation 18 – BNGSL should provide adequate written instructions for plant operations for taking, processing and responding to the results from routine sump sampling operations in THORP and have adequate control, supervision and monitoring to confirm that such operations are carried out.

Recommendation 19 – BNGSL should provide CPIC with a means of flagging whether safety-sampling results are within or outside specification and provide arrangements for responding to such results within THORP.

Recommendation 20 – BNGSL should improve oversight (in particular supervision, monitoring, audit and review) at all levels of management and put in place adequate arrangements to ensure that response to and recommendations from events are tracked, lessons learned are implemented and improvements followed through and embedded. BNGSL should also consider again the earlier MIR/98/028 and ensure processes are in place to ensure recommendations from investigations are closed out and embedded into operational practice.

Recommendation 21 – BNGSL should ensure that in THORP there are clear responsibilities defined and adequate resources provided for plant monitoring and trending so that leaks of radioactive material from primary containment into secondary containment cannot occur without being detected.

Recommendation 22 – BNGSL should review the role of the THORP HEC Plant STM, whether the job scope, range of duties and responsibilities is appropriate compared to other THORP STMs and in particular whether it is appropriate to include safe systems of work duties.

Recommendation 23 – In addition to Recommendation 4 above, in THORP BNGSL should:

- a) review the philosophy of separating out SRE maintenance into the 'Normal Plant Schedule' and proof testing into the 'Plant Maintenance Schedule' and compare the THORP arrangements with BNGSL best practice and implement a standard cross-site system;
- b) for SRE or SMs, specify the maximum time that should elapse between carrying out maintenance and the completion of proof test;
- c) review whether, for SRE or SMs, the maintenance activity and the proof test should be issued as one job card, so that the activity is not complete until proof test is satisfactorily completed;
- d) review how to use the instrument's available historical trend data within the maintenance and proof testing procedures.

Recommendation 24 – BNGSL should ensure that all THORP non-routine intrusive interventions that might affect safety or safety-related equipment are adequately recorded. This should include a review of resources. BNGSL should also develop audit and review arrangements for analysing such records.

Recommendation 25 – BNGSL should identify THORP personnel who may need to analyse data trends from the plant systems and provide adequate training for these personnel, so that they are SQEP for the task of retrieving, trending, analysing and evaluating the data.

Recommendation 26 – BNGSL should review the efficacy and rigour of the training arrangements for E&I maintenance craftsmen so that they are SQEP for the maintenance of instrumentation in THORP.

Recommendation 27 – BNGSL need to review relevant research on diagnosing non-routine faults on complex plant, review the design of appropriate training to improve fault identification skills and implement improvements in THORP.

Recommendations from the initial investigation communicated to BNGSL on 27 June 2005

- 1 BNGSL should consider changing the role of NMC to a line management role, and a DAP role, aided by a deputy in manufacturing support, to do the work.
- 2 BNGSL should consider reinstating a more frequent sump-sampling regime to give additional early warning of plant primary containment failures.
- 3 BNGSL should consider introducing routine operational limits to the CPIC analysis data so that out of specification results requiring attention are flagged up clearly.
- 4 BNGSL should review the concerns raised by this failure and consider the implications elsewhere in THORP and site wide.
- 5 BNGSL should consider why the instrument was returned to operation when it was apparently showing an alarm.
- 6 BNGSL should consider reviewing the safety case for the operation of THORP taking into account the lessons learned from the feed clarification cell incident.

*Actions NII would expect to be completed prior to restart communicated to
BNGSL on 2 November 2005*

- 1 A requirement for an overarching safety strategy paper that covers the requirements of THORP as a whole and not just the FCC workstream (LC22 (4)).
- 2 The completions of the activities BNGSL believes are required to transfer the contaminated material in the HEP SEP buffer tanks to chemical separation and beyond the THORP boundary (eg HA Evaporator Envelope).
- 3 Adequate safety case for the transfer of contaminated material in the HEP SEP buffer tanks through chemical separation plant and beyond the THORP boundary (LC14).
- 4 Adequate safety case for the operation of the feed clarification cell operations in Head End (LC14).
- 5 Operating strategies for upstream and downstream of the FCC both within THORP and those areas affected by THORP's feed envelope and throughput (LC34).
- 6 Adequate safety case for the THORP plant on reduced throughput or other conditions necessary for the revised operation of the feed clarification cell (LC14).
- 7 The consideration of contingency options that need to be in place in the event of a further failure of head end or chemical separation, eg a safety case and commissioning for a reversal of the fuel feed chute (LC34).
- 8 Implementation of an adequate framework for management of safety across the whole of B570 including as a minimum the provision of adequate technical support and trend analysis (LC25, 26 & 27).
- 9 Acceptable close out of Bol recommendations, requirements from NII Improvement Notices and additional requirements from NII technical investigation except via prior agreement with NII.
- 10 Implementation of 1998 event management investigation recommendations where they differ from the current Bol requirements.
- 11 Review of arrangements for changes in operational modes throughout THORP eg new operating instructions, STM guidance (LC24).
- 12 In-cell inspection of all critical cells and vessels within cells on the basis of a 'start off right' philosophy (LC28).
- 13 Identification of a new continuous/regular monitoring regime for the integrity of cells and vessels (LC28).
- 14 Implementation of new EIM&T strategy and arrangements for the immediate areas of concern (eg in-cell inspection, revised pneumatic maintenance)(LC28).
- 15 BNGSL readiness inspection.
- 16 Allocation of planned time for NII readiness and compliance inspection.

Issues that NII would expect to be initiated prior to start up, have a project programme and have established agreed end points with the NII - communicated to BNGSL on 2 November 2005

- 1 Fatigue assessment of nozzles and pipework of in-cell vessels. This consists of identification of vessels that may undergo in-situ vibration, identification of vulnerable nozzles and assessment of those nozzles that have a safety role or could stop or reduce the throughput of the overall fuel processing (LC28).
- 2 Implementation of the new in-cell inspection regime for all 'non-critical' cells and vessels within cells (LC28).
- 3 The consideration of longer term and wider Sellafield contingency options, which need to be in place in the event of a further failure of THORP and which impact on the oxide fuel operating plan (LC34).
- 4 EIM&T strategy and arrangements for THORP B570 (eg in-cell inspection, revised pneumaticator maintenance) (LC28).
- 5 Incorporation of THORP within a site-wide programme devoted to safety culture change in a finance driven environment (LC36).
- 6 Implementation of the site-wide programme for safety culture change within THORP (LC36).

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