Health & Safety Executive
HM Nuclear Installations Inspectorate

An investigation into a dropped fuel element incident at Chapelcross Nuclear Power Station

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Foreword

This report sets out the findings of the investigation into an incident at BNFL's Chapelcross Nuclear Power Station carried out by HM Nuclear Installations Inspectorate (NII), part of HSE's Nuclear Safety Directorate. On 5 July BNFL reported that during routine defuelling activities on Reactor 3, a basket containing twenty-four low rated irradiated Magnox fuel elements had fallen a few feet within the discharge machine onto the door at the top of the fuel discharge well. This well is just over 80ft (24.4m) deep and is used to discharge spent fuel from the reactor. BNFL thought that the door was closed. Seven days later BNFL were able to deploy a remote TV camera into the discharge machine and this revealed that twelve of the elements were missing. Further remote inspection showed that although the discharge well door was fully closed the missing elements must have fallen past the door and down the discharge well into a water filled transport flask at the bottom.

The NII investigation began shortly after BNFL notified it of the event on 5 July 2001. Inspections were carried out between 9-12 July, 23-25 July and 10-12 September 2001. The investigation was initiated because dropping irradiated fuel elements is a serious issue even when, as in this event, BNFL had advised NII that there had been no release of radiological activity.

The investigation has found that no worker or member of the public incurred any harm from release of radioactive material. It has identified the likely cause of the event, and established that there was no deliberate attempt at deception with respect to reporting events or status of plant. The NII investigation has produced several recommendations and BNFL has now implemented a programme to address these. Progress against the programme is being monitored as part of NII's normal process of regulation. Should progress be inadequate, NII will not hesitate to use its enforcement powers to ensure safety is maintained.

If you have any comments, or would like further information on the issues discussed in this report, write to the Chief Inspector at the address below:

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SUMMARY

At 1.20 am on 5 July operators at BNFL's Chapelcross Nuclear Power Station were preparing to lower a discharge basket containing twenty-four irradiated Magnox fuel elements from No.6 discharge machine on Reactor 3 (R3). Before this routine activity could be completed the discharge basket became detached from its basket grab and fell onto the discharge well door underneath the discharge machine. BNFL reported the occurrence of this event to HM Nuclear Installations Inspectorate (NII), a part of the Health and Safety Executive's Nuclear Safety Directorate (NSD). The basket of fuel was initially reported as only having fallen a few feet onto the door which is at the top of the discharge well down which spent fuel is lowered. The door was thought to be closed. Seven days later the results of remote TV examinations found that twelve elements were missing from the discharge machine and had fallen into a water filled transport flask at the bottom of the discharge well.

Dropping irradiated fuel elements is a serious issue and, even though BNFL had informed NII that there was no release of radioactivity, NSD's Director and HM Chief Inspector of Nuclear Installations instructed that a team of inspectors should be sent to Chapelcross to investigate the incident, report its findings, and make recommendations on the need for action.

The investigation focused on determining what caused the basket to become detached from the grab, why it took seven days to discover that not all of the fuel had remained inside No.6 discharge machine, and whether there were grounds for health and safety enforcement action. To achieve these ends it looked at the operation of the defuelling equipment, the potential radioactive release from the broken fuel elements and associated health consequences, the performance of personnel, the design aspects and safety justification for operating the equipment, maintenance, training, and at the appropriateness of an existing station improvement programme.

The investigation identified a number of recommendations to improve the safety of the defuelling process and these are now being addressed by BNFL. Overall it concluded:

(i) that no worker or member of the public incurred any harm from the release of radioactive material as a result of the event;

(ii) that such incidents can be prevented by implementing two plant modifications to the defuelling equipment;

(iii) that there was no deliberate attempt at deception with respect to reporting events or status of plant; and

(iv) through the application of HSE's enforcement criteria, prosecution of BNFL was not appropriate and that the BNFL response to the identified recommendations should be monitored through NII's normal regulatory processes.

CONTENTS

INTRODUCTION

Chapelcross and Calder Hall Nuclear Power Stations

1. The Chapelcross Nuclear Power Station is situated near the town of Annan, between Dumfries and Carlisle on the north side of the Solway Firth. It consists of four similar reactors the first of which was commissioned in 1958 followed by the other three in 1959. Their design and specification are similar to those of the Calder Hall power station located on the south-east side of BNFL's Sellafield site on the Cumbrian coast which were commissioned between 1956 and 1958.

2. The reactors contain fuel elements made from uranium metal contained within magnesium alloy "Magnox" cans. There are 1696 channels within each reactor's graphite core and each channel contains up to six fuel elements.

3. The reactor core is housed within a steel pressure vessel that provides the containment system for the reactor coolant. The reactor is surrounded by a reinforced concrete biological shield to provide protection from the intense radiation generated by the fission process. The fuel in each reactor is cooled by a flow of pressurised carbon dioxide gas. The hot carbon dioxide gas is passed through steel ducts to the four boilers on each reactor. Steam from the boilers drives turbines which produce fifty megawatts of electrical power (net) per reactor.

4. Periodically the fuel is replaced. Unlike the later Magnox reactors, the Chapelcross and Calder Hall reactors are only refuelled when they are shutdown and depressurised. It was during one of these planned refuelling periods that the incident occurred.

The Incident and NII's Investigation

5. At 1.20 am on 5 July operators at BNFL's Chapelcross Nuclear Power Station were changing some fuel on Reactor 3. They were preparing to lower a discharge basket containing twenty-four irradiated Magnox fuel elements from inside the No.6 discharge machine through its radiologically shielded traverser and into the discharge well (see Figures 1 and 2). Before this activity could be completed the discharge basket became detached from its grab assembly and fell a few feet onto the door at the top of the discharge well that at the time was thought to be closed.

6. BNFL reported the occurrence of this event to NII at 7.00 am on 5 July in accordance with the requirements of the Conditions attached to its Nuclear Site Licence. NII set up its Response Centre at Bootle to co-ordinate its response to the event. The site inspector was sent to the site and he arrived at 10.48 am. At 6.00 pm on 5 July BNFL stood down the Chapelcross Emergency Control Centre on the basis that the basket of fuel was in a stable condition and no radioactivity had been released. On notification of this state NII decided to stand down its Response Centre.

7. Dropping irradiated fuel elements is a serious issue and even though BNFL had informed NII that there was no release of activity, NSD's Director and HM Chief Inspector of Nuclear Installations instructed that a team of inspectors be sent to Chapelcross to investigate the event. Two inspectors with administrative support

arrived at Chapelcross on 9 July to begin the investigation. They returned to NII's HQ on 12 July.

8. BNFL introduced a remote imaging camera into the defuelling machine to investigate the condition of the fuel and on the evening of 12 July BNFL informed NII that the results of the enhanced remote imaging revealed that twelve of the elements were missing from the discharge machine. A Site Incident was declared at 7.55 pm on 12 July by the Station Manager in response to the changed status of the incident.

9. Initial information suggested that there was the possibility of damaged fuel at the bottom of the Discharge Well. On learning of the changed circumstances NII suspended its formal investigation into the incident on 13 July and reinitiated its nuclear incident response arrangements. The Torness Site Inspector, who was returning from Torness in Scotland, was diverted to Chapelcross to monitor BNFL's activities pending the arrival of a new team of inspectors to oversee BNFL's recovery operation. Further remote inspection through a ventilation shaft showed that the missing elements had fallen into a water filled transport flask at the bottom of the discharge well (see Figures 1 and 2). The NII teams were stood down at 9.00 pm on 17 July when all fuel elements had been accounted for and those which had dropped to the bottom of the discharge well had been recovered and were in a safe state in the reactor storage pond.

10. On 19 July NII resumed its investigation and an expanded team of four inspectors visited Chapelcross for three days between 23-25 July. The key issues for the investigation team were:

(i) What caused the basket to become detached from the grab?

(ii) Why did it take seven days to discover that not all of the fuel had remained inside No.6 Discharge Machine?

(iii) Was there evidence on the grounds of health and safety to warrant enforcement action for breach of licence conditions or other statutory requirements?

11. The investigation team examined equipment, records and drawings, interviewed staff involved and, where appropriate, took statements. It also had access to inspectors who were involved in NII's response to the event, and the video records and drawings they used whilst monitoring the licensee's response.

12. The team reported to NII's management on 31 July with interim conclusions, identified areas requiring further investigation, and gave a view on the regulatory implications. Two members of the team completed the investigation by visiting Chapelcross between 10-12 September.

DESCRIPTION OF THE PLANT

13. The key components associated with the defuelling process are shown in Figures 1 and 2 and a brief description of these is provided in Appendix 1.

14. To remove fuel from the reactor and place it in a spent fuel storage pond, the operators have to:

(i) load an empty fuel basket into the discharge machine;

(ii) move the discharge machine to the required position over the reactor core;

(iii) lift the fuel elements out of the reactor and into the fuel basket;

(iv) transfer the discharge machine, containing the loaded fuel basket, to above the discharge well;

(v) open the discharge well door;

(vi) lower the basket down the discharge well and into a water filled shielded flask;

(vii) fix the lid onto the flask and transfer it to the spent fuel storage pond.

RESULTS OF THE INVESTIGATION

15. The results of the investigation are presented below by describing the significant aspects of the defuelling process, the likely circumstances that led to the incident, the response of the staff at the station, and consideration of health consequences from any release of radioactivity from the broken fuel elements. The investigation of possible contributing factors is also reported.

Connecting the Basket Grab to the Discharge Basket

16. At the start of the process the operator lowers the basket grab down the discharge well onto the top of an empty fuel basket that has been placed at the bottom of the discharge shaft. Once the jaws of the grab are positioned around the lifting lugs of the discharge basket they are electrically driven into a closed position to latch the basket to the hoist. This is achieved by the counter rotation of the inner and outer cylinders. We found that there was no means of ensuring that the jaws properly latch onto the discharge basket pintle lifting lugs. Figure 3 shows the pintle lifting lug correctly seated within the basket grab jaws. Figure 4 shows a simulation of the grab jaws partially open. There is evidence from the as-found condition of the grab assembly to suggest that the jaws may not have been fully closed when the grab was connected to the basket at the start of operations.

17. Subsequent tests carried out by BNFL have shown that during closure of the grab, “spring back” can occur which can result in the jaws not being fully closed. These tests have shown that if there is only 25-50% relative movement between the inner and outer cylinders the discharge basket can still be lifted without the jaws being fully closed. The tests have also shown that there is a critical position where the jaws can spring open under the weight of the discharge basket. It is possible

that if the jaws of the grab had not been fully closed and were close to this critical position a jolt could cause them to spring open and allow the basket to drop.

18. A mechanical indicator on the basket grab shows the relative position of the two concentric cylinders. The indication is provided by a slot cut into the outer cylinder and a recessed dimple in the surface of the inner cylinder. When the dimple is at one end of the slot the grab jaws are fully open and at the other end they are fully closed (Figure 5).

19. Our investigation found that it is only possible for the operator to attempt to confirm the position of the dimple within the slot, if it is aligned with either a camera mounted inside the discharge chamber (which has very limited capability), or an introscope which again has only a limited field of vision. This alignment with the camera does not routinely happen because the grab assembly is suspended on a long cable and freely rotates as it is raised and lowered. Interlocks prevent the operators entering the discharge chamber and visually confirming that the grab assembly had been correctly connected to the basket.

20. Operator action during the initial connection of the grab to the discharge basket is limited to pressing sequence interlocked buttons on control panels mounted on the outer walls of the discharge chamber. The Operating Instruction only requires the operator, who is at ground floor level outside the discharge chamber, to listen for a sound which is assumed to be indicative of the grab closing and successfully engaging onto the discharge basket. At no stage throughout the time that the basket is attached to the grab is the operator required to attempt to make any visual checks to confirm that this assumption is correct, nor is the safety significance of ensuring a successful connection highlighted in the Operating Instructions.

21. Our investigation concluded that safety would be improved by the installation of additional cameras within the discharge chamber to enable the operator to check and confirm that the basket grab is correctly latched before attempting to raise the basket up the discharge well.

Disconnection of the Grab Hoist/Electric Grab Driving Mechanism from the Basket Grab

22. After attaching the empty basket the operator raises it into the discharge machine at the top of the well. A steel pin is then inserted into the top of the grab which transfers the weight of the discharge basket onto the top of the discharge machine and allows the electric grab driving mechanism (the electric head) to be disconnected.

23. Once the electric head has been removed two red alignment marks on the top face of the basket grab can be seen. These can be used by the operator to confirm that the jaws are fully latched before beginning defuelling operations. However, we found that this confirmation is not required in the Chapelcross Operating Instructions.

24. An alternative, and what is considered to be a better approach, is to fit a mechanical lock over the jaws. As a result of a similar event at Calder Hall in 1985, in which a fuel discharge basket was dropped from the grab and fell 81ft (24.7m)

down the discharge well, a plant modification was made which resulted in a retaining device, called a “top hat”, being fitted over the top of the basket grab. This retaining device locks the jaws in a fully closed position. Our investigation found that an equivalent modification was not made at Chapelcross and concluded that safety could be improved by such a modification.

Fitting the Discharge Machine Door

25. To protect the operatives from radiation whilst manoeuvring the discharge machine the operator fits the machine’s bottom door. To do this the discharge machine is moved from the discharge well door to its position above the door jack where the door is fitted onto the bottom of the discharge machine. The weight of the basket is then supported by the turntable on the inner surface of the door assembly. Under normal circumstances this results in the discharge basket being pushed upwards by about 10 mm relative to the grab assembly and removes its weight from the grab jaws, but this is not sufficient to cause a basket to unlatch. If however the basket was to be lifted by 20 mm, the jaws become free to rotate and then there is the possibility that they could open. We found no evidence that this occurred during this incident.

Loading Fuel Elements into the Discharge Machine

26. Once the operator has fitted the discharge machine door he moves the discharge machine from the traverser onto the pile cap. In order to load fuel elements into the discharge basket each of the basket’s twenty-four fuel element pockets are sequentially rotated to align with the fuel element grab. The indexing system used to rotate the basket through 360^{o} imposes a jolt that is capable of causing relative movement between the inner and outer cylinders of the basket grab assembly and hence potential for the grab jaws to open. Under normal circumstances retention up-stands on the end of each grab jaw prevent this occurring because they locate against the discharge basket pintle lifting lugs (Figures 3, 4 and 6).

27. Once all the fuel elements have been loaded the basket is once again gradually indexed through 360^{o} to allow an operator to look through the introscope on the side of the discharge machine to visually check that each fuel element is correctly aligned within its retention pocket. This rotation operation imposes a further jolt on the connection between the basket grab and discharge basket pintle lifting lugs.

Removal of the Discharge Machine Door

28. Once the discharge basket has been filled the operator moves the discharge machine to the door jack so that its door can be removed. After this is complete the discharge basket is once again suspended from the basket grab. The operator then uses the traverser to move the discharge machine until it is above the discharge well door. Interlocks are provided to ensure that the discharge well door is closed during this operation.

Reconnection of the Grab Hoist/Electric Grab Drive Mechanism to the Basket Grab and Opening of the Discharge Well Door

29. To permit lowering of the basket into the transfer flask, the operator has to reconnect the electric grab driving mechanism. In preparation for this the Operating Instructions require the operator to open the discharge well door. In addition the electric head cannot be connected to the basket grab until the discharge basket has been indexed into a fixed alignment position. This indexing process imparts further jolts onto the connection between the grab jaws and pintle lifting lugs of the suspended basket. These also have the potential to introduce relative movement between the inner and outer cylinders of the grab assembly (see paragraph 26). It was during a third such index movement that the basket fell from the grab.

30. Licensees classify their Operating Instructions in terms of safety importance such that the most important are followed line by line and steps are checked and signed off. The current Chapelcross Operating Instruction for activities associated with transferring fuel elements from the discharge machine into the transit flask has been used since 1995. BNFL's classification of the instruction for this process did not require it to be at the point of work, or place an explicit requirement on operators to complete activities in a particular sequence, or provide a check sheet to assist and provide a record to confirm sequential completion of key activities. The sequence of activities in the procedure suggests that the operator is expected to fully open the discharge well door prior to aligning the basket grab for connection to the electric head but we found that on some occasions custom and practice has led to both activities being done in parallel. Clearly on this occasion, at the time of the incident, the door had not been fully open and this prevented the basket from falling down the discharge well. We conclude that the defuelling procedures and QA arrangements should be reviewed and a programme for improvement implemented.

31. The hoist well door only opens or closes when the operator is depressing the respective panel button, movement stops as soon as the button is released. The investigation found no evidence to suggest that without operator intervention the door could open or close in an uncontrolled manner. Only a "door closed" or "door open" light is available on the discharge machine control panel and the operator is not provided with any information about intermediate positions. However, the position of the door was significant in the operator's response to this incident. We therefore conclude that consideration should be given to providing the operators with better information on the position of the door.

32. Our investigation recorded measurements taken during a demonstration of the Chapelcross Reactor 2 defuelling system. These showed that within fifteen seconds the hoist door moves from fully closed to fully open. They also showed that, if the "hoist door open" button had been depressed for less than three seconds, the gap would have been sufficient for twelve elements from one side of the basket to fall past the partially open door, given that simultaneously the fuel elements bounced out of their retention pockets.

33. Our investigation also found that the discharge basket being used at the time of the incident only had a small rolled edge at its base which provided limited retention capability (Figure 7). This would not have been sufficient to prevent fuel

elements from jumping out of their recess as a result of the impact load from the basket striking the door of the hoist well. We conclude that this type of discharge basket should be withdrawn from service.

34. A video film examined by NII's Investigation Team provided evidence consistent with the basket falling onto a partially open discharge well door. It showed that twelve of the twenty-four fuel elements were still retained within the discharge machine and were intact. However, eleven of these elements had bounced out of the bottom of the discharge basket (Figure 7) and although their upper half remained in a pocket location, the lower end of each element was resting on the upper surface of the discharge well door. The basket was lying at an angle and close up to one side of the discharge machine. There were score marks on the door which suggested that the discharge basket could have been pushed across as the discharge well door closed. The empty pocket locations were in a continuous arc on the side of the basket that the door opens from. There was also evidence of impact damage to one side of the discharge well door which again suggested that the basket had fallen onto it when it was partially open.

The Likely Circumstances that Led to the Incident

35. Our investigation team judged that the jolt imposed on the basket during the final alignment movement would have been sufficient to make it fall from the grab if the jaws were sufficiently open to allow the discharge basket pintle lugs to topple off the retention up-stands of the grab jaws. Consequently, we concluded that the most probable cause of the basket becoming detached was due to this jolt being coincident with the jaws either gradually opening during defuelling until they reached the critical position where they could spring open (see paragraphs 17 and 26) or for the basket to have been manoeuvred without the jaws being fully closed at the time of initial latching (see paragraphs 16 and 17). The basket must then have fallen onto a partially open hoist well door.

Chapelcross Response to the Incident

36. When the discharge basket became disengaged from the basket grab the operators working on top of the discharge machine reported hearing a very loud "bang". They immediately concluded that the noise was caused by the fuel basket falling from the grab and hitting something. Their initial judgement was quickly confirmed when they looked through the discharge machine introscope and saw that the discharge basket was lying at an angle with its top surface level with the penetration, a drop of several feet. The limited field of view provided by the introscope prevented the operators from being able to see what had happened to all the fuel in the basket.

37. Immediately after the event none of the shift team members who had been working on the discharge machine could explicitly recall anyone taking action to initiate opening the discharge well door. However, one of them did report that just as the discharge basket fell he saw the "discharge well door closed" light extinguishing. This person then moved to the discharge machine's control panel and depressed the "discharge well door close button". At the time he stated that the button could only have been depressed for about a second since the "door closed light" almost

immediately re-lit. Consistent with most of the Shift Team at the time of the event he believed that it took at least thirty seconds for the discharge well door to move from fully closed to fully open. The operators therefore attributed no significance to this action.

38. The shift team management also attributed no significance to the report that the "discharge well door closed" light had gone out. This was because no-one could recall pressing the "discharge well door open" button, the reported time-scale needed to depress the "discharge well door close" button was judged to be insufficient to create a gap through which fuel could fall, and use of the introscope had provided visual evidence that the basket was inside the discharge machine. Consequently, when the shift team management and its staff were asked on several occasions by people such as the Station Manager and the Operations Manager whether the door had been opened, they were provided with confident answers. At that time, this led to the belief that the discharge machine door had not been opened, and consequently the discharge basket was within the discharge machine with all the twenty-four fuel elements.

39. Our investigation found that the initial response of the shift team management and health physics supervisor focused on the correct issues. These were to take action which would protect the health and safety of station staff and mitigate against the possibility that some fuel elements might be damaged or overheating. Environmental monitoring was established, filtered ventilation was also set up along with access controls to limit people coming onto the pile cap. The hydraulic and electrical supplies to the equipment were also isolated. A limited visual check, using the introscopes, confirmed that the discharge basket was still retained inside the discharge machine and BNFL could see sufficient fuel elements to give it confidence to conclude that elements were still in the discharge machine.

40. We found that the approach taken with respect to isolation of the equipment was consistent with securing the plant in a safe configuration by preventing further operation of the fuelling equipment. However, the design of the system is such that in isolating the electrical supplies to the defuelling equipment, operators inadvertently isolated some gamma radiation monitors which were capable of monitoring for the presence of spent fuel elements in the discharge chamber below the discharge well. Spent nuclear fuel elements are readily detectable from the gamma radiation they emit and, if the gamma radiation monitors had been working, they would have given an indication that fuel was present in the transit flask. This would have alerted the operators to the fact that fuel elements had fallen past the discharge well door at the time of the event. We conclude that, to improve safety, the gamma monitors should be supported by an independent power supply .

41. The person instructed to complete the electrical isolation by removing the fuses was authorised to do this work but was not familiar with all the defuelling equipment, particularly the instrumentation such as the gamma monitors on the discharge chamber wall. Therefore, he could not have been expected to appreciate the consequences of isolating the supplies. The operator training aspects of this finding are being taken forward as part of the wider improvement of training arrangements that is already under way (see paragraph 55).

42. Our investigation found no evidence to suggest that there was a deliberate attempt at deception with respect to reporting events or status of plant. All the evidence indicates that throughout the period from 5-12 July everyone involved in either reporting or responding to the event believed that all the fuel was retained inside the discharge machine. Monitoring results appeared to confirm this belief. Consequently, the situation was considered stable and the focus was to ensure continued protection with respect to health and safety and obtain information as a precursor to developing a recovery programme to retrieve the fuel from the discharge machine.

43. The BNFL response involved monitoring to confirm that radiological conditions remained stable, and that fuel temperatures remained acceptable. The carbon dioxide atmosphere within the discharge machine was controlled to introduce a further barrier to any possibility of a fuel fire. Arrangements to use complex remote cameras to establish the extent of any fuel damage within the discharge machine and confirm that the discharge well door was not significantly damaged and likely to fail were also developed.

44. On 7 July BNFL inserted a remote camera through an introscope penetration on the side of the discharge machine. The video film from this camera provided inconclusive information. Actions were then taken to remove the basket grab from the discharge machine and insert more sophisticated remote camera equipment through this opening. Preparation to do this was very thorough, cautious and included safety case clearance. This took several days to complete and the second camera entry was not made until 12 July. This inspection provided the unexpected evidence that not all the fuel had been retained inside the discharge machine. Once the Station Manager learnt that twelve elements were unaccounted for he reviewed the position and he declared a Site Incident at 7.55 pm on 12 July and informed NII.

45. The station's management team, with the benefit of hindsight, recognise that during the station's response to the event it could have been more rigorous in its questioning and challenging of the assumption that all twenty-four elements were still in the discharge machine. Our investigation concludes that BNFL's emergency response arrangements should emphasise the need to question and independently verify all facts concerning incidents.

Health Consequences

46. Our investigation confirmed that the twelve fuel elements that were not retained in the discharge machine fell into a water-filled transit flask at the bottom of the fuel discharge well. Three of the fuel elements were broken in the fall. BNFL concluded that, based on the irradiation history and cooling time of the fuel, there would have been no significant release of volatile fission products such as iodine. We agree with this analysis. We are confident that there was no significant release of radioactive material as a result of this event. This is supported by the results of subsequent local and environmental monitoring. Our investigation concludes that no worker or member of the public incurred any harm from release of radioactive material as a result of this event.

Design Aspects

47. The design of the defuelling equipment is basically the same as when the station was commissioned in the mid 1950's. In 1994, in response to a NII regulatory action, additional interlocks were fitted to the defuelling equipment to provide enhanced safety to protect the operators.

48. The potential for a basket of fuel elements to drop down the discharge well in an uncontrolled manner was considered by BNFL in the aftermath of a similar event that occurred at Calder Hall in 1985. In this event a basket full of fuel fell the full height of the well into a water filled flask at the bottom. The basket on hitting the water in the flask acted like a piston and decelerated without any significant damage to the fuel. BNFL concluded that a safety case for this type of fault could be made provided that whenever fuel was being lowered down the well there was a water filled flask at the bottom.

49. BNFL therefore decided to base its safety case on an administrative procedure. This required the operators to position a water filled transit flask at the bottom of the discharge well and to fully open the discharge shaft door before attempting to connect the basket to the electric head and lower the discharge basket. However, the interlock system does not prevent the door being moved during the alignment of the upper and lower halves of the grab before they are joined.

50. Our investigation identified the possibility of a single failure in the basket hoist loading system leading to an uncontrolled drop of fuel. We could find no evidence to suggest that the safety justification for operating the discharge machine and lowering the discharge basket down the discharge well had been reviewed or questioned by BNFL in light of current standards and expectations. Current standards would not normally accept the potential for irradiated nuclear fuel to free fall over 80ft (24.4m) as the result of a single failure of a component. We conclude that such a review should be undertaken by BNFL.

Maintenance

51. Our investigation found that there is little planned preventative inspection and maintenance on the equipment associated with the fuel route and in particular the discharge route. Rather a breakdown maintenance philosophy appears to be the norm backed up by pre-operation testing. In particular, prior to the start of a defuelling campaign, the equipment is operated to test that it is in satisfactory working order. This is carried out by operations staff with maintenance staff standing by to address any problems identified. The process does not require comprehensive testing of individual components and their settings to confirm their readiness for use. We conclude that the inspection and maintenance arrangements for the fuelling routes should be reviewed and reasonably practicable improvements made to the process for confirming the readiness of equipment.

52. During defuelling on Reactor 3 the staff had experienced a higher than normal frequency of defuelling equipment defects, particularly with respect to interlocks. This led to an operations review at the beginning of June 2001. In June the

Chapelcross management suspended defuelling until full consideration of these problems had been completed, adjustments made to the equipment and tests completed. However, we found that none of the previous equipment defects were directly related to the subsequent dropping of the basket.

53. One of BNFL's initiatives associated with its programme designed to improve standards has focused on minor event reporting and the appointment of a Learning From Experience (LFE) Manager. Because of these new initiatives some of the operating difficulties were not only raised as plant defects but were also reported as minor events requiring investigation. The LFE manager had also noted an adverse trend of seven minor events early into the reactor shutdown compared with the maximum expectancy of two. The minor event reports were considered by a panel of three people and a similar proposal for action was made as that already taken by the operations review .

54. On each of the two days preceding the dropped fuel event the control panel light indicating "discharge well door closed" was not illuminating even though the door was believed to be fully closed. Each of these occurrences were investigated and reported as cleared before operations were resumed. We judge that the occurrences during the two days preceding the dropped fuel event could have contributed to the operators' belief that although the "discharge well door closed" lamp was seen to extinguish coincident with the dropping of the basket this was neither significant nor unusual.

Training

55. Our investigation identified a number of deficiencies in training arrangements related to previous major staff reductions. BNFL had earlier recognised the need to enhance staff capabilities and at the time of the incident it was part way through a training programme to significantly improve staff performance and behaviour. The BNFL training programme is based on three fundamental elements namely providing good quality training facilities, having experienced and competent trainers, and allowing staff the opportunity to complete agreed training programmes. The first has recently been completed, the second is almost complete and proposals are being considered which will ensure staff can be released for training. This programme has been undertaken as a result of previous NII discussions and we judge that the completion of it will address the training deficiencies noted during this investigation.

Chapelcross' Existing Improvement Programme

56. NII are already working to ensure that BNFL improves safety culture at Chapelcross. This arose from concerns about the impact of destaffing in the 1990s and is being addressed by the new Chapelcross management team and the workforce. BNFL had appointed the new Station Manager to bring experience from operating other BNFL Magnox stations and with the support of the new BNFL senior management he has been successful in increasing staff numbers and improving station performance. The investigation confirmed the NII's Chapelcross Site Inspector view that the station has an adequate programme in place to improve standards and expectations in line with modern best practice.

PRESENT POSITION

Defuelling Embargo

57. As a result of the event BNFL voluntarily suspended reactor fuelling activities at both Chapelcross and Calder Hall until it understood how the event could have occurred and, for each station, had produced a satisfactory safety case to justify resumption. BNFL has agreed that it will not lift its embargo on defuelling at either station until NII is satisfied that there is an adequate case to demonstrate that it is safe to do so.

Fuel Recovery

58. During September and October 2001 BNFL developed a proposal for the recovery of the twelve fuel elements left inside the discharge machine. Towards the end of October NII agreed that there was an adequate safety justification for this work to be undertaken and authorised the commencement of the recovery. Complex remote handling equipment returned the elements to the discharge basket and reconnected it to the basket grab. The basket was then lowered from the discharge machine into a transit flask. No problems arose during the recovery and the elements have been transferred to the spent fuel storage ponds and have now been sent to Sellafield for reprocessing. Examination has not identified any significant damage to this fuel that had been retained in the discharge machine.

59. To complete our investigation we inspected the extent of damage to the basket on 22 November 2001 after it had been recovered. We concluded that the damage was consistent with it having fallen a few feet onto a partially open discharge well door.

Requirement for BNFL Action in Response to NII's Investigation

60. NII's application of the HSE enforcement criteria to the results of its investigation showed that it was inappropriate to prosecute BNFL. This was mainly because there was no harm to personnel and no intentional or blatant disregard for the law.

61. BNFL investigated the incident fully and initiated its own programme of improvement. Our investigation has also identified the need for BNFL to complete a programme of work (see below). Whilst some of the work programme is specific to Chapelcross, the majority requires action at both Chapelcross and Calder Hall due to their close links and similarity in design.

62. Specific to Chapelcross is the need to fit a Calder Hall "Top Hat", improve the inspection process for confirming the readiness of defuelling equipment, and installing a gamma monitor with independent electrical supply in the discharge well area to check for the presence of irradiated fuel elements. The requirements common to the fuel routes of both stations are: completing inspection of load bearing components before resumption of routine defuelling; reviewing the defuelling safety case against modern standards; installing additional cameras within the discharge chamber; providing improved information to the operator about the status of the

discharge well door; improving the procedural and QA arrangements of the defuelling cycle; demonstrating the qualifications and experience of personnel involved in the defuelling cycle; reviewing the arrangements for responding to breakdowns/intermittent faults and routine reviews of the continuing performance of the plant.

63. We consider that after fulfilling the immediate engineering and operational modifications BNFL needs to re-commission the fuel route to demonstrate that the staff are adequately trained in the new procedures and the modified equipment functions properly.

CONCLUSIONS

64. No worker or member of the public incurred any harm from release of radioactive material as a result of the event (see paragraph 46).

65. The mechanisms that could have caused the uncontrolled release of the basket from the basket grab can be prevented by implementing two plant modifications to the defuelling equipment; these are: (i) installing cameras inside the discharge chamber to allow the operator to confirm full and correct latching by the basket grab, and (ii) fitting the Calder Hall "top hat", (see paragraphs 21 and 24).

66. There was no deliberate attempt at deception with respect to reporting events or status of plant (see paragraph 42).

67. Application of HSE's enforcement criteria to the results of the investigation has shown that it would not be appropriate to prosecute BNFL. However the NII Site Inspectors will ensure BNFL completes the necessary improvement programmes (see paragraphs 60 and 61) through their normal regulatory activities.

68. Improvements can be made to further reduce the potential for equipment failures within the fuel route and enhance operator performance. (see paragraphs 62 and 63).

RECOMMENDATIONS

69. In order to prevent a repeat of this accident, to further reduce the potential for equipment failures within the fuel route and to enhance fuel route operator performance, we recommend that BNFL complete the following:

Before the Resumption of Routine Defuelling at Chapelcross

(1) Install the Calder Hall "Top Hat" mechanism and train personnel in its operation and maintenance to prevent unplanned opening of the grab jaws (see paragraph 24).

(2) Review and improve as far as is reasonably practicable the inspection and maintenance process for confirming the readiness of defuelling equipment at the start of each refuelling cycle (see paragraph 51).

(3) Install an independent electrical supply to the gamma monitor in the discharge chamber to provide an effective operational check for the presence of irradiated fuel elements (see paragraph 40).

Before the Resumption of Routine Defuelling at Chapelcross and Calder Hall

(4) Inspect the load bearing items of the grab hoist unit and grab assembly and correct any significant deficiencies (see paragraph 50).

(5) Remove from service discharge baskets which only have a small rolled fuel retention lip (see paragraph 33).

(6) Install additional TV cameras to provide the operator with information to confirm that there is effective latching between the grab and the discharge basket (see paragraph 21).

(7) Review the defuelling procedures and associated QA arrangements and implement the necessary improvements (see paragraph 30).

(8) After implementing the necessary plant and process improvements, demonstrate that the shift teams are suitably qualified and experienced to carry out their defuelling duties (see paragraph 63).

After the Resumption of Routine Defuelling at Chapelcross and Calder Hall

(9) Revise the fuel route maintenance arrangements, within one month of the resumption of routine defuelling, to ensure that in the event of a breakdown or intermittent fault the equipment is not returned to service until the root cause has been identified and any underlying problems rectified (see paragraphs 52 to 54).

(10) Introduce arrangements, within two months of the resumption of routine defuelling, to systematically review the performance of the fuel route, learn from experience and seek improvement (see paragraphs 51 to 54).

(11) Complete, within two months of the resumption of routine defuelling, an optioneering study on how to provide the operator with better information on the position of the discharge hoist well door whilst it is opening or closing, and provide NII with a programme for any proposed modifications (see paragraph 31).

(12) Review, within six months of the resumption of routine defuelling, the refuelling safety case against modern standards and then implement a programme to complete all reasonably practicable modifications arising out of

the review. The scope of the review needs to justify the continued capability of all the equipment used to fuel and defuel the reactors, consider all potential equipment failure modes, and discrepancies in the modification history between Chapelcross and Calder Hall (see paragraph 50).

Generic to BNFL Nuclear Power Stations

(13) BNFL should ensure that its emergency arrangements requires operators to systematically challenge assumptions about plant status during and following an incident to ensure that they are implementing the correct emergency response procedures (see paragraph 45).

APPENDIX 1

Description of the Plant

Figures 1 and 2 show the fuel handling route from pile cap to discharge bay and the significant plant or components associated with the dropped fuel incident. A brief description of the equipment is provided below with reference to any additional more detailed Figures;

(i) Discharge Machine - This is a gas tight flask which is mounted on a four wheeled bogie and operates at reactor floor level. It is made of cast iron rings of sufficient wall thickness to provide radiation shielding from the active fuel elements as they are drawn up into the discharge machine from the reactor core. There is a shield door at the bottom of the machine that can be removed or replaced by a hydraulic jack (see (iii) below).

(ii) Irradiated Fuel Discharge Basket - This is a container which has twenty-four equal divisions or pockets at its periphery (Figure 6). Individual fuel elements withdrawn from the reactor core are placed in these pockets. The basket grab (see (vi) below) latches onto lugs attached to a centralising device in the top of the basket (Figure 6) and is used to raise it into or lower it out of the discharge machine. The basket is located inside the discharge machine by attaching the basket grab to the top of the machine. Its weight is carried on a rotating table in the bottom door of the discharge machine once this has been refitted.

(iii) Hydraulic Jack - This is used to remove the shielded door fitted to the bottom of the discharge machine and to lower it into a recess in the traverser pit, until it is required to be replaced in the machine again.

(iv) Traverser - This is a vehicle which moves on rails in a pit adjacent to the reactor pile cap which contains the hydraulic jack and discharge well door. The discharge machine is placed on top of the traverser when it has to be moved from the reactor floor onto the hydraulic jack for the removal of the discharge machine door. Once this is complete the traverser is used to move the discharge machine onto the discharge well door.

(v) Grab Hoist and Electric Grab Driving Mechanism (Figure 2) - This contains a winch unit with a cable to which is attached the electric head. The head contains the electric grab drive mechanism needed to open or close the jaws on the basket grab. The winch unit is used to raise or lower the discharge basket when it is attached to the grab hoist.

(vi) Basket Grab (Figure 2) - Its main feature is two concentric cylinders about 10ft (3m) in length. The lower end of this assembly provides the grab for lifting the discharge basket and the upper end connects into the electric head by means of an “allen” screw, orientating pins and a key-way. The drive from the electric head rotates the jaws of the inner cylinder relative to the outer cylinder to either latch onto or delatch the grab assembly from a discharge basket (Figure 3). Routinely, once the grab is latched onto an empty discharge basket, it is not released until the basket has completed the full cycle of movements between the pile cap and the discharge bay and it is placed into a water filled transit flask located at the base of the discharge well.

(vii) Discharge Well Door - This is a flat steel plate with a rounded end which moves horizontally to provide either access or egress to the top of the discharge well.

(viii) Discharge Well - This is a vertical shaft which links the pile cap with the discharge chamber.

(ix) Discharge Chamber - This provides a shielded facility into which either discharge baskets or water filled transit flasks can be positioned at the bottom of the discharge well. It also contains a facility for removing and refitting the shielded lid of the transit flask.

(x) Transit Flasks - These are shielded water filled containers with a removable lid. They transport the discharge baskets of irradiated fuel from the discharge chamber to other plant areas such as the storage ponds.

(xi) Two gamma monitors are located inside the discharge chamber and provide an interlock function to prevent the discharge chamber access doors being opened before the lid has been replaced on a flask containing irradiated fuel elements. The interlock is triggered by measuring radiation levels which are above background but below the alarm setting for the instruments. Consequently the readings on the gamma monitors increase in relative value to background when a basket of fuel is placed within a water filled transit flask at the bottom of the discharge well but do not go into alarm.

(xii) Discharge Machine Introscopes - These are two small eye piece penetrations, one in each side of the discharge machine. They have a very limited field of vision and are used by the operators to confirm that fuel placed in the discharge basket appears to be correctly located.

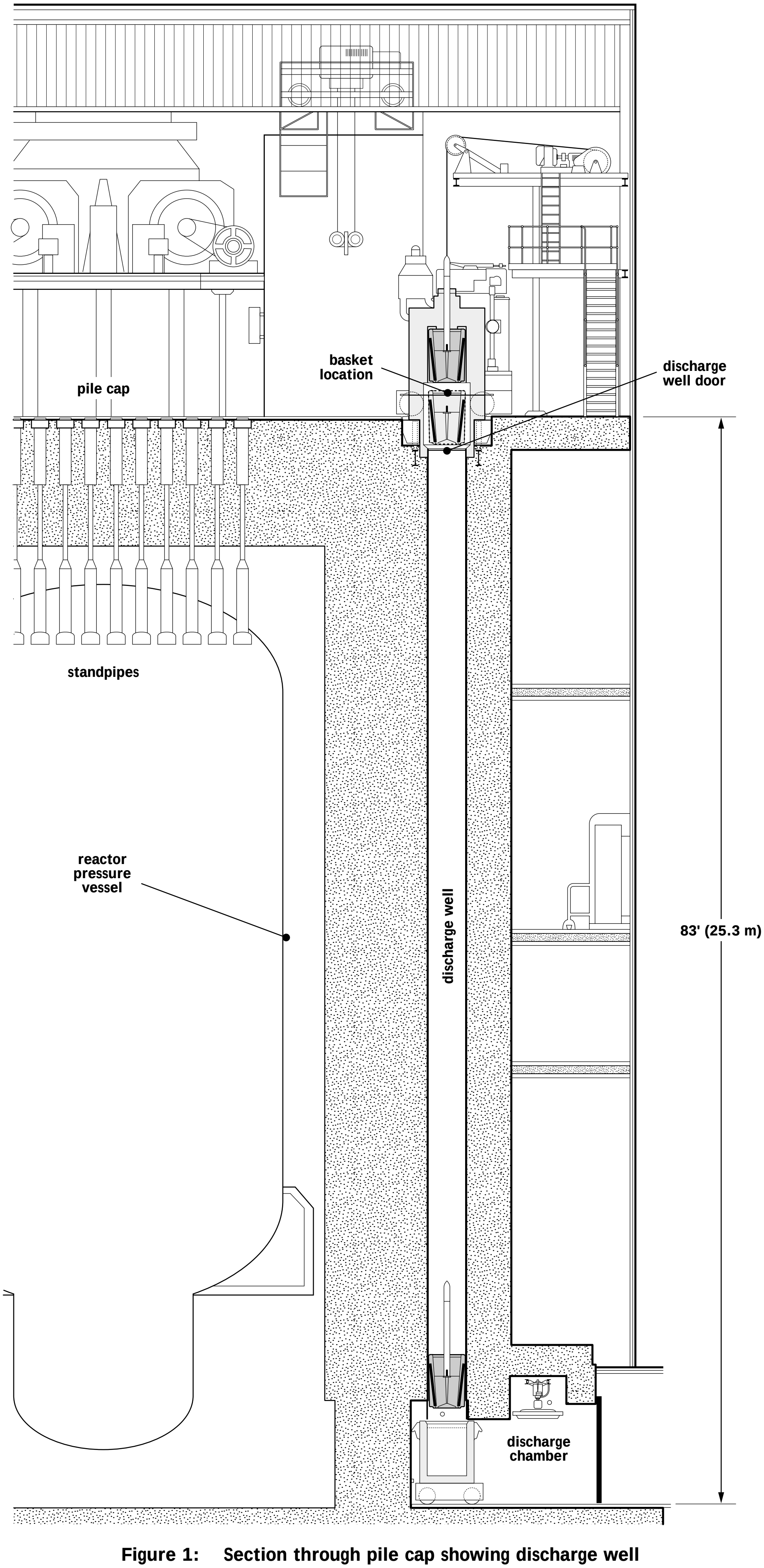

Figure 1: Section through pile cap showing discharge well

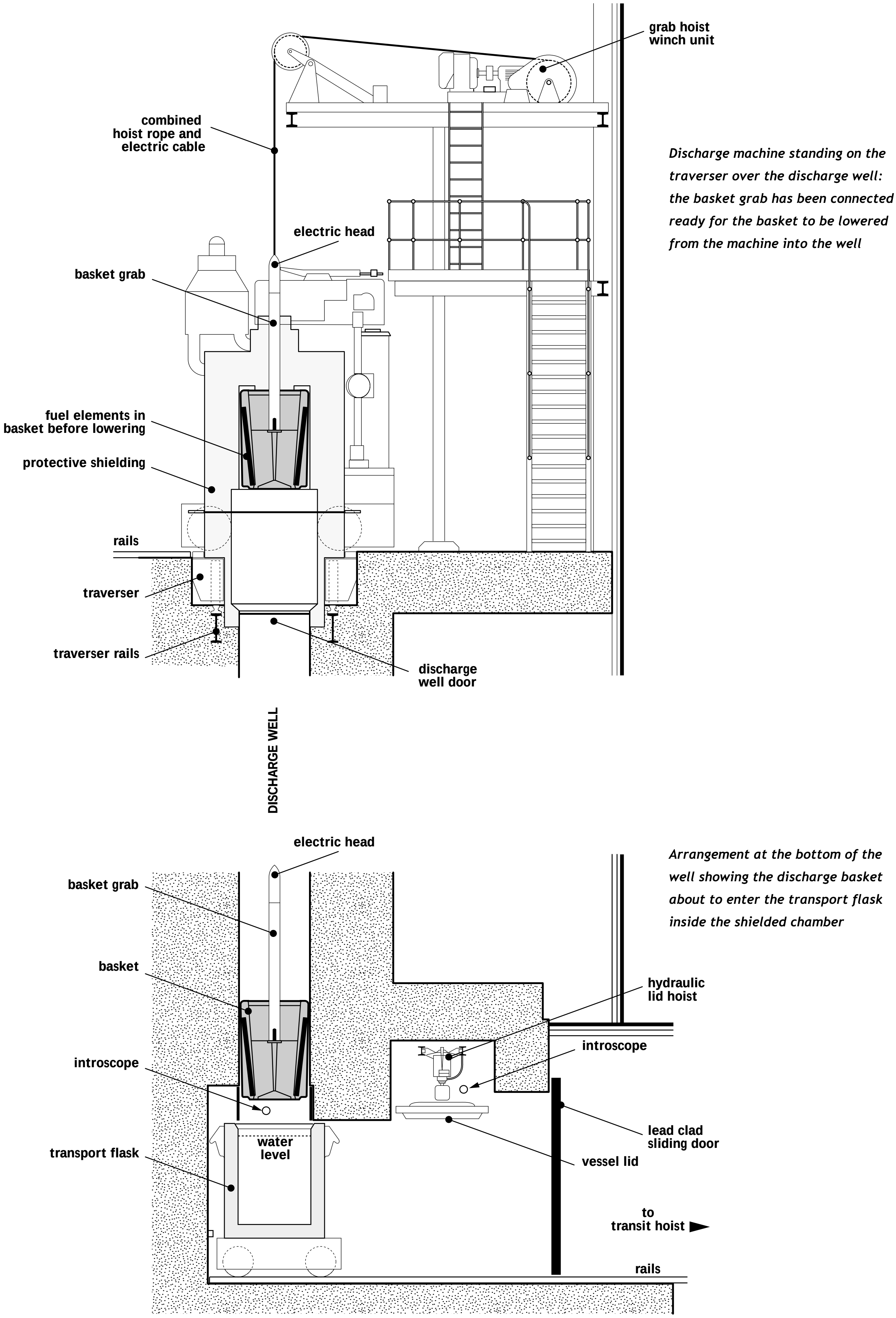

Figure 2: Fuel handling route from pile cap to discharge chamber

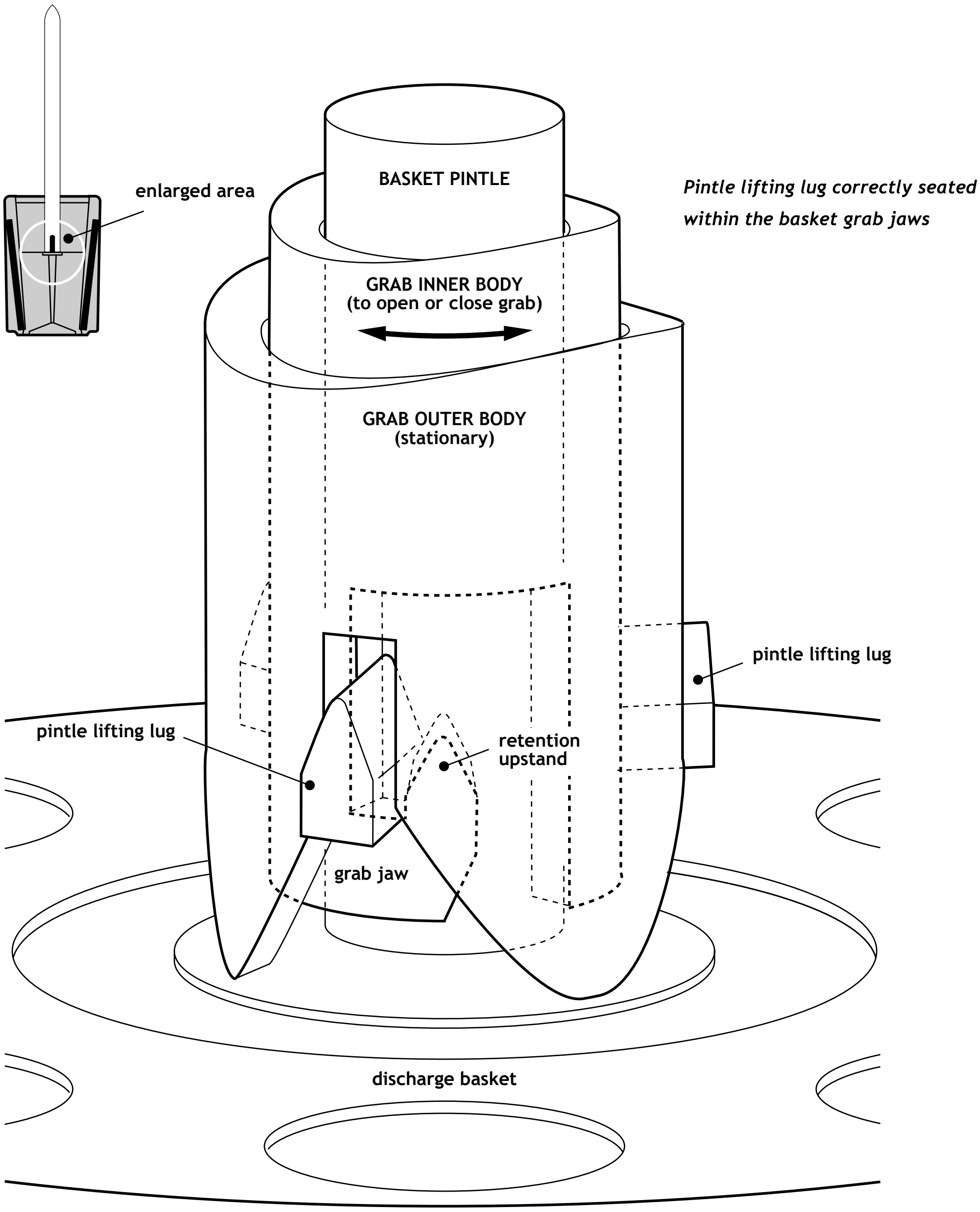

Figure 3: Grab jaws

Figure 4: Jaws of the basket grab in partially closed position

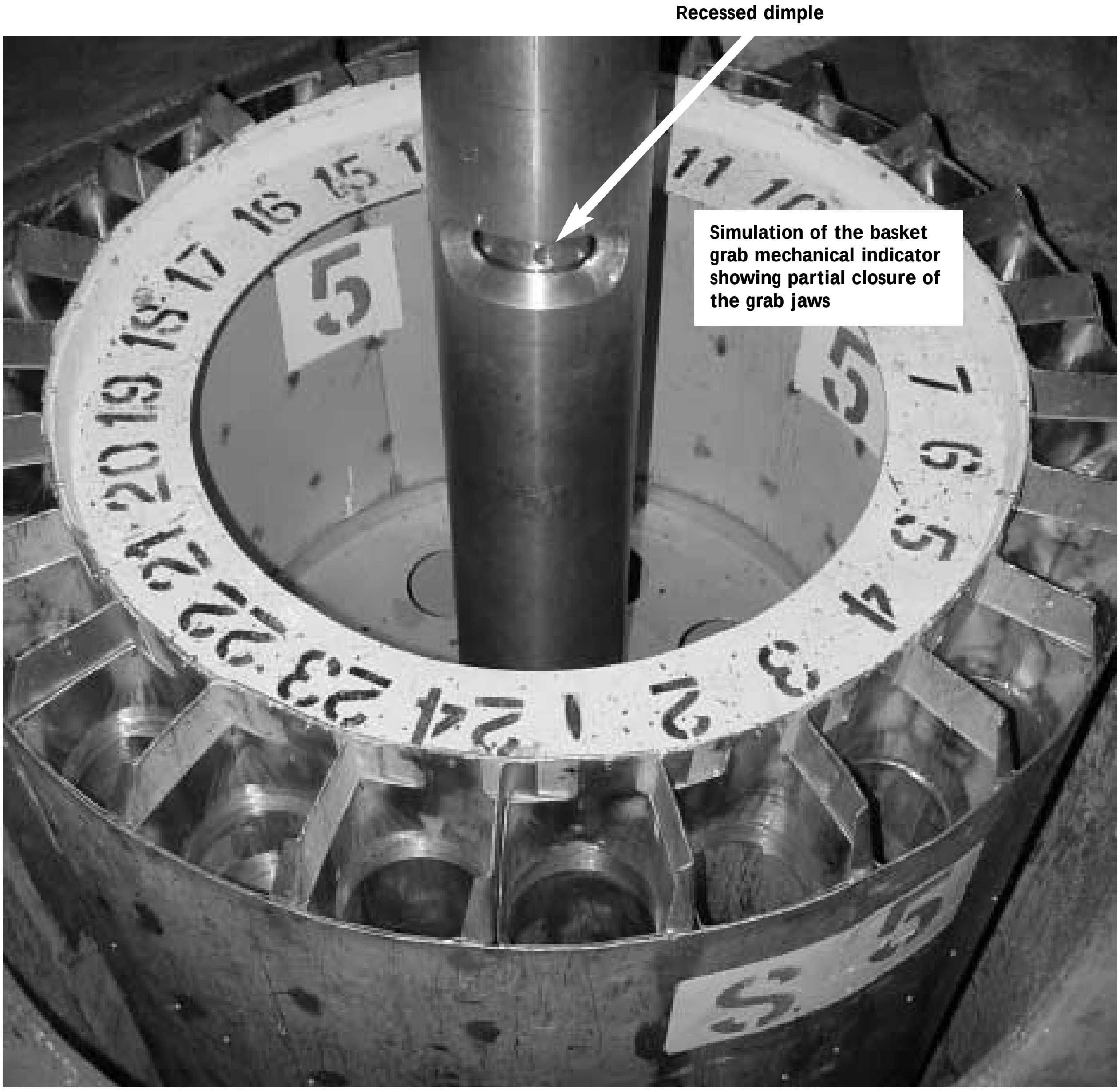

Figure 5: Basket grab mechanical position indicator

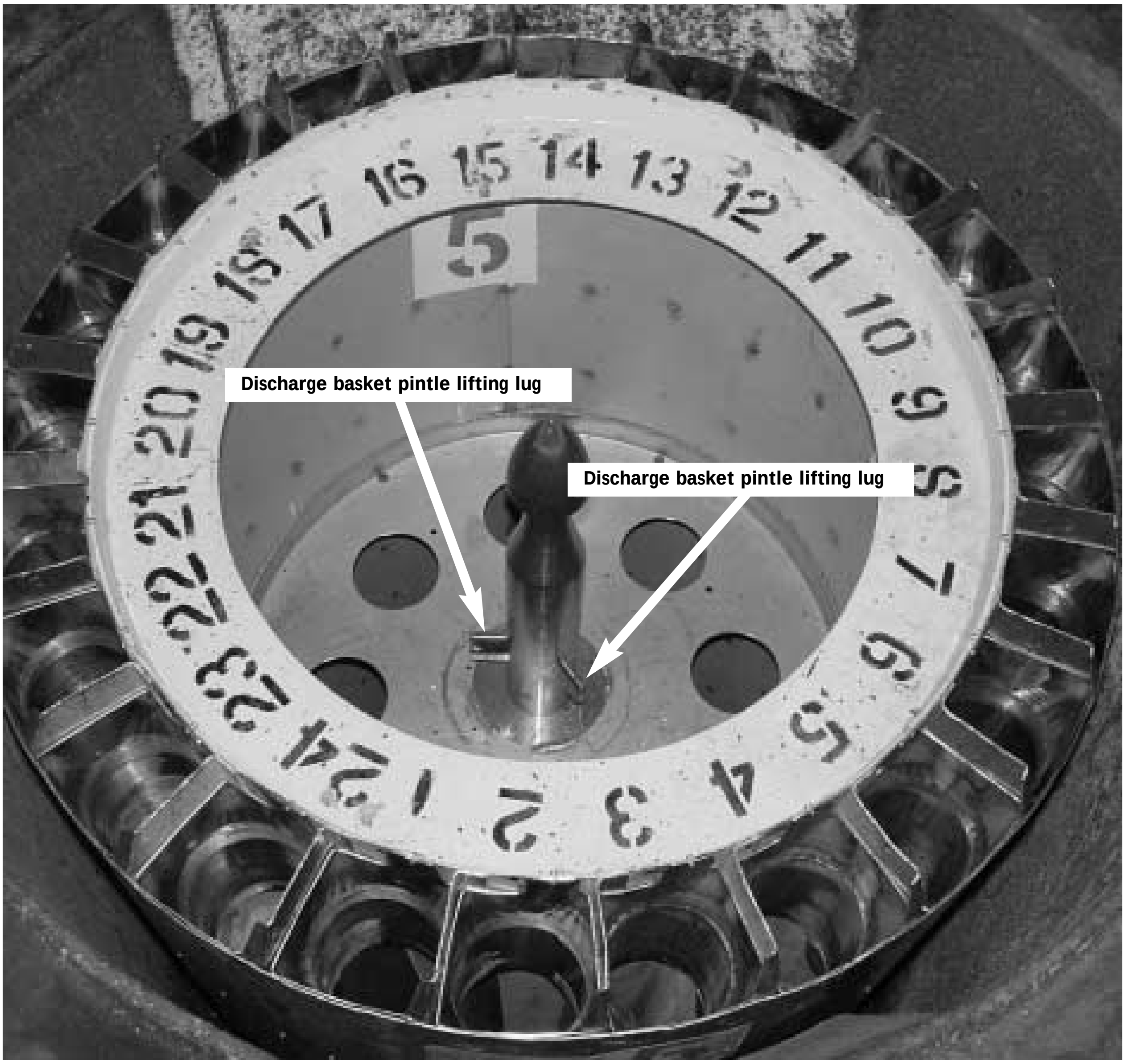

Figure 6: Top view of discharge basket

Figure 7: Fuel elements inside discharge basket

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