BNFL

Board of Inquiry Report

Event No: BN05040181 (**SIR:**35/05 / **IER:**SE 9924)	**Date of Event:** 20/04/2005
Report Title: Fractured Pipe With Loss of Primary Containment in the THORP Feed Clarification Cell	
Report Authorised by Convening Authority: B Snelson – Managing Director, British Nuclear Group Sellafield	
Signed:	Date: 26 May 2005

1. Summary

On 20th April 2005, Cell 220 in the Thermal Oxide Reprocessing Plant (THORP) at Sellafield was inspected by camera revealing a significant quantity of dissolver liquor in the base of the cell. The inspection was undertaken as a result of calculated discrepancies in the nuclear material balance and indications of dissolver liquor in one of the cell sumps. The inspection revealed that a feed pipe to accountancy vessel V2217B had failed by fracture at a location very close to the vessel. The quantity of dissolver liquor in the cell was estimated at $83.4m^3$.

The investigation has revealed that dissolver liquor had been leaking into the cell for a period of some months. It is likely that the pipe suffered major failure on or around 15/01/2005 although it is suspected that the pipe started to leak prior to this date, possibly as early as July 2004.

The base of the cell drains to a sump fitted with level detection instrumentation. Furthermore, samples are scheduled to be taken routinely from the sump. The operations staff did not act appropriately to off normal conditions in either the level instrumentation or the sampling process.

The accountancy vessels operate in a suspended mode, hanging from rods passing through the roof of the cell. This report concludes that the pipe fractured due to fatigue stresses induced by excessive movement of the vessel. These stresses arose as a result of modifying the design and not maintaining the intent i.e. restraining vessel movement. Recommendations from the investigation include:

- Review and justify future operation of the accountancy vessels in light of the exposure to fatigue induced stresses.
- Consider and assess where necessary the risk to other suspended tanks and confirm piping design practice for pipes subject to mechanical loads from pulsed pumping devices.

The loss of significant quantities of liquor could and should have been averted by earlier detection of leakage into secondary containment. Immediate and root causes have been identified and recommendations made:

- Implement near real time tracking of nuclear material movements.
- Review and improve sump management including sampling practices and alarm management.
- Review and improve maintenance regime for pneumercators.
- Review and improve operational management awareness of nuclear safety fundamentals.

This report also makes a number of important observations based on evidence from this and previous events. A "new plant" culture is considered to exist which lead to operational complacency with regard to the integrity of the primary containment. In addition, it is considered that THORP's operational management must improve the safety culture on the plant to ensure that all future equipment and human performance issues are met with a questioning attitude and conservative response.

2. Membership of the Inquiry Team

- [redacted] - Chairman [redacted]
- [redacted] - Lead Investigator - [redacted]
- [redacted] - Investigator - [redacted]
- [redacted] - Investigator - [redacted]
- [redacted] - Union Representative (Staff) - [redacted]
- [redacted] - Union Representative (TU) - [redacted]
- [redacted] - Secretary - [redacted]
- [redacted] - NDA Representative (observer) - [redacted]
- [redacted] - NDA Representative (observer) - [redacted]

The Inquiry Team was given significant support by [redacted]

3. Terms of Reference

- To investigate the circumstances leading up to and surrounding the event that came to light on 20 April 2005 involving the arising of significant quantities of dissolver liquor in the secondary containment of the THORP Feed Clarification Cell.
- Using the HPES methodology (to include Task, Change and Barrier Analysis combined with Event and Casual Factors Charting) to determine the root cause(s) of the event
- To review the root causes of this event for other areas of THORP and the site as a whole, and make recommendations aimed at preventing a recurrence.
- To establish a timeline for the event, including precursors up to the discovery of dissolver liquor in the secondary containment.
- To review and critique the operational decision making against the event timeline
- To make appropriate recommendations to address the immediate and root causes of the event.
- To identify any breaches in the requirements of the relevant Safety Cases.
- To identify any deficiencies in the relevant Safety Cases.
- To identify any breaches in the requirements of the relevant Site Regulations.
- To identify any deficiencies in the relevant Site Regulations.
- To identify any required changes to the event categorisation in light of the investigation findings.
- To identify recommendations of environmental significance.
- To identify the appropriate Senior Manager(s) to take responsibility for the management of corrective actions.
- To identify the appropriate Senior Manager to take ownership of the event for the purposes of compiling Company Statistics.
- To identify the wider learning lessons and determine the best means of communication.

A summary demonstrating how each of the above Terms of Reference has been addressed is included as Appendix 1 to this report.

4. Circumstances Leading up to and Surrounding the Event

The Board of Inquiry pursued two major streams of investigation, namely :

- How and why the pipe failed.
- The operational awareness and response to the pipe fracture.

This report first outlines why the pipe failed, including a review of the design, construction and operational intent of the accountancy vessel. There is then a critique of the operational awareness of the failure, the indicators and the response to those indicators.

A brief description of the process and simple diagram of the accountancy vessels is included in Appendix 2.

The event timeline has been included as Appendix 3.

4.1 Failure Mode

The Accountancy Vessels V2217A&B are suspended from the cell roof, supported by four rods which pass through the roof of the cell to a weigh mechanism above. For brief periods the vessel is lowered to rest on a steel frame inside the cell to allow the weigh system to establish a datum, or for calibration purposes. At all other times the vessels are operated while suspended.

The Board of Inquiry are very confident that the feed pipe to accountancy vessel V2217B failed as a result of fatigue that resulted from relative movement of the vessel and the feed pipe. The rationale supporting this finding is as follows:

- There is evidence in the shift log which suggests the accountancy tanks vibrate during operation. This is supported by anecdotal evidence from operators.
- There is video footage of the other accountancy vessel operating during the recovery which clearly shows significant movement of the vessel during agitation and emptying cycles.
- The location of the fracture is consistent with fatigue failure. The pipe failed at the nozzle into the vessel and was subject at this point to the highest fatigue stresses of any nozzle on the two accountancy vessels.
- Post event assessments show that for a tank movement producing a deflection of +/- 1 to 3 mm at the failed nozzle, the stresses would correspond to fatigue lives of 3×10^6 to 1.5×10^5 cycles respectively. The amplitude of the vibration and the elements of the operating cycle which produce vessel movement have not been positively identified. Estimates of the number of cycles the tanks have experienced, based only on cycle times for the pumping devices, are in the region of 8.0×10^5. Agitation during emptying, or at any other time, and higher frequencies of tank movement would increase the number of cycles the tanks have been subject to. The observed movement and crude estimate of the number of cycles are wholly consistent with the failure being due to fatigue.
- There is evidence to suggest a staged failure of the pipe by crack development, propagation and ultimately a more significant pipe failure. This is consistent with fatigue induced failure.

Without the ability to closely inspect the fracture site it has not been possible for the Board of Inquiry to draw absolute conclusions about the failure mode. It may be that, even if physical samples from the fracture site could be recovered, the damage to the failed surface from repeat exposure to dissolver liquor has destroyed conclusive evidence. However, given that:

- There is no evidence to support other potential failure modes such as erosion, corrosion or stress induced corrosion cracking.

- There is no evidence from construction records to suggest any material defects or problems with the quality of manufacture.
- There is compelling evidence as noted above that the pipe has been subject to fatigue stresses.

the Board of Inquiry concludes that the pipe failed due to fatigue cracking.

4.2 Time of Failure

There is evidence that dissolver liquor started to leak from the pipe around July 2004. This evidence includes Shipper Receiver Discrepancy data, sump samples and material balance calculations (carried out as part of the investigation). The evidence is described in more detail later in this section and is identified in the Timeline (Appendix 3).

There is further evidence from level instrument responses, sump temperature responses and Shipper Receiver Discrepancy data to suggest that there was a step change in the leak rate on or around the 15/01/2005, indicating a step change in the magnitude of the pipe failure. Immediately prior to this time, the tank had undergone a period of operation where it was agitated almost continuously. The tank had also just been set down and raised from the steel frame to allow the weigh mechanism to be calibrated.

4.3 Cause of Failure – Vessel Design, Commissioning and Operation

The original design of the accountancy vessels provided for seismic restraints to prevent lateral movement. Concept diagrams indicate a vessel which could move in the vertical plane (for weighing purposes) with mechanical stays holding the vessel in position horizontally. The concept design also recognised that the seismic restraints would limit mechanical movement and induced stresses from pumping devices. This concept translated into restraint blocks on the fabrication drawings for the steel frame around the vessels. Therefore the original design intent was to operate the vessels suspended but with a lateral restraining system.

However, when the safety case for the basis of design was produced the vessels were seismically uncoupled from the steel frame. To accommodate this change, it is clear from visual evidence that the restraint blocks have not been fitted and that some of the steelwork has been modified to provide additional clearance between the accountancy vessels and the steel frame.

The Board of Inquiry has found no evidence that the design was reviewed to consider fatigue stresses following the modification to remove restraints. The Board considers it inconceivable that, had the calculations been performed, it would have been acceptable to operate the tanks in a suspended mode without lateral restraint. Further investigation would be required to confirm this due to the very large volume of design and commissioning records.

The Board of Inquiry have determined that the design intent was modified and that this occurred at some point after the original design of the vessels and support steelwork, but before the early commissioning. However, due to the vast quantities of historical information available the Board of Inquiry considers that further investigation, to determine why the design intent was missed during both the design evolution and commissioning, should be pursued as a recommendation.

There is evidence to suggest that the tanks have recently been agitated for longer periods than required to take homogenous samples. This will have contributed to the timing of the failure.

4.4 Nuclear Material Accountancy

There was some indication of a slight deviation in nuclear materials accountancy from the [redacted] campaign [redacted] from 14/07/04 to 03/08/04). This registered a Shipper Receiver Difference (SRD) of 0.59%, which, although outside the normal expected tolerance of +/- 0.45% was not significant enough to cause concern. However, with hindsight this may have been an indication of an issue developing.

The first clear indication that there was a significant discrepancy in accountancy occurred on the 17/03/05 when the Safeguards Department notified the [redacted]. The e-mail indicated that there was a SRD of 3% for the [redacted] Campaign [redacted] which ran from 09/09/04 to 29/01/05. Due to the complexity of the calculations this discrepancy was still believed by both the [redacted] and Safeguards Department to be a calculation error. An independent check on the calculations also confirmed the discrepancy.

The Safeguards Department organised a meeting (22/03/05) to review the results. Initial indications from the ongoing [redacted] campaign [redacted] carried out between 31/01/2005 and 25/02/05) indicated no significant loss. The meeting therefore concluded that the problem was limited to the [redacted] campaign and caused by an error in the calculation. A subsequent recheck of [redacted] on the following day (23/03/05) suggested that there did appear to be a discrepancy. As a result, the Safeguards Department accelerated final balance calculations for both the completed [redacted] and the ongoing [redacted] campaigns.

On 13/04/05 the Safeguards Department e-mailed the [redacted] highlighting that the final analysis for the [redacted] campaign [redacted] now indicated a loss of 3.9%. This was followed the next day by an e-mail (dated 14/04/05) from the Safeguards Department to the [redacted] identifying a third SRD of 9%, for the [redacted] campaign [redacted]

At the same time as receiving information on the [redacted] campaign SRD, [redacted] also traced sample results from the sump in the feed clarification area of the cell. These indicated the presence of a significant concentration of Uranium in the Feed Clarification sump on both the 26/11/04 and the 24/02/05 (see 4.5 for further explanation of sampling circumstances and relationship between Buffer Sump and Feed Clarification Sump). [redacted] then raised the issue with the [redacted] and in turn with the [redacted] on 15/04/05; highlighting the SRD, the sump results and requesting a camera inspection of the cell.

A subsequent calculation, completed by the [redacted] on the 18/04/05, confirmed by mass balance that approximately 19te U (equivalent to approximately 85m^3 of dissolver liquor) had been lost from the primary systems over the three campaigns.

[Note: The Board of Inquiry have used information from control system trends to undertake spot material balances at key times in an attempt to pinpoint the time of failure. These balances are indicated on the timeline as shaded areas and show a discrepancy between the volume being fed from the constant volume feeder and the volume received in the tank. It is important to note that these are spot samples for feeds to accountancy vessel V2217B only. The discrepancies noted by the nuclear materials accountancy are totalled over a full campaign and include feed going to accountancy vessel V2217A. Therefore the material balance will show a higher percentage loss of material than the SRDs.]

4.5 Sampling Operations

There are two sumps located in Cell 220, one sump collecting from the area under the clarification process and known as the Feed Clarification Sump (F2226) and one collecting from the area where the accountancy and buffer vessels are located called the Buffer Sump (F2268). It is the Buffer Sump F2268 where the leaked dissolver liquor has collected. The Buffer Sump F2268 is sampled by ejecting some of the sump contents to a catchpot above the Feed Clarification Sump. The automatic sampling system then draws the sample from the catchpot and presents this liquor to a pre-evacuated sample bottle. The sample bottle is then automatically sent to the HA laboratory in THORP for analysis.

The safety case requires sump liquor to be sampled before being ejected. However, this is only required where there has been an unexpected rise in level. The sample results are required to confirm that the liquor to be ejected remains within the 3.5g/l Pu concentration assumed by the criticality safety case and therefore acceptable to possible receipt tanks. The system is also configured to automatically prompt a sump sample every three months although this is not a requirement of the safety case.

The Operating Instruction for sumps F2226 and F2268 (OI/02/0411) is a category B instruction. There is no record of any compliance record sheets being completed since Dec 2000 for the use of this instruction.

There is a history of nil sample volumes from the Buffer Sump F2268. Samples taken on 05/06/03, 03/10/03, 01/03/04, 30/05/04, 28/08/04, 26/11/04, 24/02/05, two on 14/04/05 and one on 15/04/05 were all reported as nil. A nil volume means that there was no liquor in the sample bottle for the laboratory to analyse and can be caused by a mis-match in timing in the system i.e. ejecting the liquor to the catchpot either too early or too late for the autosampling system to grab a sample. Apart from the second sample taken on the 14/04/05 and the sample on the 15/04/05 the evidence indicates that no attempt was made to retake any of the other nil volume samples.

From 05/06/03 to the time when the liquor was discovered there was one successful sample taken from sump F2268 which yielded a result of 50.1g/l U. However, this sample was taken at 00:35 on 28/08/04 when the computerised link between the Sellafield Laboratory Information Management System (SLIMS) and the THORP Chemical Plants Information Computer (CPIC) was not operational (detailed in observation 5.6). The result was faxed to THORP along with many other sample results. There is a record in the autosampling register of a repeat sample being taken from F2268 later that night shift. However, the non-routine sample request form to prompt this sample cannot be found due to missing records in the archives. The Inquiry has been unable to determine why the repeat sample was requested.

When liquors from Sump F2268 are ejected to the catchpot for sampling, the catchpot then drains back into the Feed Clarification Sump F2226. Therefore, during the normal course of sampling, Buffer Sump liquor will be transferred to the Feed Clarification Sump. There are two samples from the Feed Clarification Sump which indicate positive uranium results, taken on 26/11/04 (9g/l U) and 24/02/05 (61g/l U). There is no evidence to suggest that any of these results were acted upon. Indeed, some of the operations DAPs report that it was not unusual to get positive sump activity results although prior sample history shows no uranium. Furthermore, the basis of THORP design is for clean sumps and it is not credible to get a positive uranium result of the magnitude observed unless it was from a significant leak. With hindsight, it is clear that these positive results were for dissolver liquors from the Buffer Sump F2268 draining from the catchpot into Feed Clarification Sump F2226.

Evidence indicates that it was on the 14/04/05 that the [redacted], acting in response to three Shipper Receiver Differences (SRD), located the positive Uranium sample results from the Feed Clarification Sump F2226 on CPIC. This is the first indication of any operational response to the sample results. The one positive result from the Buffer Sump was not located because it had been faxed over and had not yet been manually uploaded into CPIC. The sample results from the Feed Clarification Sump F2226, coupled with the SRDs, were subsequently raised with operations management and prompted the request for a camera inspection. It worth noting that, because the positive results were from the Feed Clarification Sump, it was thought at the time that the potential problem was located in that part of the cell.

4.6 Sump Level Pneumercator

Sump F2268 is fitted with an instrument to measure the liquor level. The instrument is a pneumercator type device and is designated as LIJ2596. The instrument is to warn the operator of liquor loss. The equipment is Safety Related, a requirement derived from the plant criticality safety case. The radiological safety case makes no reference to the need for sump monitoring.

There is a significant history of erratic alarm operation associated with the Buffer Sump level LIJ2596. Between 01/07/04 (the last proof test of the instrument) and 22/03/05 the alarm has flagged a Lo or Lo-Lo status over 100 times. During this period there is evidence in the shift logs that the alarm was investigated on the 8&9/12/04. However, the recorded information shows that in spite of hearing acid flowing into the sump (in accordance with normal procedures) the level reading did not change. There is no evidence that the instrument was corrected. Following this investigation the Lo and Lo-Lo alarm continued to flag up, some 51 times up to 22/03/05. There is no evidence of investigation or corrective action during this period.

On the 15/01/05 LIJ 2596 recorded a rapid increase in sump level by 8cm. This level rise (recorded on the DCS trend log history) subsequently decayed away such that the pneumercator returned to reading the level prior to the rise. There was also a rise in sump temperature of 3^{o}C at exactly the same time although the cell temperature remained within expected parameters. The sump temperature increase did not decay away and steadily increased up to the time the event was discovered. The temperature information is available from the log history but is not parameter which operators normally monitor.

The camera inspection on 20/04/05 confirmed the presence of significant quantities of dissolver liquor although the level instrument continued to read normal sump level. A maintenance request was raised on 22/04/05 to check LIJ2596. When the air supply to the high pressure leg was investigated it was found that the indicator ball in the air supply rotameter was stuck at normal flow. It was also reported that the flow had been turned down significantly resulting in the level reading much lower than actual. When the air flow was adjusted to the correct setting, the level indicated by LIJ 2596 jumped from 0.2m to 1.8m confirming the presence of significant quantities of liquor in the sump. The Board of Inquiry has not been able to determine why and when the air had been turned down but believes this condition may have been inadvertently left by previous maintenance work.

Following the event, and during monitoring of the dissolver liquor held in the cell, a slight downward drift in level was detected. This prompted a further check of the instrument which revealed that the pressure transmitter had drifted out of calibration. The transmitter was changed on 07/05/2005 and the level returned to the previous reading. The level has since remained steady up to the time of compiling this report.

4.7 Management Response immediately prior to the inspection

The e-mail from the Safeguards Department (17/03/05) concerning a SRD for the [redacted] campaign was the first indication of awareness that something significant was amiss. For reasons described in section 4.4 above, the issue was not raised with operations management (including the [redacted] until Friday 15/04/05.

Due to the existence of the positive uranium readings from the Feed Clarification Sump F2226 (26/11/04 & 24/02/05) it was believed at the time that the potential problem lay in the Feed Clarification Area of Cell 220. The single positive sump result from the Buffer Sump (the 50.1g/l U taken on 28/08/04) was not available on the CPIC system because when the computerised link between the laboratory SLIMS and CPIC was down, the analysis laboratory had switched the SLIMS into what is known as 'minor customer' mode. This mode allows easier manual retrieval of information but disables any automatic upload of results when the computer link is reinstated – the sample history has to be manually recovered into CPIC. The result from the 28/08/04 was not found and entered into CPIC until after the event. All data available to the operations management pointed to the feed clarification area of the cell so the camera inspection was planned for this area.

The camera inspection was initially planned for the weekend of the 16&17/04/05. The investigation action plan stipulated that the inspection had priority over production. However, during a routine call to the operation team over the weekend, the [redacted] was made aware of concerns that there were inadequate resources to prepare for camera inspections. In a subsequent discussion over the same weekend the [redacted] agreed that it was not reasonable for the shift teams to undertake all of the work and that preparation for camera inspections would be deferred until the day teams returned on the Monday (18/04/05). [redacted] reports that he was not aware of the underlying reasons for the inspection at the time of the conversation.

The [redacted] was told by the [redacted] late on Monday 18/04/05 of the material balance SRD, of the sump results and that production was to be suspended for a camera inspection of the Feed Clarification area on Tuesday 19/04/05. The [redacted]

[redacted] confirmed later that same day to the [redacted] that the production stand down was continuing to allow the Buffer area of the cell to be inspected the following day (Wednesday 20/04/05). This inspection subsequently revealed the presence of significant quantities of dissolver liquor in the base of the buffer area of the cell.

5. Observations

5.1 *New Plant Culture*

The loss of the dissolver liquor was brought to an end by the accountancy process which had indicated a discrepancy over a month before the liquor was found by camera inspection. The reaction of all staff interviewed, be they Accountancy, Operators, Team Leaders or Managers was that they believed material losses on this scale could not conceivably be due to a leak; there had to be an error in the paperwork.

Universal incredulity in a major rupture had, at its base, the belief that THORP was a new plant built to the highest standards i.e. it could not leak. Such faith in the integrity of the plant is misplaced; robust design will minimise the risk of loss of containment but cannot be guaranteed to eliminate it. Only by appropriate vigilance can the ongoing integrity be assured. This faith in integrity is reflected in the safety case:

"The vessels and pipework in the Feed Clarification and Accountancy Cell are all welded construction and have been fabricated to a high standard of integrity. Therefore, a major leak onto the cell floor is regarded as unlikely. Nevertheless, if such an event were to occur the operator would be alerted to the situation by the sump alarm"

Unfortunately the sump alarms did not alert the operators and recommendations have been made to address this fact. The 'new plant' culture pervades all levels within the THORP organisation. It is necessary to note that this culture has continued despite previous experience to demonstrate that leaks can and do happen and when they have happened in the past recognition of this fact has been slow and made the situation worse. Two examples are particularly relevant.

a) In 1998 a coarse fines ejector in the dissolver cell outlet pipe became holed through erosion. Highly active liquor escaped into the secondary containment. This went unnoticed for a period of years despite sump level, sump sampling and contamination of radiological probes suggesting that a problem existed. Recommendations were made (following a Management Investigation) about sump sampling and level monitoring.

b) In February 2005, 3 workers became grossly contaminated after carrying out a thermocouple change in the Dissolver C thermowell pocket. This contamination indicated that dissolver liquor had leaked into the pocket. In the Board of Inquiry report on the event it was noted that the event was ".... A good example of the consequences of 'new' plant mentality and placing too much reliance on plant integrity and not enough on the 'What if?' principal."

The leak into the Buffer sump of Cell 220 bears all the hallmarks of these previous events. Anomalous plant indications were not recognised promptly and loss of containment was not considered credible. Previous events do not seem to have affected this attitude. All this has lead the Board of Inquiry to form a view that the THORP Head End operational culture is complacent with regard to detecting losses from primary containment and has not fully learned the lessons of previous events. To help improve matters the following suggestions are offered for consideration:

i) Operational personnel participate as fully as possible in the clean-up and recovery exercise that will be necessary to return THORP to routine service. Involvement, particularly of the control room staff, will enable personnel to see at first hand the consequences of a primary containment breach.

ii) The safety case is revised to no longer claim the leakage is unlikely. Instead it should be emphasised that although leakage will be contained, it requires constant vigilance and the questioning and follow-up of off-normal indications to ensure that leakage is detected and halted at the earliest possible time. This change would need to be explained to all operating staff.

5.2 *Operational Management Effectiveness*

All levels of THORP Operational Management were unaware of mounting concern from accountancy and safeguards on inventory anomalies until three consecutive high Shipper Receiver Differences had occurred. Even when operational decisions were made to carry out a CCTV inspection of the cell, it appears that misunderstanding at senior management level over why this was being done led to production in THORP receiving a higher priority than inspection preparation over the weekend of 16&17/04/05. Operations Management were also unaware of long standing problems with the buffer sump level instrument and sump sample results.

In its performance objective on Safety Culture, WANO says that
" Individuals at all levels of the organisation consider nuclear safety as the overriding priority. Their decisions and actions are based on this priority and they follow up to verify that nuclear safety concerns receive appropriate attention. The work environment, the attitudes and behaviours of individuals, and the policies and procedures foster such a safety culture."
The WANO objective represents the 'world class' standard.

This event has demonstrated that despite high quality construction, serious faults can occur within THORP which breach primary containment. Given the history of such events so far, it seems likely that there will remain a significant chance of further plant failures occurring in the future even with the comprehensive implementation of the recommendations in this report. An objective for THORP's operational management should therefore be to improve the safety culture to ensure that any further plant failures are rapidly detected and operationally responded to in a conservative manner.

It is therefore suggested that:

i) THORP Operational Managers frequently monitor, observe and assess plant and process conditions as well as operator work practices and performance by personal visits to the workplace. The Operational Manager objective from these visits is to be fully conversant with current operational conditions and issues so that they are able to follow up equipment and human performance issues and reinforce the importance of nuclear safety, questioning attitudes and conservative decision making.

ii) Where senior managers do not have a background that gives them a deep understanding of the chemistry, thermodynamics and physics of their processes, they should have a 'technical advisor' assigned to them to whom they could look to for immediate advice and coaching.

5.3 *Sump Operations – Instructions and Training*

The sump operator instruction OI/02/0411 is a Category B instruction, giving guidance on sampling and washdown of the sump. The instruction is category B to comply with a criticality safety case operating instruction that requires:

"If there is an unexpected level rise in either cell 220 sump, a sample must be taken and

analysed for plutonium as soon as reasonably practicable.
If the analysis results indicate a plutonium concentration of 3.5g/l or greater, then advice must be sought from the Site Nuclear Safety Officer. Otherwise the sump should be emptied as soon as reasonable practicable"

The operating instruction is ambiguous, and places at the discretion of the operator what would be considered unexpected. Recommendations have been placed to address the lack of clarity in the instruction. However, what is not ambiguous is the requirement to sign the compliance record sheet (CRS) for the operator instruction as a category B. There is no record of any CRS for the instruction for over 4 years even though the sumps have clearly been topped up and ejected.

Furthermore, once signed by the group of team members present when the instruction was modified the familiarisation record sheet (FRS) for the operator instruction was archived. Therefore new team members have not signed the FRS to indicate they understand the instruction. A system of training log inserts was used to overcome this shortfall but this has been stopped without the Head End Chemical Plants management team awareness. The implications of this are that the DAP has no means of tracking training against category B Operator Instructions.

Investigation into the Head End Chemical SQEP system revealed that 24 SQEP packages (which had all associated Head End Chemical OI's crossed referenced within them) had been revoked and replaced with 7 high level SQEP packages which were originally written for reassessment of SQEP operators - not for the SQEP'ing of a new starter. It is the intention of the training department to remove the OI cross references within the SQEP packages. The [redacted] was unaware of the revocation of the 24 SQEP packages.

Site License Regulations (SLR) 224 clauses 1.2.4, 4.1and SLR 224 b clauses 7.1.16, 7.1.17 require:
- There must be adequate arrangements for training for operating instructions.
- Senior managers must keep records for training for new / revised operating instructions for as long as an individual is employed in their area of responsibility.
- Supervisors receiving a controlled copy of an instruction must ensure that all team members are made familiar with relevant / revised instructions.
(FRS's are therefore required for category A & B instructions)

It is suggested that action is taken to:

i) Ensure practices for signing CRS for categorised instructions are compliant with regulations.
ii) Review the appropriateness of SQEP packages for training new operators and the mechanisms by which new operators are confirmed as trained against category A and B instructions.

5.4 *Lifetime History Records*
It is important to note that significant effort was required to trace all of the relevant history and information for the accountancy vessels. Although drawing records are relatively straightforward to recover, associated calculation packages, modifications during design, etc. are not readily available and have to be individually traced in archives. It is therefore suggested that:

i) Consideration be given to structuring lifetime records to ensure that design intent, design parameters, commissioning and operational history is compiled in a package form for major items of plant and equipment.

5.5 *Recording of Maintenance*
Interrogation of the Computerised Maintenance Management System (CMMS) revealed a

limited history for the Buffer Sump level instrument LIJ 2569. The routine annual maintenance and the investigation carried out on the 22/04/05 are recorded. However, a log history print taken on the 13/05/05 revealed that no record of the investigation undertaken on the 8&9/12/04 and no record of the transmitter change carried out on 07/05/05. This lack of a computerised record for non-routine maintenance on an instrument, particularly one designated as safety related, is of concern. Therefore the following is suggested:

i) THORP Head End Chemical Plants review use of the Computerised Maintenance Management System with particular attention to adopting practices which ensure that non-routine maintenance is adequately recorded including:
- the reason for the non-routine maintenance.
- the findings of any investigative work.
- the corrective action taken.

5.6 *Switching of SLIMS to 'minor customer'.*
When the positive sample result from the 28/08/04 was faxed over there is no evidence to suggest that if CPIC was operational it would have prompted an operator response. Indeed, other positive results issued via the computer link for sump F2268 (on 9/11/04 and 25/02/05) did not raise operator responses. Therefore when the computerised link was down it is the operational attitude to sump management which is deemed to be the most significant contributory factor. Recommendations have been made to address this issue.

The significance of the link being down is more relevant to the camera investigation. During the down period, the SLIMS system was switched into 'minor customer' mode to allow the laboratory to more easily manually compile results for faxing. When switched to 'minor customer' mode any retrieved results are not automatically uploaded from SLIMS to CPIC when the link is re-established – results have to be uploaded manually. The 28/08/04 sample result from F2268 was not uploaded manually and therefore was not available to the operations team when investigating the accountancy discrepancies. As a consequence, the investigating team initially believed the problem to be in the Feed Clarification area of the cell. It is clearly undesirable to increase the risk of missing plant history so the following is suggested:

i) The switching of SLIMS to 'minor customer' mode is restricted and enabled only by formal authorisation of the laboratory management. If 'minor customer' mode is enabled, then positive measures must be put in place to ensure all of the information not automatically uploaded is re-entered into the computer.

6. Wider Learning Lessons and Means of Communication

The BOI has identified a number of areas where specific improvements are required. Targeted actions have been placed within the organisation to ensure that the learning from this investigation has been embedded.

There are three key areas that are applicable for wider learning:

- Pneumercator Operations
- Materials & Liquor Accountancy
- Nuclear Fuel Accountancy

- The following questions should be asked by Heads of Manufacturing (or equivalent):

For your Pneumercator Systems do you:

- Undertake routine inspection walkdowns?
- Maintain the systems?
- Log the results of findings?
- Do you provide positive confirmation that equipment is returned to service in a fit state following maintenance?

For Materials & Liquor Accountancy:

- What controls are in place to ensure that operators respond correctly to 'off-normal' conditions in all sump areas, e.g.: in-cell and other areas?
- Do operators in your area know how to respond to sump arisings for the processes that they operate?
- Do you undertake routine maintenance and inspection of all sumps and associated sampling equipment to ensure that they function as designed?

For Nuclear Fuel Accountancy:

- For significant process operations where liquors are involved, what systems do you have available to you that can be used for the detection of loss of primary containment other than a reliance on real time material accountancy e.g. mass balance, volume flow etc.

To assist in general briefing of this event the Sellafield Operating Experience Feedback Engineers will produce a Learning Pack for this event that will be distributed via the OEF Co-ordinator network and considered at Local Event Review Team Meetings.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.1 Failure Mode				
7.1.1 There is evidence indicating that the vessel design for the accountancy tanks (V2217A&B) allowed for static and thermally induced loads. There is no evidence available indicating any consideration of fatigue stresses.	**8.1.1 The feed pipe to accountancy vessel V2217B failed due to fatigue induced stresses. Recommendations 9.1.1 to 9.1.4 are made to ensure fatigue failure is appropriately considered in the future operation of the Accountancy vessels.**	9.1.1 The magnitude and frequency of movement of Accountancy Tank V2217A should be measured in order to provide input data for fatigue assessments in 9.1.2 These measurements should cover all operationally allowable operating states.	Not applicable.	Pre-requisite to returning tanks to operational service.
7.1.2 Post event calculations indicate that very little movement is required to induce fatigue stresses in the failed pipe.		9.1.2 The residual fatigue life of the penetrations on Accountancy Tank V2217A&B should be estimated before these tanks are returned to normal operational service.	Not applicable.	Pre-requisite to returning tanks to operational service.
7.1.3 The video footage of V2217A during the recovery operation clearly indicates movement of the vessel during agitation and emptying operations. The vessels designs are the same and therefore V2217B would be expected to react in a similar manner.		9.1.3 Future operation of the Accountancy Tanks should minimise fatigue loading on the tank penetrations, consistent with safeguard and accountancy requirements.	Not applicable.	Defining operating regime is a pre-requisite to returning tanks to operational service.
		9.1.4 All future operation of THORP accountancy tanks should be under an adequate regime of leak detection including, where practicable, regular viewing using CCTV to detect loss of primary containment.	Not applicable.	Defining the surveillance regime is a pre-requisite to returning tanks to operational service.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.2 Design Intent.				
7.2.1 Early design papers indicate that the accountancy vessels were designed to be operated while suspended on the weigh system. These papers also indicate the vessels would be seismically restrained in the lateral direction and recognised that the lateral restraints would perform the additional function of restraining against mechanical movement.	**8.2.1 The design intent for the accountancy vessels was modified for seismic reasons. The modification removed any lateral restraining system. The design did not adequately address the secondary function of limiting the mechanical movement and hence the induced stresses. The design modification was inappropriately conceived or implemented for a suspended vessel. Recommendations 9.2.1 to 9.2.3 are made to ensure other suspended vessels are not at risk.**	9.2.1 Carry out an assessment of fatigue induced by potential movements for any other suspended tanks in THORP and at Sellafield (to include as a minimum the Pu Harp Tanks)	Across Sellafield for suspended tanks that contain hazardous materials.	By end August 2005.
7.2.2 The design drawing for the steelwork around the vessel indicates the presence of lateral seismic restraints.		9.2.2 Carry out a review to ensure that the piping design practice for Sellafield adequately addresses the potential for fatigue induced stresses arising from operation of Reverse Flow Diverters (RFDs) or other pulsing liquor movement devices.	Applies to British Nuclear Group Sellafield practices.	By end June 2005.
7.2.3 The subsequent basis of design safety case indicates that the tank was to be operated decoupled from the support steelwork for seismic reasons.		9.2.3 Incorporate the need for fatigue assessment on suspended tank systems in the relevant design guides.	Applies to British Nuclear Group Sellafield practices	By end December 2005.
7.2.4 The as built steelwork does not include any lateral restraints and has been modified to provide additional clearance between the vessel and the steelwork.		9.2.4 Investigate the design and commissioning documents to confirm, as far as reasonably practical, the reason for the failure to translate original design intent into operations. Confirm the current management systems (both design and commissioning) would have detected and prevented the loss of design intent.	Applies to British Nuclear Group Sellafield practices.	By end June 2005.
7.2.5 No evidence can be found that during the change from seismically restrained to unrestrained there was any recognition that vessel movement was likely and that fatigue stresses needed to be checked.				

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.3 Materials Accountancy.				
7.3.1 The Shipper Receiver Difference in the nuclear materials accountancy figures first drew attention to the fact that material was being lost from the primary containment. However, the accountancy figures are only available at the end of a campaign which could be many weeks or even months after the start of a campaign.	**8.3.1 While is it commendable that the diligence of the Safeguards Department alerted THORP operations to the SRDs, the Nuclear Materials Accountancy system is intended to provide overall accountancy balances. The system is not designed to (nor is it intended that it should) be responsive enough to track material on a more real time basis. Recommendation 9.3.1 addresses the issue of tracking material in the plant on a more responsive basis.**	9.3.1 Introduce a nuclear material tracking regime into all relevant parts of the THORP operations with the objective of promptly detecting primary containment failure or misdirection of material. The procedures implementing this regime should specify actions against trigger levels following off-normal results being received.	Applicable across THORP	Pre-requisite to returning to normal operational service.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.4 Sump Sampling.				
7.4.1 There are many occurrences when the sample system returns a nil volume from sampling sump F2268. 7.4.2 There is no evidence to suggest any follow up action for many of the occurrences when a sump sample returns a nil volume. 7.4.3 Sump samples with positive uranium results (i.e. an appreciable fraction of the uranium concentration of the dissolver liquor) are not acted upon. Furthermore, the significance of the results is not recognised. 7.4.4 The operating instruction for the Buffer Cell sump and Feed clarification cell sump (OI/02/0411) is ambiguous about when a sample should be taken. 7.4.5 The operating instruction (OI/02/0411) makes reference to the need to establish Pu concentration in the event of an 'unexpected' rise in level in Cell 220. However, all sample results indicate that Pu is not normally a requested analysis for the cell sumps.	**8.4.1 The sampling of sumps is not perceived as an important means of confirming the ongoing integrity of primary containment systems. Consequently, there is a lack of attention to sump samples and a lack of understanding of the significance of sample results. Recommendation 9.4.1 is made to address this issue.**	9.4.1 Active cell sump sampling in THORP Head End should be regarded as an important means of confirming on-going integrity of primary containment systems. Formal and specific requirements should be placed on: - sample frequency and sample species. - action levels including actions to be taken following levels being exceeded. - actions to be taken in the event of failure to take a sample or a nil volume result. Trigger levels and corresponding actions should be based on conservative assumptions that activity in sumps indicates that leakage from primary containment has occurred, unless this can be positively eliminated as the cause. OI/02/0411 should be modified to include these requirements and the relevant DAP should be made responsible for ensuring these requirements are carried out.	Not applicable	Pre-requisite to returning to normal operational service.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.4.6 The safety case HAZAN C6 for Cell 220 alludes to use of the level instrumentation to detect and prompt sampling for 'unexpected' level rises. However, level increases could be masked by e.g. condensate arisings and therefore level detection is not an assured means of detecting a build up of fissile material in the sumps nor is it assurance of detecting small losses in primary containment.	**8.4.2 The THORP Head End safety case is deficient in assuming that loss of primary containment or build up of fissile material would be detected by 'unexpected' level rises. Recommendation 9.4.2 is made to address this issue.**	9.4.2 The THORP Head End safety case should be reviewed to determine whether additional protection, such as routine sump sampling, is required to assure primary containment integrity and prevent build up of fissile material in sumps.	Consider for applicability across THORP	Pre-requisite to returning to normal operational service.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.5 Sump Level Instrumentation Management.				
7.5.1 There are repeated events on the DCS log where the sump F2268 has flagged alarms and been in alarm for significant periods (i.e. weeks) of time. There is no record of the alarms in the standing alarms log. There is a tolerance of sump alarms, which are not perceived as important in running the plant.	**8.5.1 Sump alarm levels are not perceived as an important means of assuring primary containment integrity. Recommendations 9.5.1 and 9.5.2 are made to reinforce this perception.**	9.5.1 Sump high level alarms within THORP Head End active cells should be treated as an important means of quickly detecting significant primary containment failure. Operator responses to Lo-Lo, Lo and Hi alarms should be specified in Operating Instructions. There should be a presumption in these procedures that a high alarm is indicative of a loss of primary containment unless this can be positively eliminated as the cause.	Consider for applicability across THORP.	Pre-requisite to returning to normal operational service.
7.5.2 Between the proof test being completed on the 01/07/04 and the requested maintenance on 22/04/05 (following the event) there is evidence of only one maintenance event on the 08/12/04 & 09/12/04 recorded in the Shift Operations Log. This is in spite of the erratic behaviour of the alarm on many other occasions.		9.5.2 The feasibility of linking active cell sump Hi-Hi alarms within THORP Head End to automatically intervene in operations should be investigated and implemented if safe and practical. The alarm should prevent the *initiation* of all transfers within, into or out of the affected cell until the cause of the alarm can be confirmed.	Consider for applicability across THORP.	Pre-requisite to returning to normal operational service.
7.5.3 Other than the maintenance noted in 7.5.2 above, there is no evidence of any action taken by operations in response to the alarms.				

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.5 Sump Level Instrumentation Management (continued).				
7.5.4 When investigated on the afternoon of the 22/04/05, it was found that the air flow to the high pressure leg of the pneumercator LIJ 2569 (Buffer Sump level indicator) had been turned down. When adjusted the instrument immediately began registering a significant level in the sump. 7.5.5 The instrument was successfully proof tested on 01/07/04. It is stated that during the visit on the 8-9/12/04 and during a visit on the morning of the 22/04/05 that only the calibration of the transmitter was checked, no attempt was made to adjust the air flow. When the air was turned down is not known. 7.5.6 Following a drift in the level reading (post event) the transmitter on LIJ 2569 was checked on 07/05/05 and found out of calibration. It is suspected that the transmitter is also faulty.	**8.5.2 In spite of the pneumercator reading erratically and in alarm for significant periods of time there are records of only limited investigation no recorded corrective action. The maintenance for Safety Related LIJ 2569 was inappropriate. Recommendation 9.5.3 is made to address this issue.**	9.5.3 Maintenance, proof testing procedures and operational surveillance for Safety Related pneumercators in THORP should be improved to minimise the possibility that unrevealed failure of the pneumercators exist on the plant. This should address both the physical procedure carried out on plant and investigative / diagnosis procedures.	Consider for applicability across Sellafield.	For THORP, pre-requisite to returning to normal operational service.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.6 Operational Response 7.6.1 Some DAPs did not recognise the significance of the sump sample results as indicating the presence of dissolver liquor in the sump. 7.6.2 Despite compelling evidence to the contrary, including three significant SRDs and two sump samples indicating that a significant quantity of uranium bearing liquor in the sump, the plant was allowed to continue operating over the weekend of the 16&17/4/05.	**8.6.1 There is a lack of understanding of some key fundamentals related to indicating assurance of the ongoing primary containment of nuclear material in THORP Head End. Recommendation 9.6.1 is made to address this issue.**	9.6.1 All THORP Head End DAPs and Managers with operational responsibilities should be interviewed to check their understanding of the nuclear safety fundamentals and key safety case requirements of the plant and process for which they are authorised. Any shortfall from the expected level of understanding should be promptly corrected by remedial training and re-examination.	Director of Operations to consider and determine if there is any wider applicability.	Pre-requisite to returning to normal operational service.
7.7 Previous Incidents 7.7.1 There have been previous incident involving the undetected loss of primary containment.	**8.7.1 Previous actions arising from recommendations have been ineffective in promoting the early detection. Recommendation 9.7.1 is made to address this issue.**	9.7.1 A staged and programmed review of the effectiveness of corrective actions should be carried out by the Head of OU in accordance with the suggested timescales. The progress should be reported to the relevant management safety committee.	Not applicable.	Not applicable.

7. EVIDENCE	8. CONCLUSIONS	9. RECOMMENDATIONS	WIDER APPLICABILITY	SUGGESTED TIMESCALES
7.8 Management of Suggestions Suggestions have been made, in section 5 of this report, to provide guidance on dealing with some of the Inquiry observations.	**8.8.1 A formal mechanism of considering observations and suggestions should be employed to demonstrate adequate response.**	9.8.1 Where suggestions have been included under the Observations, section 5, the suggestion and any ensuing action response should be assessed and endorsed by the relevant management safety committee.	Not applicable.	Not applicable.
7.9 Ownership of Event Not applicable.	Not applicable.	9.9.1 The Head of THORP should own the event for reporting purposes.	Not applicable.	Not applicable.

10. Event Summary.

For statistical purposes the following summary must be completed as Part 10 of the Inquiry Report.

10.1 Leading Activity.

Tick one as appropriate:

✓	Routine Operations.		Commissioning.
	Shutdown/Start-up.		Decommissioning.
	Decommissioning.		Construction.
	Maintenance (planned).		Training.
	Maintenance (breakdown).		Other.

10.2 Immediate Causes.

Tick all that apply:

Unsafe Acts:

Behaviour:	
• Violation.	
• Error.	✓
• Sabotage/Vandalism.	
Competence:	
• Experience.	✓
• Training.	✓
• Skills.	

Tick all that apply:

Unsafe Conditions:

Workplace:	
• Access and Egress.	
• Working Environment.	
• Housekeeping.	
• Welfare Facilities.	
Plant and Equipment:	
• Suitability for use.	✓
• Ergonomics.	
• Control systems – functionality.	

10.3 Root Causes.

Tick all systems with shortcomings that contributed to the event:

Management Systems:	
General:	
• Safety Case.	✓
• Risk Assessment.	
• Procedures & Systems of Work.	✓
• Emergency Arrangements.	
• Audit, Review and Monitoring.	
• Hazard Reporting Systems.	✓
• Management of Change (C19).	
Unsafe Acts:	
• Selection/Recruitment.	
• Training.	✓
• Supervision.	✓
• Control of Interfaces.	
• Control of Itinerants/Contractors.	
Unsafe Conditions:	
• Design.	✓
• Purchasing.	
• Maintenance.	✓
• Commissioning/Decommissioning.	
• Plant Modification.	✓
• Waste and Effluent Management.	

Tick all shortcomings identified:

Shortcomings:	
Inadequate Coverage:	
• Scope.	
• Frequency.	
Insufficient Resources:	
• Time, numbers etc.	
• Competencies.	✓
Unclear Responsibilities:	
• Not against named individuals etc.	
• Ill-defined deliverables.	
• Ill-defined performance measures.	✓
Information: Procedures, Guidance etc.	
• Not readily available.	
• Inaccurate / not up-to-date.	
• Too much / too little detail.	
• Unclear wording etc.	✓
Identification etc of shortcomings:	
• Inadequate review and audit.	
• Lack of management ownership.	✓
• Actions not 'SMART'.	
• Inadequate action tracking.	

Appendix 1

Means of Addressing Terms of Reference.

Term of Reference:	Addressed how/where in report:
1. To investigate the circumstances leading up to and surrounding the event that came to light on 20 April 2005 involving the arising of significant quantities of dissolver liquor in the secondary containment of the THORP Feed Clarification Cell.	*Addressed in section 4*
2. Using the HPES methodology (to include Task, Change and Barrier Analysis combined with Event and Casual Factors Charting) to determine the root cause(s) of the event	*Addressed via the timeline in Appendix 3*
3. To review the root causes of this event for other areas of THORP and the site as a whole, and make recommendations aimed at preventing a recurrence.	*Reviewed via OEF. Suggestions included under section 5 and recommendations in section 9 with explicit guidance on wider applicability..*
4. To establish a timeline for the event, including precursors up to the discovery of dissolver liquor in the secondary containment.	*Addressed via the timeline in Appendix 3*
5. To review and critique the operational decision making against the event timeline.	*Addressed in section 4 and via Observations in Section 5..*
6. To make appropriate recommendations to address the immediate and root causes of the event.	*Addressed in Section 9. A number of observations and suggested courses of action have also been raised in Section 5.*
7. To identify any breaches in the requirements of the relevant Safety Cases.	*No breaches identified. However, ambiguity in sampling requirements addressed via recommendations in section 9.*
8. To identify any deficiencies in the relevant Safety Cases.	*Observations in section 5 and recommendations in Section 9 identify underlying optimistic assumption in safety case concerning integrity of primary containment. Specific issues with regard to detecting losses covered in Section 9*
9. To identify any breaches in the requirements of the relevant Site	*Failure to record use of Category B instruction not a contributory factor but an*

Regulations.	*observation raised in response to failure to record use of OI. Lack of recognition of sump in confirming containment addressed via Section 9.*
10. To identify any deficiencies in the relevant Site Regulations.	*None identified.*
11. To identify any required changes to the event categorisation in light of the investigation findings.	*None identified.*
12. To identify recommendations of environmental significance.	*None identified.*
13. To identify the appropriate Senior Manager(s) to take responsibility for the management of corrective actions.	[redacted]
14. To identify the appropriate Senior Manager to take ownership of the event for the purposes of compiling Company Statistics.	[redacted] - *addressed via recommendation 9.9.1.*
15. To identify the wider learning lessons and determine the best means of communication.	*Addressed in Section 6*

Appendix 2

Description of Feed and Clarification, Accountancy and Buffer Storage Cell 220.

The cell is effectively split into two areas with two separate sumps. The area containing the feed clarification vessels and effluent sentencing tanks is serviced by sump F2226, the area including the accountancy and buffer storage tanks is serviced by sump F2268.

Liquor from the Head End Dissolver Cell, enters cell 220 and is passed into the centrifuges (G2200A/B) for clarification. This clarification removes the "fine fines" from the liquor prior to transfer to one of the two Accountancy Tanks (V2217 A/B).

The accountancy tanks have a working volume of approximately 23m^3 and receive flowsheet product liquor of typically 250g/l Uranium in solution as Nitrate in 2.9M Nitric Acid. These tanks work on a batch basis, alternating fill, accountancy weigh and empty cycles.

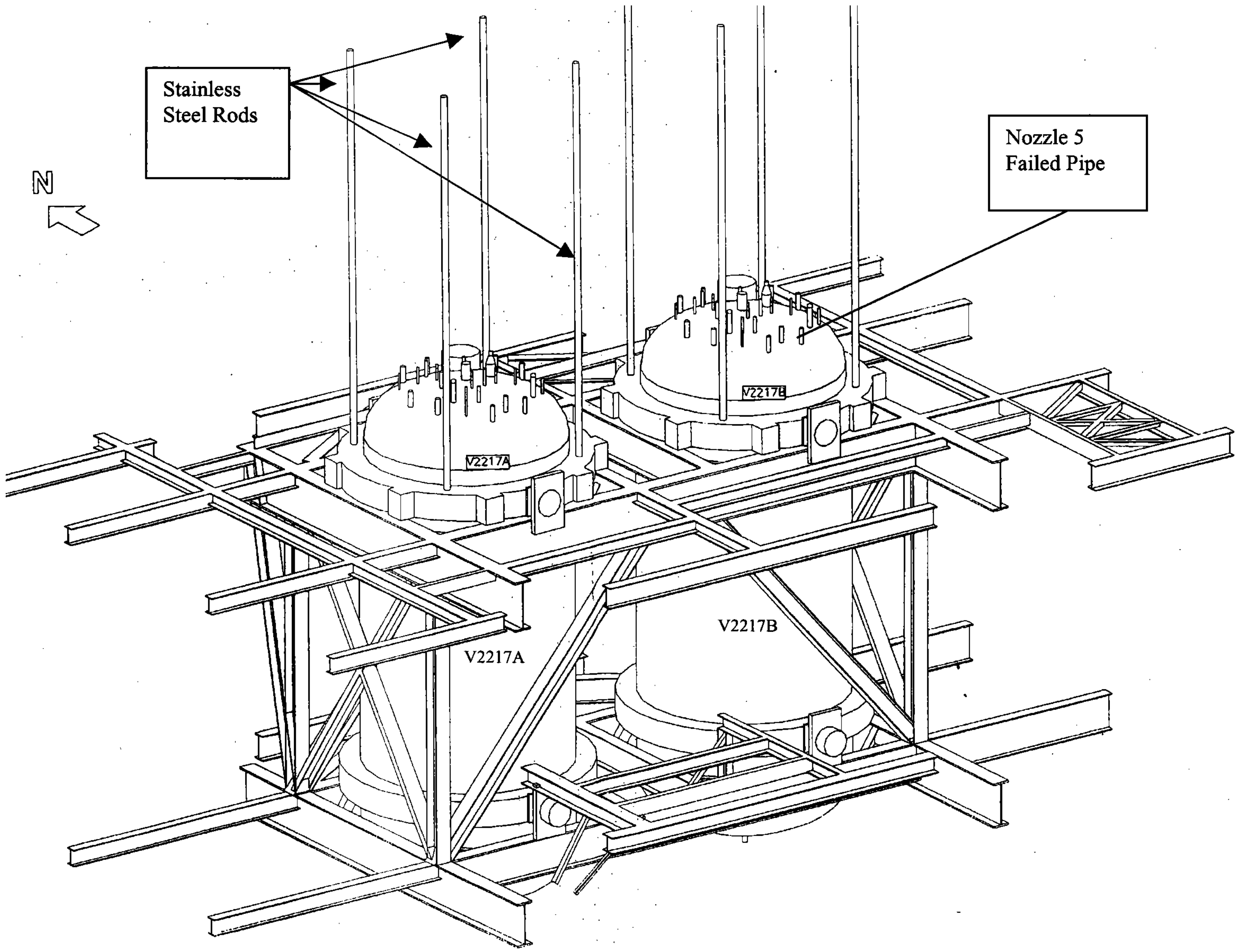
The accounting uses two basic methods, weight measurement and level measurement, coupled with sample analysis. Once the measurements have been taken and sample volumes confirmed the liquor is transferred in to one of the three Buffer Storage Tanks (BST's V2241A-C) using Reverse Flow Diverters (RFD's).

As part of the operation of the accountancy system, the two accountancy tanks undergo sequenced agitation from installed agitation/ejector systems, internal to each tank. This ensures that the liquor is homogeneous and that the sample taken is representative of the body of the liquor.

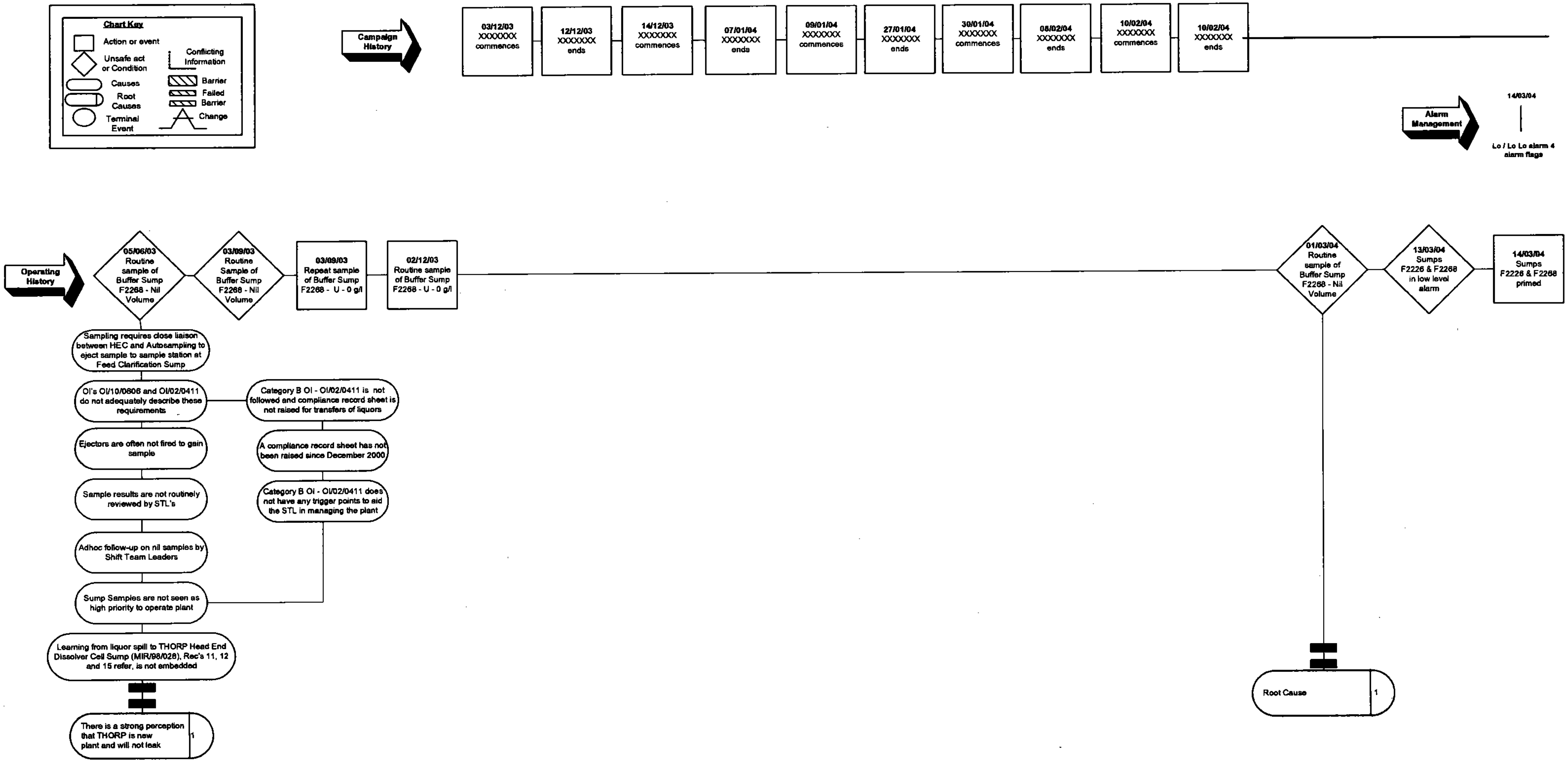
The two tanks are hung from four stainless steel rods that pass through the cell ceiling to weigh tables in the above cell. Steelwork exists within the cell that the accountancy tanks are lowered onto for weigh calibration and purposes. The support rods are fixed through a stainless steel collar around the tank near to the upper dished end. This upper collar also serves the purpose of supporting the tank when it is lowered to rest on the steelwork. The trunnions fixed to both collars were fitted to allow handling for construction purposes and bear no weight during calibration or normal operation.

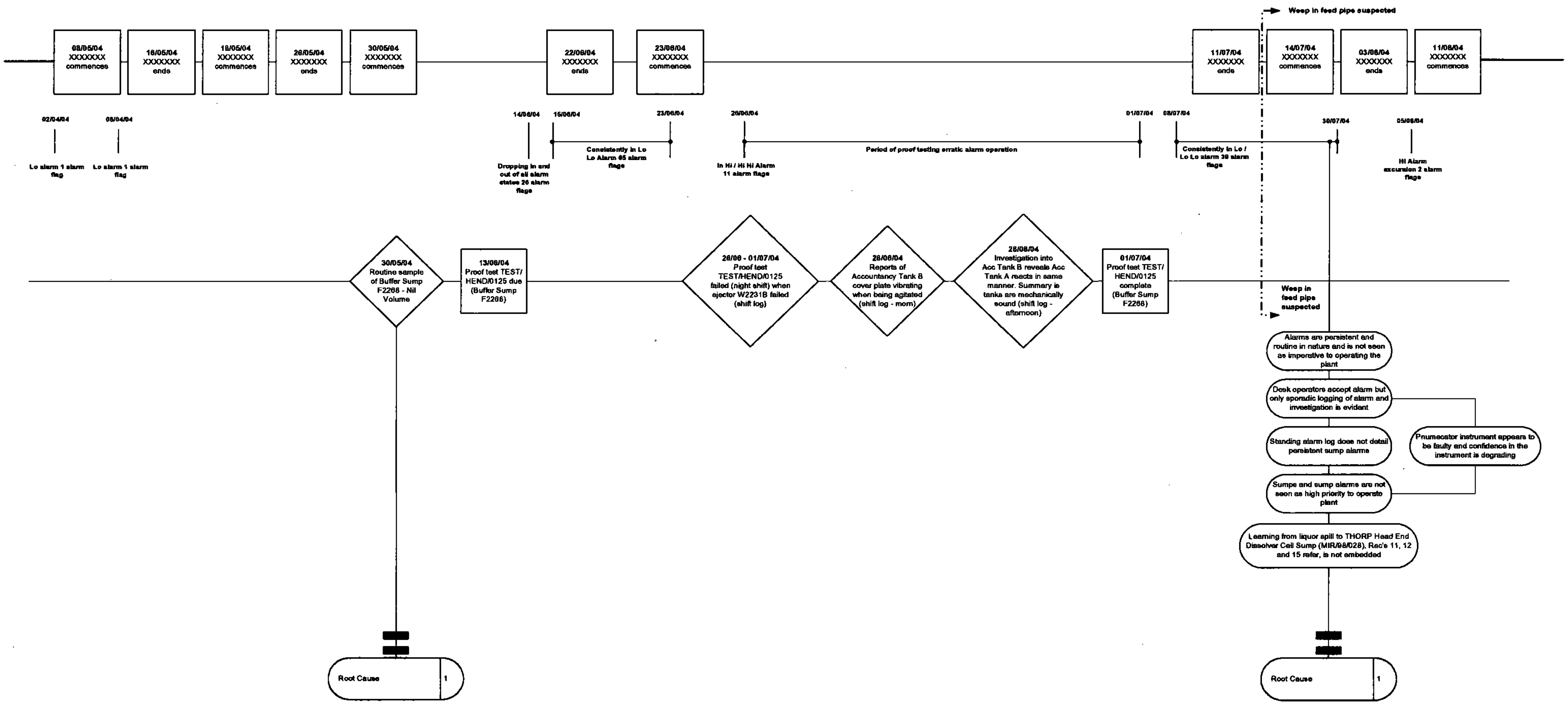
The steel structure below the tanks is fabricated in carbon steel and protected with a painted covering. It is in the form of two levels, at 5.75m and 1.75m, with extensive vertical bracing between the two levels. This steelwork is supported by plates cast into the concrete walls of the cell. None of the steel structure is located below the level of the 0.3M stainless steel cell bund. See fig 1.

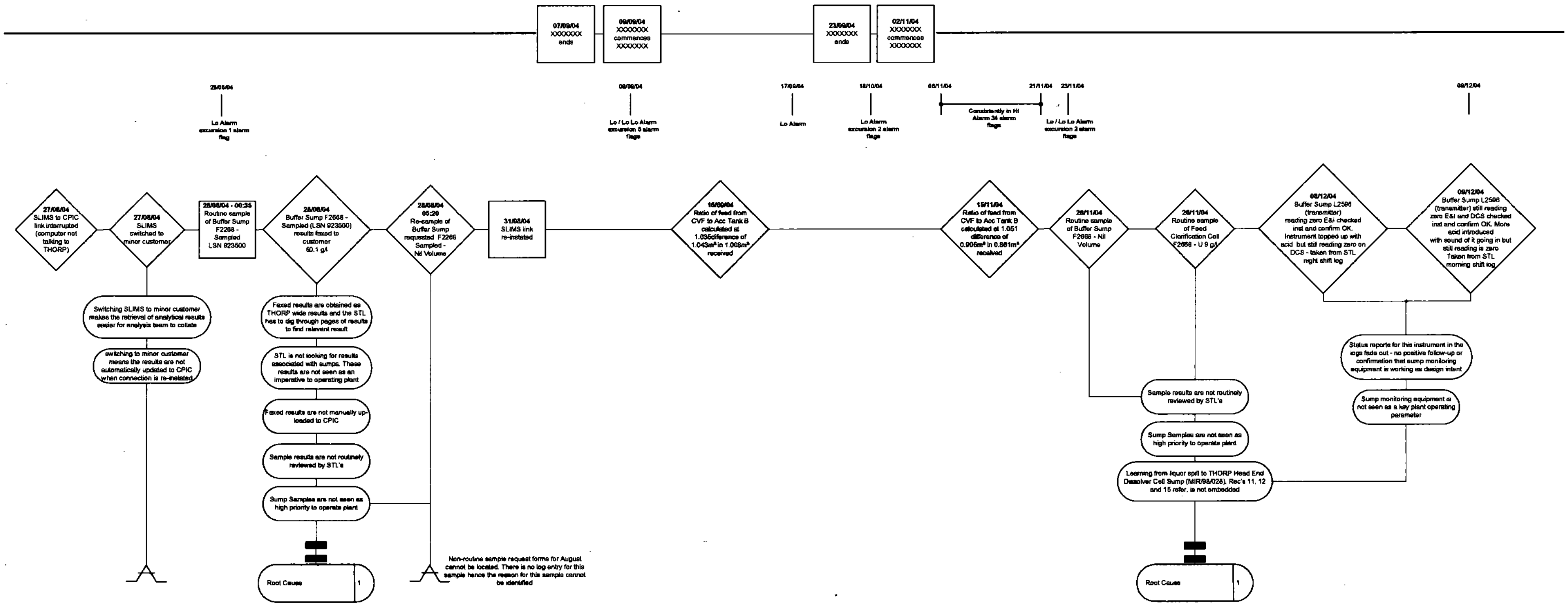
Fig 1 View from the southeast showing carbon steel structure and both accountancy tanks.



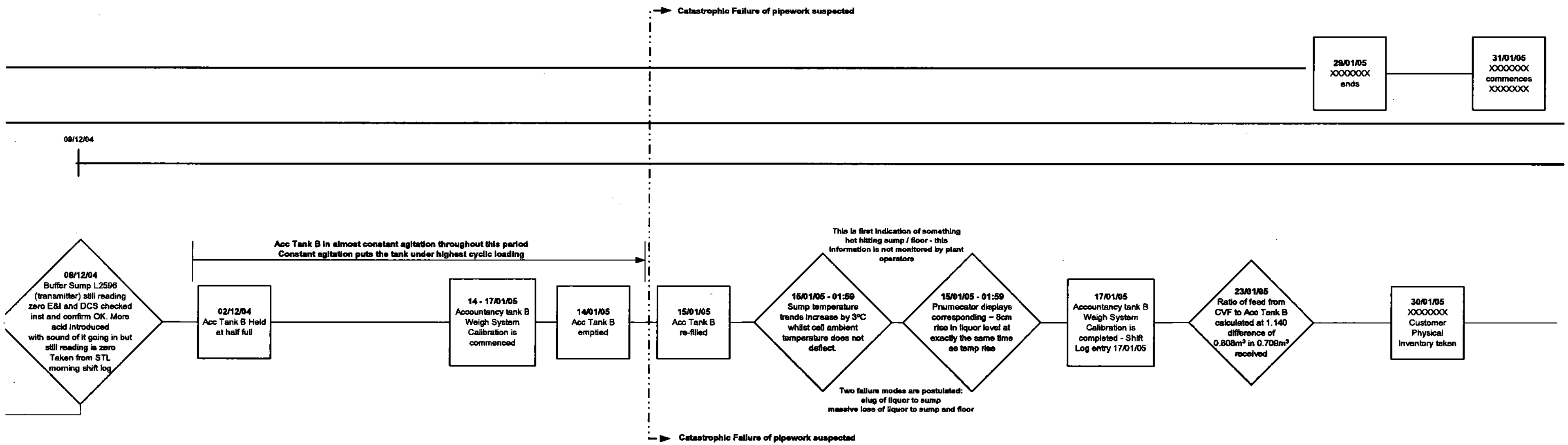
Appendix 3 Timeline including Task, Change and Barrier Analysis combined with Event and Causal Factors Charting

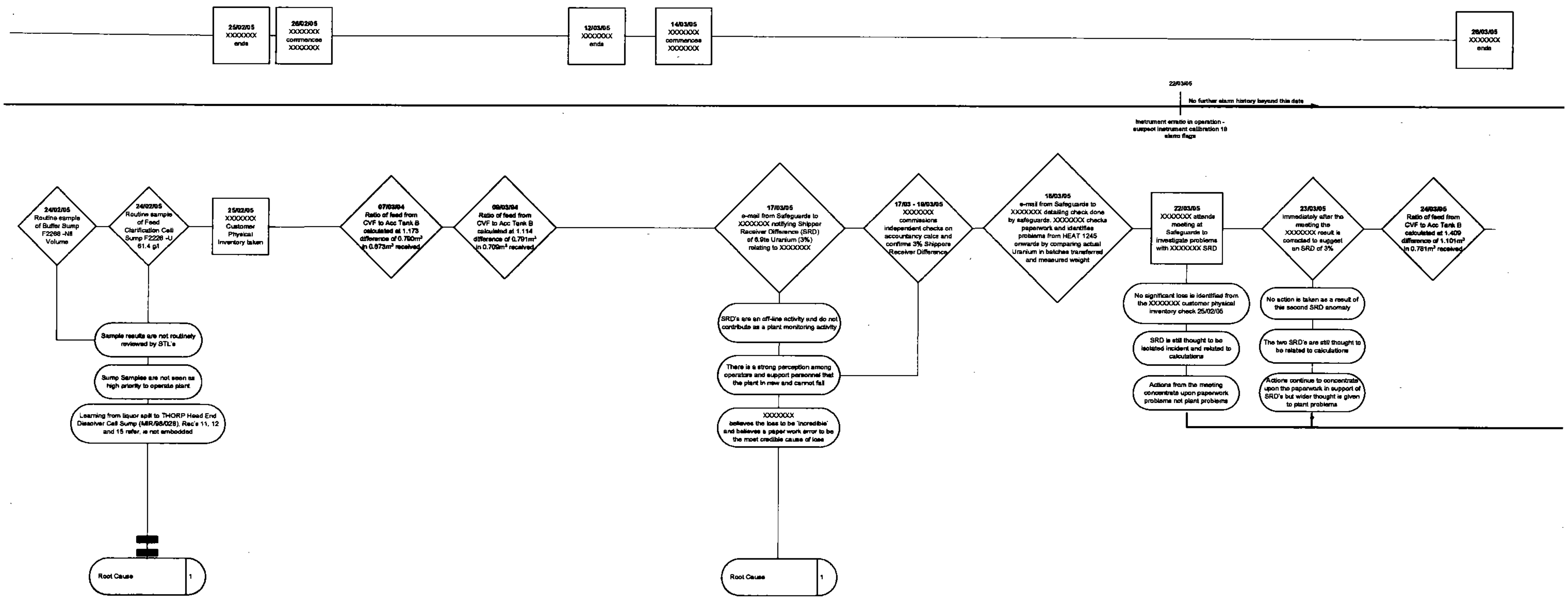


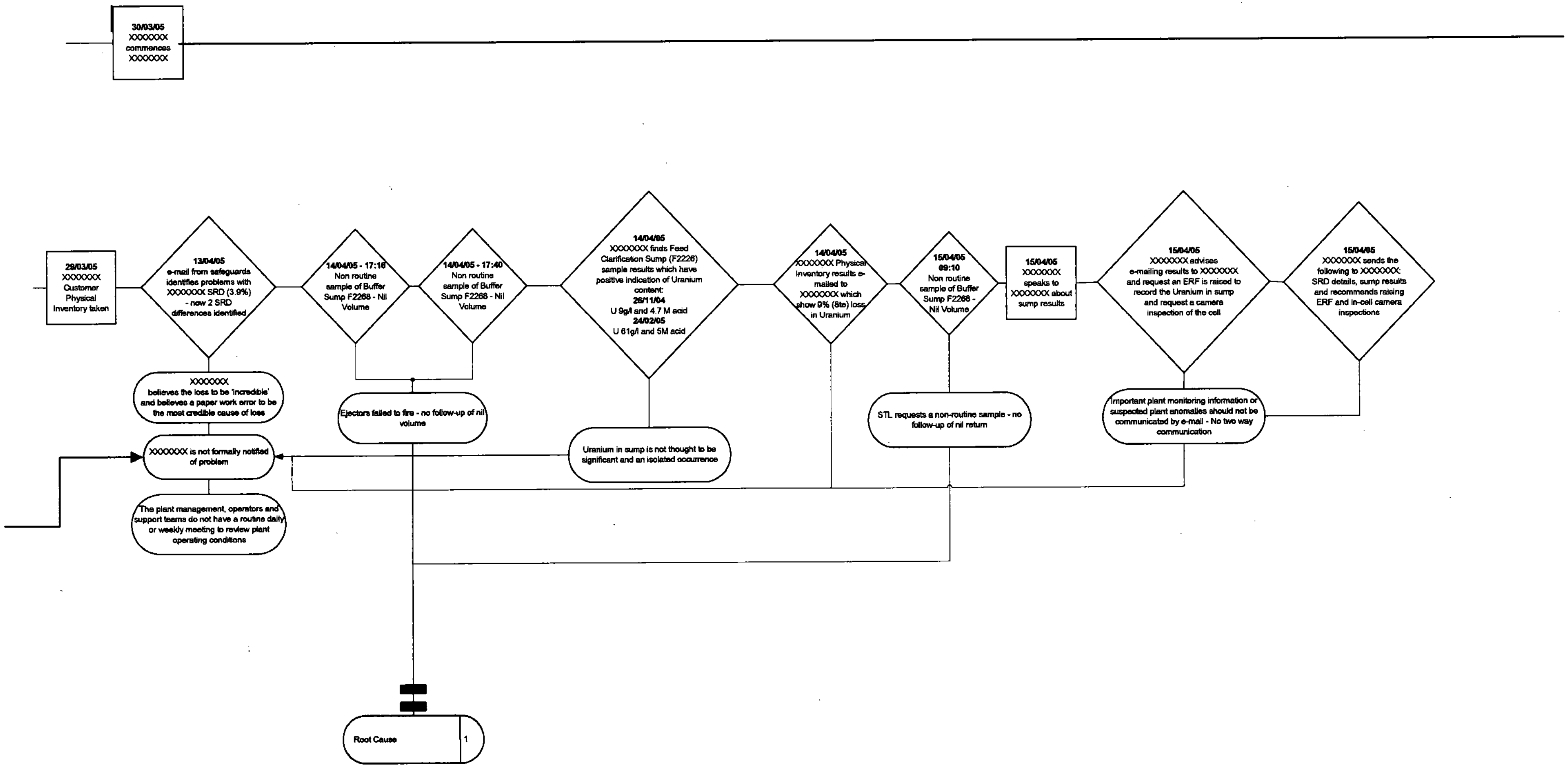

08/05/04 XXXXXXX commences
16/05/04 XXXXXXX ends
19/05/04 XXXXXXX commences
26/05/04 XXXXXXX ends
30/05/04 XXXXXXX commences
22/06/04 XXXXXXX ends
23/06/04 XXXXXXX commences
11/07/04 XXXXXXX ends
14/07/04 XXXXXXX commences
03/08/04 XXXXXXX ends
11/08/04 XXXXXXX commences
Weep in feed pipe suspected
02/04/04
Lo alarm 1 alarm flag
08/04/04
Lo alarm 1 alarm flag
14/06/04
Dropping in and out of all alarm states 26 alarm flags
15/06/04
23/06/04
Consistently in Lo Lo Alarm 65 alarm flags
26/06/04
In Hi / Hi Hi Alarm 11 alarm flags
Period of proof testing erratic alarm operation
01/07/04
08/07/04
Consistently in Lo / Lo Lo alarm 39 alarm flags
30/07/04
05/08/04
Hi Alarm excursion 2 alarm flags
30/05/04 Routine sample of Buffer Sump F2268 - Nil Volume
13/06/04 Proof test TEST/ HEND/0125 due (Buffer Sump F2268)
26/06 - 01/07/04 Proof test TEST/HEND/0125 failed (night shift) when ejector W2231B failed (shift log)
28/06/04 Reports of Accountancy Tank B cover plate vibrating when being agitated (shift log - morn)
28/06/04 Investigation into Acc Tank B reveals Acc Tank A reacts in same manner. Summary is tanks are mechanically sound (shift log - afternoon)
01/07/04 Proof test TEST/ HEND/0125 complete (Buffer Sump F2268)
Weep in feed pipe suspected
Alarms are persistent and routine in nature and is not seen as imperative to operating the plant
Desk operators accept alarm but only sporadic logging of alarm and investigation is evident
Standing alarm log does not detail persistent sump alarms
Sumps and sump alarms are not seen as high priority to operate plant
Pnumecator instrument appears to be faulty and confidence in the instrument is degrading
Learning from liquor spill to THORP Head End Dissolver Cell Sump (MIR/98/028), Rec's 11, 12 and 15 refer, is not embedded
Root Cause
1
Root Cause
1

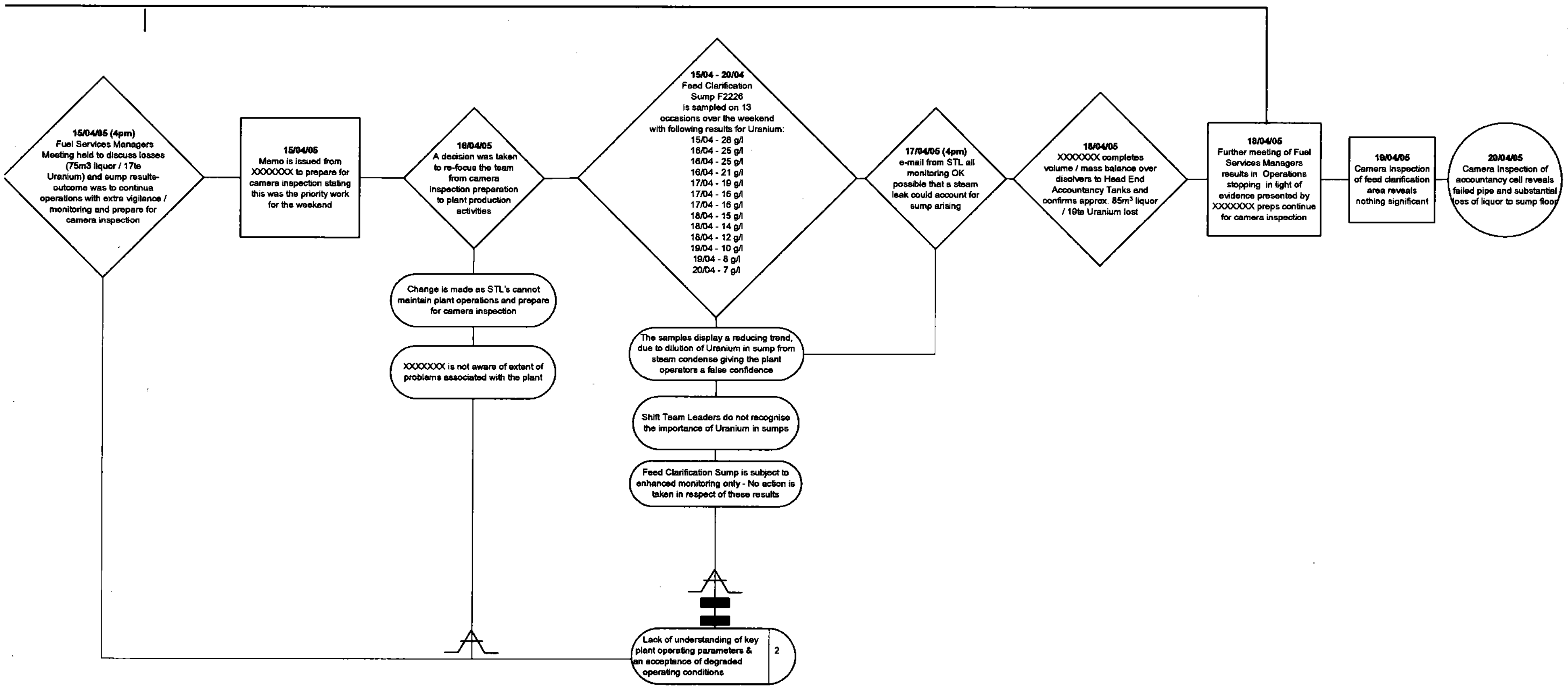


07/09/04 XXXXXXX ends
09/09/04 XXXXXXX commences XXXXXXX
23/09/04 XXXXXXX ends
02/11/04 XXXXXXX commences XXXXXXX
28/08/04 Lo Alarm excursion 1 alarm flag
09/09/04 Lo / Lo Lo Alarm excursion 5 alarm flags
17/09/04 Lo Alarm
18/10/04 Lo Alarm excursion 2 alarm flags
06/11/04 21/11/04 Consistently in Hi Alarm 34 alarm flags
23/11/04 Lo / Lo Lo Alarm excursion 2 alarm flags
09/12/04
27/08/04 SLIMS to CPIC link interrupted (computer not talking to THORP)
27/08/04 SLIMS switched to minor customer
28/08/04 - 00:35 Routine sample of Buffer Sump F2268 - Sampled LSN 923500
28/08/04 Buffer Sump F2668 - Sampled (LSN 923500) results faxed to customer 50.1 g/l
28/08/04 05:20 Re-sample of Buffer Sump requested F2266 Sampled - Nil Volume
31/08/04 SLIMS link re-instated
16/09/04 Ratio of feed from CVF to Acc Tank B calculated at 1.036diferance of 1.043m³ in 1.008m³ received
15/11/04 Ratio of feed from CVF to Acc Tank B calculated at 1.051 difference of 0.905m³ in 0.861m³ received
26/11/04 Routine sample of Buffer Sump F2666 - Nil Volume
26/11/04 Routine sample of Feed Clarification Cell F2668 - U 9 g/l
08/12/04 Buffer Sump L2596 (transmitter) reading zero E&I checked inst and confirm OK. Instrument topped up with acid but still reading zero on DCS - taken from STL night shift log
09/12/04 Buffer Sump L2596 (transmitter) still reading zero E&I and DCS checked inst and confirm OK. More acid introduced with sound of it going in but still reading is zero Taken from STL morning shift log
Switching SLIMS to minor customer makes the retrieval of analytical results easier for analysis team to collate
switching to minor customer means the results are not automatically updated to CPIC when connection is re-instated
Faxed results are obtained as THORP wide results and the STL has to dig through pages of results to find relevant result
STL is not looking for results associated with sumps. These results are not seen as an imperative to operating plant
Faxed results are not manually up-loaded to CPIC
Sample results are not routinely reviewed by STL's
Sump Samples are not seen as high priority to operate plant
Root Cause 1
Non-routine sample request forms for August cannot be located. There is no log entry for this sample hence the reason for this sample cannot be identified
Sample results are not routinely reviewed by STL's
Sump Samples are not seen as high priority to operate plant
Learning from liquor spill to THORP Head End Dissolver Cell Sump (MIR/98/028), Rec's 11, 12 and 15 refer, is not embedded
Root Cause 1
Status reports for this instrument in the logs fade out - no positive follow-up or confirmation that sump monitoring equipment is working as design intent
Sump monitoring equipment is not seen as a key plant operating parameter


Catastrophic Failure of pipework suspected
29/01/05 XXXXXXX ends
31/01/05 XXXXXXX commences XXXXXXX
09/12/04
08/12/04 Buffer Sump L2596 (transmitter) still reading zero E&I and DCS checked inst and confirm OK. More acid introduced with sound of it going in but still reading is zero Taken from STL morning shift log
Acc Tank B in almost constant agitation throughout this period
Constant agitation puts the tank under highest cyclic loading
02/12/04 Acc Tank B Held at half full
14 - 17/01/05 Accountancy tank B Weigh System Calibration is commenced
14/01/05 Acc Tank B emptied
15/01/05 Acc Tank B re-filled
This is first indication of something hot hitting sump / floor - this information is not monitored by plant operators
15/01/05 - 01:59 Sump temperature trends increase by 3°C whilst cell ambient temperature does not deflect.
15/01/05 - 01:59 Pnumecator displays corresponding – 8cm rise in liquor level at exactly the same time as temp rise
Two failure modes are postulated:
slug of liquor to sump
massive loss of liquor to sump and floor
17/01/05 Accountancy tank B Weigh System Calibration is completed - Shift Log entry 17/01/05
23/01/05 Ratio of feed from CVF to Acc Tank B calculated at 1.140 difference of 0.808m³ in 0.709m³ received
30/01/05 XXXXXXX Customer Physical Inventory taken
Catastrophic Failure of pipework suspected


25/02/05 XXXXXXX ends
26/02/05 XXXXXXX commences XXXXXXX
12/03/05 XXXXXXX ends
14/03/05 XXXXXXX commences XXXXXXX
26/03/05 XXXXXXX ends
22/03/05
No further alarm history beyond this date
Instrument erratic in operation - suspect instrument calibration 18 alarm flags
24/02/05 Routine sample of Buffer Sump F2266 -Nil Volume
24/02/05 Routine sample of Feed Clarification Cell Sump F2226 -U 61.4 g/l
25/02/05 XXXXXXX Customer Physical Inventory taken
07/03/04 Ratio of feed from CVF to Acc Tank B calculated at 1.173 difference of 0.760m³ in 0.673m³ received
09/03/04 Ratio of feed from CVF to Acc Tank B calculated at 1.114 difference of 0.791m³ in 0.709m³ received
17/03/05 e-mail from Safeguards to XXXXXXX notifying Shipper Receiver Difference (SRD) of 6.9te Uranium (3%) relating to XXXXXXX
17/03 - 18/03/05 XXXXXXX commissions independent checks on accountancy calcs and confirms 3% Shippers Receiver Difference
18/03/05 e-mail from Safeguards to XXXXXXX detailing check done by safeguards. XXXXXXX checks paperwork and identifies problems from HEAT 1245 onwards by comparing actual Uranium in batches transferred and measured weight
22/03/05 XXXXXXX attends meeting at Safeguards to investigate problems with XXXXXXX SRD
23/03/05 Immediately after the meeting the XXXXXXX result is corrected to suggest an SRD of 3%
24/03/05 Ratio of feed from CVF to Acc Tank B calculated at 1.409 difference of 1.101m³ in 0.781m³ received
Sample results are not routinely reviewed by STL's
Sump Samples are not seen as high priority to operate plant
Learning from liquor spill to THORP Head End Dissolver Cell Sump (MIR/98/028), Rec's 11, 12 and 15 refer, is not embedded
Root Cause
1
SRD's are an off-line activity and do not contribute as a plant monitoring activity
There is a strong perception among operators and support personnel that the plant is new and cannot fail
XXXXXXX believes the loss to be 'incredible' and believes a paper work error to be the most credible cause of loss
Root Cause
1
No significant loss is identified from the XXXXXXX customer physical inventory check 25/02/05
SRD is still thought to be isolated incident and related to calculations
Actions from the meeting concentrate upon paperwork problems not plant problems
No action is taken as a result of this second SRD anomaly
The two SRD's are still thought to be related to calculations
Actions continue to concentrate upon the paperwork in support of SRD's but wider thought is given to plant problems


30/03/05 XXXXXXX commences XXXXXXX
29/03/05 XXXXXXX Customer Physical Inventory taken
13/04/05 e-mail from safeguards identifies problems with XXXXXXX SRD (3.9%) - now 2 SRD differences identified
14/04/05 - 17:10 Non routine sample of Buffer Sump F2268 - Nil Volume
14/04/05 - 17:40 Non routine sample of Buffer Sump F2268 - Nil Volume
14/04/05 XXXXXXX finds Feed Clarification Sump (F2226) sample results which have positive indication of Uranium content: 26/11/04 U 9g/l and 4.7 M acid 24/02/05 U 61g/l and 5M acid
14/04/05 XXXXXXX Physical Inventory results e-mailed to XXXXXXX which show 9% (8te) loss in Uranium
15/04/05 09:10 Non routine sample of Buffer Sump F2268 - Nil Volume
15/04/05 XXXXXXX speaks to XXXXXXX about sump results
15/04/05 XXXXXXX advises e-mailing results to XXXXXXX and request an ERF is raised to record the Uranium in sump and request a camera inspection of the cell
15/04/05 XXXXXXX sends the following to XXXXXXX: SRD details, sump results and recommends raising ERF and in-cell camera inspections
XXXXXXX believes the loss to be 'incredible' and believes a paper work error to be the most credible cause of loss
XXXXXXX is not formally notified of problem
The plant management, operators and support teams do not have a routine daily or weekly meeting to review plant operating conditions
Ejectors failed to fire - no follow-up of nil volume
Uranium in sump is not thought to be significant and an isolated occurrence
STL requests a non-routine sample - no follow-up of nil return
Important plant monitoring information or suspected plant anomalies should not be communicated by e-mail - No two way communication
Root Cause
1


15/04/05 (4pm)
Fuel Services Managers Meeting held to discuss losses (75m3 liquor / 17te Uranium) and sump results- outcome was to continue operations with extra vigilance / monitoring and prepare for camera inspection
15/04/05
Memo is issued from XXXXXXX to prepare for camera inspection stating this was the priority work for the weekend
16/04/05
A decision was taken to re-focus the team from camera inspection preparation to plant production activities
Change is made as STL's cannot maintain plant operations and prepare for camera inspection
XXXXXXX is not aware of extent of problems associated with the plant
15/04 - 20/04
Feed Clarification Sump F2226 is sampled on 13 occasions over the weekend with following results for Uranium:
15/04 - 28 g/l
16/04 - 25 g/l
16/04 - 25 g/l
16/04 - 21 g/l
17/04 - 19 g/l
17/04 - 16 g/l
17/04 - 16 g/l
18/04 - 15 g/l
18/04 - 14 g/l
18/04 - 12 g/l
19/04 - 10 g/l
19/04 - 8 g/l
20/04 - 7 g/l
The samples display a reducing trend, due to dilution of Uranium in sump from steam condense giving the plant operators a false confidence
Shift Team Leaders do not recognise the importance of Uranium in sumps
Feed Clarification Sump is subject to enhanced monitoring only - No action is taken in respect of these results
Lack of understanding of key plant operating parameters & an acceptance of degraded operating conditions
2
17/04/05 (4pm)
e-mail from STL all monitoring OK possible that a steam leak could account for sump arising
18/04/05
XXXXXXX completes volume / mass balance over disolvers to Head End Accountancy Tanks and confirms approx. 85m³ liquor / 19te Uranium lost
18/04/05
Further meeting of Fuel Services Managers results in Operations stopping in light of evidence presented by XXXXXXX preps continue for camera inspection
19/04/05
Camera Inspection of feed clarification area reveals nothing significant
20/04/05
Camera Inspection of accountancy cell reveals failed pipe and substantial loss of liquor to sump floor