CORONERS ACT, 1975 AS AMENDED

SOUTH  *AUSTRALIA*

FINDING OF INQUEST

An Inquest taken on behalf of our Sovereign Lady the Queen at Whyalla in the State of South Australia, on the 19th, 20th, 21st and 22nd days of June, and 7th day of July, 2000, before Wayne Cromwell Chivell, a Coroner for the said State, concerning the death of Andrew Grant Baulderstone.

I, the said Coroner, do find that Andrew Grant Baulderstone, aged 37 years, late of Fisk Street, Whyalla, died at BHP Pellet Plant, Whyalla on the 1st day of December, 1997 as a result of multiple injuries.

1. Introduction

1.1 On Monday 1 December 1997 Andrew Grant Baulderstone and his co-worker, Delwyn Sales, were working at the Pellet Plant at the Steel Works of BHP Co. Ltd. at Whyalla. They were removing material variously called "refractory", "mono", "rammable" or "plastic", a cement-like substance, from the lining of the pellet kiln.

1.2 The pellet kiln is an extremely large machine consisting of a cylinder about six metres in diameter and more than thirty metres long. The longitudinal axis of the cylinder is roughly horizontal, although angled slightly downwards at the discharge end of the cylinder. Iron ore pellets are introduced at the feeder end and, as the cylinder revolves, the pellets roll around inside the kiln and are heated to more than 1200°C. When the pellets reach the discharge end of the kiln they roll out into a chute.

1.3 The kiln is completely lined with refractory bricks, which are butted up against a steel hoop known as the bricking ring. The last 1200mm of the kiln at the discharge end is known as the discharge lip. The discharge lip consists of refractory material about 200mm thick, which is rammed against the walls of the kiln, and is anchored by steel

anchors welded to the shell of the kiln. When the refractory material is heated it becomes rock hard and insulates the steel shell of the kiln from the intense heat inside.

1.4 At about 1.30a.m. on 1 December 1997 Mr. Baulderstone and Mr. Sales were jackhammering the refractory material in the pellet kiln when, without any prior warning, refractory material above their heads collapsed and fell on them, killing Mr. Baulderstone and severely injuring Mr. Sales. Some of the pieces of refractory material weighed 400kgs or more.

2. Cause of death

2.1 A post mortem examination was carried out on the body of the deceased by Dr. J.D. Gilbert, forensic pathologist, at the Forensic Science Centre on 2 December 1997. Dr. Gilbert found that Mr. Baulderstone died from multiple injuries. He commented:-

> "1. Death was due to multiple injuries including lung lacerations and contusions associated with multiple rib fractures and rupture of the spleen and stomach. There may also have been an element of crush asphyxia. This was suggested by evidence of chest compression (left sided chest injuries) with congestion of the face and neck associated with bilateral middle ear haemorrhages and a few petechiae in the conjunctivae.
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> 2. Analysis of a specimen of blood obtained at autopsy reportedly showed a blood alcohol concentration of nil and no cannabinoids were identified. EMIT screening of a specimen of urine was negative for amphetamines, benzodiazepines, cannabinoids, methadone and opiates.
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> 3. No natural disease that could have caused or contributed to the death was identified at autopsy". (Exhibit C.3a, p4).

3. Background

3.1 The pellet kiln had been subject to a scheduled shutdown in June 1997, when a number of courses of refractory bricks and an entirely new discharge lip had been installed. The kiln had been relined two years previously. The refractory material on the discharge lip was replaced using new stainless steel clips and anchors. I will discuss the anchorage system in more detail later. By August of 1997, a number of bricks in the first course past the discharge lip showed signs of "spalling", or fragmentation. This process gradually accelerated until the outside steel shell of the kiln developed a hot spot, about 300mm square, which was glowing red hot. It had been decided to shut down the kiln on 2 December 1997, but on Friday 28 November

further damage had become apparent, and the decision was taken to shut the kiln down immediately.

3.2 Mr. John Grimes, the Senior Installations Supervisor for BHP Refractories Pty. Ltd., described the attempts to repair the kiln to First Class Constable Scarman in his statement:-

> "On Friday 28 November 1997 the kiln at the Pellet Plant at BHP was shutdown due to partial brick failure at the entrance of the kiln. This was an unscheduled shutdown. The kiln at its opening consists of 1.2m of rammable or plastic material which can also be referred to as refractory and its proper name is Plyram 85. After that section, there are several rows of bricks. About 3 weeks ago part of two of the bricks fell away. The bricks that were damaged were part of the course that butted up against the rammable. We tried to maintain the kiln as functioning by 'gunning' the area which is like a concrete spray and is used to fill the gap created by the part of the bricks that fell away.
>
> We did this for about 2 weeks and then we got a firm called Fosbel who do ceramic welding at the coke oven and are based on site to attend and attempt to fill the area with a ceramic weld. That was partially successful and lasted about a week. After that on Thursday, 27 November, Fosbel came back with a larger machine and attempted the job again. This was again only partially successful and only held the brick in for a couple of hours and in the meantime the two bricks that were originally damaged had fallen out completely and two others had cracked". (Exhibit C.41, p1-2).

3.3 Once the kiln had cooled off, it became apparent that it was necessary to remove an entire course of bricks and several areas of the refractory material. Mr. Grimes said:-

> "The plastic we could see was damaged in the area of the retainer ring, which is a ring which stops the brickwork pushing forward and pushing the plastic off the end of the kiln. It is a metal piece of flat bar which is about 150mm high x 50mm wide and is gussetted on the plastic side. It runs the full circumference around the kiln. We observed that about 300mm of that retainer ring had been burnt out and we could actually see that the anchor system which holds the plastic to the shell of the kiln was missing. Normally you can see the anchor clips which are welded to the shell of the kiln and the anchors which are embedded into the plastic, but in this instance there was a gap and the clips appeared to be missing. If you imagine the kiln entrance as a clockface, the 300mm burnout section was between 3 and 5 o'clock.
>
> Once we had identified the area that had to be removed we had to decide how to remove it as we had never taken only 1 complete row of bricks out before, its normally either 1 or 2 bricks or several rows. All of my shift supervisors and myself then had a look and decided that the safest way to remove the course of bricks would be to reverse the procedure of putting them in. That is to put the bricking rig up which supports the brickwork and remove 1 brick at a time until we get down to the bottom". (Exhibit C.41, p3).

3.4 The bricklayers started removing the first brick course, and completed that task by about 2.30p.m. on Sunday 30 November 1997. Mr. Grimes continued:-

> "We noticed on the kiln in the position of about 1 o'clock that there was a gap behind the plastic and that one of the anchor clips had broken off. We could also see that other anchor clips were intact still. We then saw that there was also 12 bricks in the second course that needed replacing. We were then going to turn the kiln around so that the damaged plastic originally in the 3 to 5 o'clock position could be moved to a position of about 6 o'clock, and the damaged plastic originally in the position of 1 o'clock would be moved to 3 o'clock. Once the repair work had been completed on the plastic in the 6 o'clock position, the kiln would be turned a second time so that the plastic in the 3 o'clock position could be moved to the floor (6 o'clock) where we were going to cut about 600mm off and see if any other anchor clips or anchors were damaged. Before this was done at about 3.00p.m., one of the brickies who was actually the safety rep, Jim McIlduff came up to me in the kiln and asked if I had seen the broken anchor clip. I said I had and explained that there were about 12 anchor clips per plastic block and that all the others looked intact. I told him what we intended to do, and he just made the comment that we wouldn't want the whole lot to come down.
>
> While Jim and I were talking, the rig was being pulled apart and that was completed at about 7.30p.m. Just prior to that, I spoke with Jock in the office and told him what was going on and what course of action we were taking. I also told him that I had organised four men from Diversified Industrial Services to come in and jackhammer out the 5 or 6 slabs of plastic in the kiln. I then went home". (Exhibit C.41, p4-5).

4. **Events leading up to the collapse**

4.1 In accordance with the modern practice of using contract labour, Mr. Grimes contacted Mr. Frank Gillaney of Diversified Industrial Services Pty. Ltd. ("DIS") to provide the workmen to jackhammer out the suspect refractory material. Mr. Gillaney telephoned six workmen, including Mr. Baulderstone and Mr. Sales, at about 7.30p.m., requesting them to be at the Diversified depot by 8.00p.m. Mr. Gillaney said that, unlike most jobs where DIS supervises its own staff, on this occasion it was all left to BHP. He said:-

> "Well, normally what we do if normally BHP rings us and gives us a job our job is supervise it, we get it up and running, we supervise it from start to finish, but when we work for the brickies, because it is a skilled job, what we normally do, is the brickies just ring us and ask for so many labour so much machinery, and we just send them over to the brickies and the brickies take over from there. So normally we just make sure they got hats, glasses, boots all their PPE, personal protective safety equipment and then we go through JSAs with them and ATWs, we always make sure if they are going into confined space they have had confined space training. You know if they are driving a truck they got the appropriate licences and what not". (Exhibit C.39, p3-4).

4.2 A "JSA" is a job safety assessment, and "ATW" is an authority to work, issued once the JSA is complete. Mr. Ian Davies, one of Mr. Baulderstone's co-workers that night, explained the system:-

> "The procedure before any work commences is that a Job Safety Analysis (JSA) is filled out to make sure that the working environment is safe. Then BHP send an Authority to work order (ATW) to our boss Frank Gillaney which details what work the company (BHP) wants done. BHP are then supposed to come up to the kiln and do an assessment on gas levels in the area to see if the levels are safe. They then fill out a confined space entry permit which includes a safety check. The watcher is supposed to fill out that form and note on it who is going into and out of the kiln. The watcher also controls who is in the area and you are not even supposed to be in the area without putting your tag on the danger board. After this has been completed, BHP then give it to Diversified which basically hands the site over to Diversified for them to control". (Exhibit C.36, p2).

As I have already outlined, that procedure did not apply in the job in question, since BHP retained "control" or supervision of the job.

4.3 Before they commenced work, the men noticed that a piece of refractory material had already fallen from above. Mr. Davies described this as a "chunk of refractory", and said that it measured approximately 6 feet x 2 feet x 1 foot, and that it had fallen from near the end where they were working. He indicated the area from which the piece had fallen in the photograph Exhibit C.35a. (T.30). Mr. Walker thought that this refractory material had fallen from the roof of the kiln (T.68), but Mr. Davies thought that it was near the entry to the kiln but not in it (T.31). The photograph clearly indicates to me that the chunk of refractory had fallen from outside the kiln, and the evidence of Mr. Kilpatrick satisfies me that the refractory material which fell was "just sprayed on" and was different from the material used inside the kiln (T.177). A scaffolding had been erected over the walkway at the entrance of the kiln in case more of this substance fell. In view of all of this evidence, I am satisfied that this issue is irrelevant to the collapse which subsequently occurred.

4.4 At about 10.15p.m. on Sunday 30 November 1997 the DIS workers began jackhammering the sections of refractory material marked out by Peter Paige, the Raw Materials metallurgist at BHP (see Exhibit C.42, p5). The men divided themselves into two crews of three men, one crew working and one resting outside the kiln.

4.5 At about 12.30a.m. Messrs Baulderstone, Sales and Walker went to "lunch". They returned around 12.50a.m. and relieved the other crew. Mr. Baulderstone and Mr.

Sales went back into the kiln and began jackhammering, while Mr. Walker remained outside the kiln trying to get a "bobcat" started with the help of another DIS worker, Tim Millward. Mr. Walker described what then happened as follows:-

> "Tim came up and was sitting on the bobcat having a look and I was standing with my back to the kiln entrance. The bobcat was only about 5m away from the entrance to the kiln and I could hear the jackhammers going. I couldn't distinguish between whether 1 or 2 hammers were going but at least 1 was. All of a sudden we heard an almighty bang. I turned around and saw a great cloud of dust come out of the kiln entrance. Tim and I rushed over and went straight in the entrance. Beforehand we had lights set up in the kiln but they were all out. We were screaming at Delwyn and Andrew and tried to get a response. We both got a light set up straight away and were also calling on the radio 'Emergency Emergency'.
>
> I looked to my left and signalled to the man in the control room to get some help but saw that he was already on the radio. I don't know his name. Tim and I wanted to go inside the kiln but looked and saw that it was fairly dangerous and the right side of the wall looked like it could fall down. The next moment Keith Robson and another BHP worker arrived and went into the kiln area and pulled a big chunk of refractory off Delwyn's chest. I could hear Delwyn saying all the names of his family and then he said 'I think I can get up'. After that he just kept moaning. I then asked Keith what we needed and he said to get some air jacks, so I went with another pellet plant worker to get them. They are like a car jack but much more powerful. I then spent the rest of the time trying to help out all the emergency services crews as best I could. I then left them with it as we had to go to a counselling session. I saw that Andrew was trapped by his legs and wasn't moving. I also didn't see much of Delwyn as I was just trying to help out where I could". (Exhibit C.36, p3-4).

5. <u>Cause of collapse</u>

5.1 Clearly, the refractory material fell because the stainless steel anchoring system, which should have held the material against the shell of the kiln, failed. This was acknowledged by Mr. David Kilpatrick, the Operations Superintendent, at the Pellet Plant (T.203), and by Mr. Don Dart, the Manager, Ore Processing for BHP Co. Ltd. As Mr. Dart said, that is the "easy part" (T.319). The more difficult question is why the anchoring system failed.

5.2 Mr Paige told me that when he inspected the kiln on 29 and 30 September 1997, he noted that where the bricks were missing, the bricking ring had been burned away and the refractory material had been undercut through abrasion, creating a wedge-shaped gap (looking side-on) about 75mms high from the shell of the kiln, and extending

300mm or so back under the block. He said that there were two such areas. To use a clock-face analogy, one was at 12o'clock, and the other at 3o'clock (Exhibit C42, p4).

5.3 The anchoring system consisted of a stainless steel clip or hook welded to the steel shell of the kiln. A stainless steel anchor, roughly "V" shaped, but squared off at the base, was placed on the hook and then tack-welded to it so that its prongs were vertical to the kiln shell. This tack-welding was designed to break under stress, to allow the anchor to pivot around the hook if the refractory material expanded. The refractory material was then installed while in a putty-like consistency by ramming it against the shell of the kiln over the anchors. When heated, the material became rock hard and the anchors were then firmly embedded in the material.

5.4 Like Mr. Grimes, Mr. Paige said that he saw that one anchor was "worn away" but:-

> "It still appeared to be hard up against the shell and (we assumed that) the rest of the anchors were still intact". (Exhibit C.42, p5).

5.5 The statement quoted above was given to Mr. Sossa, an Inspector from the Department for Administrative and Information Services - Workplace Services - on 15 December 1997. When Mr. Paige gave evidence at the inquest, however, he said that he actually saw two anchors damaged, one worn away and the other fractured by what he thought was "heat stress" (T.310). He said that he checked to see if the refractory material had moved away from the shell of the kiln, but saw no gap in the indentation between the material and the bricking ring (T.297).

5.6 Mr. Paige was quite clear that he saw damage to two anchors rather than one, and I accept his evidence about that.

5.7 Mr. Dart told me that when the course of refractory material was replaced in June 1997, new hooks and anchors were installed. The hooks and anchors were manufactured by a company in Sydney to specifications drawn up by BHP. Those specifications required a 5mm radius at the 90° bend in the hooks. Mr. Dart said that in a large percentage of the hooks that failed, there was instead a crease of about 0.5mm diameter, at the bend.

5.8 Mr. Dart produced several technical reports commissioned by BHP since this incident. Legal professional privilege had been claimed when production was requested by Mr. Sossa in 1997-98, but any such claim was waived for the purposes of the inquest.

These reports detail the investigations carried out by the company in its attempts to understand what happened. I will give a brief outline of the contents of these reports in the following paragraphs.

5.9 A report by Mr. Craig Roulston, Refractories Technologist from BHP Refractories Pty. Ltd. at Port Kembla dated 6 January 1998, concluded that the ceramic welding process, used several times before the November shutdown in an attempt to repair the damaged bricks, "would not have resulted in a significant increase in load on the anchors" (Exhibit C.43a, p3).

5.10 A report by Mr. P.L. Warburton, Principal Metallurgist with BHP at Port Kembla dated March 1998, identified that the predominant mechanism of anchor failure was fatigue fracture in the two bends of the anchor hooks, while a lesser mechanism was tensile overload of inadequate attachment welds. Of the 251 hook remnants gathered after the accident, 144 did not comply with the specified 6mm radius. (Elsewhere, the specification quoted was 5mm). 221 of the hooks fractured completely, and in all cases where the cause could be identified (42), fatigue was implicated. In approximately one third of the remnants, the "design intention of ready fracture of hook/anchor tack-welds was defeated ... owing to excessive welds. Any refractory movement would have exerted high bending moments ...". Mr. Warburton noted the presence of "sigma phase embrittlement" in a significant number of hooks. He said:-

> "It is postulated widespread hook failure allowed cracks to form through the monolithic refractory. Such cracks allowed blocks to move away from the kiln wall and open apertures for sweep by combustion gas, before falling back against the kiln. This radial cyclic movement also battered the projecting bend 1 fracture surfaces in many examples, and probably steadily shattered the refractory from the base upward". (Exhibit C.43c, p29).

5.11 A report dated 12 May 1998 from CompuMod Pty. Ltd., a company specialising in computer modelling in engineering, confirmed that:-

> "In summary, the most important factors that decrease the fatigue life of the clips are the 'hot spot' (exacerbated further by through thickness curing of the rammable), cracked rammable and clip design. Other less important factors are missing clips, or reduced number of clips and missing cooling fin spacers. Factors which have minor or no impact include bricking ring spacing or removal, changing production rates, clip orientation, adhesion of rammable to shell and removal of clips from the monolithic (uncracked) rammable". (Exhibit C.43d, p30).

The reference to "rammable" is a reference to the refractory material.

5.12 A report from Messrs G. Bowie and H. Tysar of the Product Applications Section of BHP dated July 1998 concluded that the average fatigue life of the anchor hooks with the specified 5mm radius bend was approximately 2.5 times greater than the hooks with the creased (.5mm radius) bend (Exhibit C.43f, p3).

5.13 A further report by Mr. Roulston dated November 1999 following the "finite element analysis" carried out by Compumod, concluded that:-

> "• when the bricking ring was moved 600mm further back into the kiln in 1994, making the discharge lip 1200mm wide rather than 600, it caused stresses in the bricks and refractory material "above the yield strength of the materials". As a result of these stresses, the kiln became "trumpet shaped", deforming an additional 3mm at the end;
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> • cracks in the cooling plenum (a cooling jacket around the outside of the kiln), and in the sealing flange (a flange around the outside of the kiln) would have caused significant stresses, enough to cause the kiln to become "lemon shaped", and to impose stresses well in excess of the failure strength of the bricks and corresponding refractory material . (Exhibit C.43b, p11).

5.14 A report dated November 1999 by Mr. D. Castagna of BHP's Engineering Technical Services Division at Port Kembla, evaluated all the available evidence. Mr. Castagna also examined the evidence arising from a later unscheduled shutdown of the kiln in September 1998, after which the anchor clips were again noted to have suffered mechanical bending failure. His conclusion was that the failure in 1997 was caused by:-

> "The relocation of the bricking ring (October 1994) from 800mm to 1200mm from the discharge end of the kiln, and in line with the sealing flange plate, substantially increased the stresses within the bricking ring, kiln shell, nose casting, cooling plenum and sealing flange plate to values in excess of the material yield strength. As stresses were in excess of material yield strength the cooling plenum, flange plate and bricking ring cracked through low cycle fatigue after an unknown time period. The resulting structural discontinuity in the kiln shell created a kiln cross section that flexed from cylindrical to 'lemon' shaped twice on each kiln revolution causing a substantial increase in localised kiln deflection. Nose castings loosened as a result of increased loads, from both the structural discontinuity and bricking ring relocation, further decreasing kiln shell structural stiffness. Rammable refractory panels and bricks were forced against each other due to the increased deflection causing brick spalling and lifting and excessive cyclical anchor clip loading in the vicinity of the structural discontinuity. Brick failure led to the formation of a hot spot in the kiln shell. This hot spot deformed the steel shell outwards imposing higher loads on the adjacent anchor clips and exposing them to

> furnace temperature. The increased cyclical anchor clip loading local to the hot spot and crack location caused the anchor clips to fail by bending fatigue. This process was accelerated by the presence of tight edged out of specification anchor clips and exposure to furnace temperature. The resulting area of unsupported lining increased the load on adjacent lining segment anchor clips during kiln rotation. These overloaded clips also then failed increasing the load on their neighbours and so on around the circumference of the kiln discharge lip". (Exhibit C.43h, p14).

Mr. Castagna added that the reasons why refractory failure had become apparent in the collapse in December 1997, and not earlier, were that:-

> "• the presence of tight edged radii significantly reduced the fatigue life of a majority of the anchor clips in December 1997;
>
> • the structural discontinuity on previous campaigns had not reached the severity required to cause anchor clip failure. The number of kiln cycles for a fatigue crack to initiate and then propagate to a critical length is unknown". (Exhibit C.43h, p14).

5.15 The actual mechanics of what happened on 1 December 1997 were explained by Mr. Dart. He said that, by that time, the entire anchorage system had "unzipped", leaving the refractory material in a monolithic (one piece) structure within the kiln, but no longer attached to it. As soon as Mr. Baulderstone and Mr. Sales jackhammered through the entire width of the refractory ring, it was as if they removed the keystone from an arch and the whole structure lost its integrity and collapsed (T.381, 386).

5.16 I accept Mr. Dart's evidence about these matters and the conclusions drawn in the reports I have just outlined, and find on the balance of probabilities that the circumstances of the collapse of the refractory material which caused Mr. Baulderstone's death were as they have described.

5.17 <u>Application for adjournment</u>

Mr. DiFazio, counsel for Mr. Sales, submitted that I should adjourn the inquest so that he could have the technical material provided by BHP referred for expert analysis. He said that the material was mostly "in-house" at BHP, and was untested by an independent agency.

5.18 I refused Mr. DiFazio's request to adjourn the inquest for that purpose. I did so because the technical material is quite specialised, and re-evaluating it would be a lengthy and expensive process. Only a small number of industries utilise the sort of

equipment involved here, and I would expect that the number of people with sufficient expertise to provide a useful analysis would be small.

5.19 I was favourably impressed with the apparent frankness of the witnesses from BHP, Mr. Dart in particular. The reports he produced identify a number of failures on the part of BHP which I will discuss shortly. There is not the slightest hint of a "cover up" in this case.

5.20 My function in this inquest is to determine the "cause and circumstances" of Mr. Baulderstone's death - see Section 12(1)(a) of the Coroners Act 1975. I consider that I have sufficient material before me to fulfil that task adequately. The time and resources which would be expended if Mr. DiFazio's request were to be granted would be considerable. I consider that any extra benefit to be gained thereby would not be sufficient to justify it.

6. **Could the collapse have been prevented?**

6.1 All the witnesses told me that this collapse had been unprecedented. Mr. Kilpatrick had worked at BHP for 28 years, Mr. McLaughlin for 17 years and Mr. Dart for 21 years. Even though they had seen damage to the refractory material in the pellet kiln before, they had always assumed that the material would remain anchored to the skin of the kiln. They all deposed to the great difficulty that had been experienced previously in removing the material from the shell of the kiln in the past. Mr. McLaughlin frankly admitted:-

> "In my experience in dealing with refractory materials, ... it is an extremely hard material to remove and the thought of complete anchor failure never ever occurred to me on such a scale". (T.152).

6.2 Mr. Kilpatrick told me that during two previous scheduled shutdowns of the kiln, they had used a remote-controlled machine called a "Brokk". This is a small, tracked machine which carries a hydraulic arm fitted with a jackhammer. The machine is operated by use of a remote control connected to it by a cable. Clearly, the design of the machine implies that it is useful in a confined space where there is a risk of collapse. Mr. Kilpatrick insisted that it was used because it was quicker and more efficient than manual jackhammering, taking twenty-four hours to do a job which used to take seventy (T.187). He denied that it was used because there was concern about safety (T.186). This was echoed by Mr. Dart (T.316).

6.3 The shutdown in November 1997 was unscheduled, and the Brokk machine was unavailable - it was in Groote Eylandt at another of BHP facilities. It could not be obtained for one to two weeks.

6.4 I accept that Messrs. Dart, McLaughlin and Kilpatrick would not have allowed the manual demolition to proceed if they had contemplated the possibility of a collapse. They were all in and about the kiln over that weekend, and were all at risk, although not to the same extent as the workmen. Mr. McLaughlin was still present when the jackhammering started, although he went home at about midnight.

6.5 Now that a collapse has occurred, BHP have rightly taken the approach that, unless they are able to guarantee the integrity of the anchoring system, they must demolish the whole of the refractory ring with the remote-controlled machine before workers can be permitted entry to the kiln to affect repairs. Mr. Dart said that they had tried many methods to confirm the integrity of the anchoring system, including acoustics, radar and echo-sounding technology, but none of these will provide the necessary assurance (T.343).

6.6 Some issues were ventilated at the inquest which I do not consider were implicated in the tragic outcome:-

- since the workers were hired to BHP on a "labour only" basis, I accept that it was not necessary for DIS to prepare a Job Safety Assessment, and nor was it necessary for BHP to issue a specific authority to work. The DIS workers were to be supervised by Mr. McLaughlin, who was the relevant shift supervisor at the time, although he had gone home when the accident occurred;
- being "labour only", BHP's own work safety assessment, known as an "Isolation Permit" (Exhibit C.38c), applied to the DIS workers. This of course did not address the risk of collapse. The job would not have proceeded if that risk had been identified. Accordingly, it cannot be argued that any defect in this procedure, if there was one, contributed to the accident;
- similarly, Mr. Davies did not have a Confined Space Certificate, yet he was allowed to work in what BHP assessed as a "low level confined space". This was unsatisfactory, but not causally relevant to the tragedy. Mr. Baulderstone did have such a certificate (Exhibit C.44g).

6.7 There are some areas where BHP practices prior to this accident were less than satisfactory, and which have, in my opinion, contributed to the tragedy. These include:-

- a lack of quality control over the anchor hooks, which allowed hooks which did not comply with specifications, and which had a fatigue life 2.5 times less than the standard ones, to be used when the kiln was refurbished in June 1997;
- a lack of quality control which allowed welding of the clips to the shell of the kiln to become more susceptible to heat fatigue in a small number of clips (less than 10 percent);
- conversely, a lack of quality control allowed some of the tack welds between the hooks and the anchors to be too strong, which prevented them from breaking as they were designed to do to allow hinging when the refractory material expanded. This subjected the clips to bending forces which caused fatigue stress. This occurred in approximately one third of the anchors;
- major changes were made to the design of the kiln (particularly doubling the size of the discharge lip from 600mm to 1200mm, and shifting the bricking ring so that it corresponded with the position of the sealing flange on the outside of the kiln), without proper engineering analysis of what effects these changes may cause. When using such an enormous piece of machinery, weighing hundreds of tons, even apparently minor changes had unforeseen consequences. It is surprising that BHP allowed such changes to be made without comprehensive engineering advice;
- the cracks to the cooling plenum and sealing flange were periodically welded up when the kiln was shut down. They simply reappeared when the kiln was restarted, thereby renewing the undue stress on the refractory anchors underneath. Again, it is surprising that a detailed engineering analysis was not carried out to determine the cause of the repeated cracking, and what effect it may have been having on the functionality of the kiln as a whole.

6.8 It is not for me to decide whether a collapse was "reasonably foreseeable". To do so would transgress Section 26(3) of the Coroners Act. I accept the evidence of the BHP witnesses that a collapse was unprecedented, and that they did not anticipate that such a calamity would occur. There were a number of areas where their processes and procedures were at fault, and I find that these failings contributed to the cause of Mr. Baulderstone's death.

6.9 Mr. Dart's evidence was that BHP have already attended to all of these issues. A list was tendered through him (Exhibit C.43i), which outlined action taken on many fronts, including:-

- dissemination of information to other industries using similar systems;
- an awareness package for workers and managers;
- a review of the JSA/ATW etc. system;
- a review of procedures, including the drawing system for components, and traceability of those components when used in the system;

- design of new mechanically suspended refractory linings by "formal engineering assessment, not empirical judgment";
- a review of quality specification and control, including audits;
- quality assurance procedures governing installation of components (e.g. welding);
- investigation of new systems to ensure integrity of linings and/or new lining systems (e.g. self-supporting refractory systems).

7. **Recommendations**

In view of this evidence, I do not consider it necessary to make recommendations pursuant to Section 25(2) of the Coroners Act. Any such recommendation should be made if I consider that it may help to avoid the recurrence of an event similar to the death of Mr. Baulderstone. BHP have taken the remedial action called for on the facts demonstrated before me, and the need for a recommendation has thereby been obviated.

Key Words: industrial accident

In witness whereof the said Coroner has hereunto set and subscribed his hand and

Seal the 7th day of July, 2000.

……..……

Coroner