QUEENSLAND COAL MINING BOARD OF INQUIRY

Coal Mining Safety and Health Act 1999

Establishment of a Board of Inquiry Notice (No 01) 2020

Before:

Mr Terry Martin SC,
Chairperson and Board Member

Mr Andrew Clough,
Board Member

At Court 17, Brisbane Magistrates Court
363 George Street, Brisbane QLD

On Friday, 26 March 2021 at 10am
(Day 22)

Transcript produced by Epiq

THE CHAIRPERSON: Yes, Mr Hunter.

MR HUNTER: May it please the Board, I call Dr Basil Beamish.

<BEVAN BASIL BEAMISH, **sworn**: **[10.01am]**

<EXAMINATION BY MR HUNTER:

MR HUNTER: Q. Dr Beamish, will you tell us your full name, please?
A. My full name is Bevan Basil Beamish.

Q. Your occupation?
A. I'm a mining consultant.

Q. You operate a business known as B3 Mining Services?
A. That's correct.

Q. What does B3 Mining Services do?
A. B3 Mining Services supplies testing and consulting services to the mining industry and any other industries that have issues with materials that self-heat.

Q. Would you tell us what your qualifications are, please?
A. My qualifications are a BSC honours class IIA, a Master of Science in mining engineering from the University of New South Wales, and a PhD in mining engineering from the University of Auckland.

Q. In addition to your role with B3 Mining Services, do you hold any academic appointments?
A. I have worked as an academic over my career - one term at the University of Auckland for a period of time from 1987 through till 1998, with intermittent leave from that position to take up a research position at James Cook University in 1991 and 1992, and then a sabbatical in 1997. I then joined the University of Queensland in 1998, where I stayed until the end of 2012.

Q. You mentioned that your company provides services to any industry that uses materials that self-heat. That includes coal, I take it?
A. That includes coal, it includes metal concentrates and it includes waste rock materials as well.

Q. You were engaged by RSHQ in connection with this matter. There is a PowerPoint that summarises your findings which will assist you in telling us what you found, so I wonder if that might be displayed. Now, this page sets out your scope of work. Would you just explain that to us?
A. Okay. The scope of work was agreed to with the inspectorate, and what we agreed to look at was the behaviour of the Goonyella Middle seam with respect to spontaneous combustion, and it was subdivided into the following scope that's shown there. We were looking at the assessment of the potential for spontaneous combustion of that Goonyella Middle seam coal under normal mining conditions, so as it would exist at the mine operation.

We were also looking at the aspect of assessing if there's any increased potential of induced coal spon com due to external heat sources if the coal were to come into contact with those sorts of materials or any material that could increase the temperature of the coal above the normal ambient.

I was also looking at assessing of impact of increased virgin rock temperatures as workings become progressively deeper. That's just a matter of course, in the fact that the coal seam is changing in depth over time.

Also, the fourth point there was to assess the increased potential for coal spontaneous combustion due to induced heat from the use of polyurethane resin injection with particular reference to an ACIRL report that was produced in 1999 on previous testing and any other technical evaluations and reports that I would need as reference material. I needed to then consider the increase in the step change that might result from the exothermic reaction temperature that has been defined from testing in licensing requirements for some of these materials.

Q. The coal that you were being asked to look at was coal from the Goonyella Middle seam at Grosvenor mine?
A. It was coal from the Goonyella Middle seam at Grosvenor mine, yes.

Q. You had previously undertaken a spontaneous combustion assessment with respect to coal taken from the Grosvenor mine?
A. Yes, that's right.

Q. Did you do that in 2014?
A. I did it in 2014, yes.

Q. And then again in 2019?
A. And again in 2019, yes.

Q. We won't go to the report, but in 2014 did you flag the risk of spontaneous combustion as a result of the application of an external heat source, like PUR?
A. In that particular report, we did put a paragraph into the report that highlighted that if the coal were to be artificially raised to a higher elevated temperature than the mine ambient, then the risk of the spontaneous combustion would be increased.

Q. Did you make a similar observation in your report in 2019?
A. We did.

Q. In that report, did you in fact show - did you undertake some actual testing that supported the conclusion?
A. Yes. In 2019, that particular comment became more than just a paragraph; it actually became a separate chapter or separate section of the report in its own right, primarily because we did do some additional testing that we had refined in that five-year period from when the original report in 2014 was done that enabled us to establish the sort of temperature that the coal would need to be heated to to create a spontaneous combustion event.

Q. Was there anything about the history of mining the Goonyella Middle seam that prompted you to pay increasingly more attention to this possibility?
A. The puzzling thing about the Goonyella Middle seam is that it has what we would consider the low intrinsic reactivity, based on the R70 tests that we would have done over the years. It continually produces a value that's less than 0.3, or less than 0.5 is the standard level, but usually anywhere from 0.3 down to basically 0.05. It varies on slight - the coal properties, but the point is it puts it in the category of low intrinsic spontaneous combustion propensity. That was a very puzzling thing, because there have been numerous events that have occurred in the Goonyella Middle seam. So it raised the issue then, what other triggers may be at play in creating spontaneous

combustion events in that seam.

Q. When you say "numerous other events", are you talking about spontaneous combustion events?
A. I am, yes.

Q. We will go into the detail of what you did in a moment, but can you explain to us the spontaneous combustion process, and in particular I'm interested in knowing about what factors might cause variability amongst different coals in terms of that spontaneous combustion propensity?
A. The word "spontaneous", as I believe Martin Watkinson has already pointed out, is a little bit of a misnomer. It doesn't happen at the drop of a hat. The spontaneous part is at the upper temperature end, when it does get to an ignition point, really.

The whole process from low ambient mine temperature is an incubation process. The coal self-heats; it reacts with the oxygen in the air, which is a heat-generating mechanism, so that's a heat gain. It then has a balance of whether that heat is retained or it's lost over a number of different mechanisms, and some of that loss can be from convection - air cooling is one of the common things people think of; conduction, heat going out into contact with rock which doesn't actually self-heat itself; and also evaporation, which is a thing that a lot of people lose sight of.

The coal has a moisture content in it internally, and evaporating moisture is a fairly energy-intensive process, so you have this whole heat balance mechanism going on. If you picture in your mind a see-saw, you have this point. Now, if the point tips towards heat retained, the actual oxidation reaction itself is temperature dependent, so now the reaction itself gets a little bit faster, and so it goes around the loop again, comes back again, and now the balance goes and keeps tipping, and if you get past that tipping point, you can go into what we would consider is thermal runaway, where there is no coming back from that particular point.

Q. The reactivity of coal or the propensity of coal to spontaneously combust depends upon the coal itself?
A. It is two - it is a number of combinations. It depends on the coal. So those are the intrinsic

behaviours, the coal properties. It also depends on the mining method. It also depends on the conditions that are present for that particular coal.

For example, I could be mining the same coal in New South Wales with the same intrinsic reactivity as Queensland, but I would have a different outcome because in New South Wales the starting point temperature is much lower in a lot of places, for example, up in Lithgow. So I could be mining a coal with a much higher intrinsic activity in Lithgow and not create an issue; whereas in Queensland, where the temperatures are higher because of the geothermal gradient, a much higher starting point, that oxidation reaction can kick away a little bit faster.

Q. What about the composition of the coal itself?
A. The composition of the coal is important from the point of view that the coal is made up of what you would consider is an organic component and an inorganic component. So there are mineral constituents in the coal that don't contribute to the heat source; there are also some mineral constituents that can contribute if they are present in the right form.

There is a misnomer out there that if I've got pyrite in my coal, I have an issue because pyrite is going to cause a spon com. That's not correct. It has to be the right form of pyrite, and it's a thing that is commonly referred to as spongy pyrite. It is a very porous type of pyrite, and it has to generally be formed about the time that the coal has been deposited, not introduced at a later stage. So there's a lot of misconceptions there.

Q. Just pausing there for a second, is pyrite a factor in the case that we are concerned about here?
A. Definitely not.

Q. I'm sorry, I interrupted. Go on.
A. Yes, and we will get to that when we see the coal quality information of these samples, but not in this case.

The other mineral constituents, things like quartz and clays and so on that would be present with the coal - they are just a heat sink. What they tend to do is, the intrinsic reactivity of the coal will decrease in response to those because the coal is using its energy to heat up this stuff that's not reacting.

Q. We will see the term "ash" referred to --
A. Yes, ash is the product that's generated after you burn the coal, so the minerals burn and they become their oxides. They go down to the basic form of oxides, and that's what the ash is.

Q. So when we talk about high ash and low ash coal, what do you mean?
A. They have a high mineral matter content or a low mineral matter content.

Q. Is it the case that if there is high mineral matter content, then that lowers the reactivity of the coal, that is, it makes it less reactive?
A. Yes, it does.

Q. Is that for the reasons you just explained, the heat sink effect?
A. Yes, it's the heat capacity - the mineral matter sucks the heat out of the coal reaction.

Q. Does this slide show the samples that you were provided with and set out the tests that you did on each of the samples?
A. That's correct. These are the core depth, as you can see there, from 467.12 metres and goes all the way to 468.10 metres.

Q. So you had a core of about a metre?
A. About a metre, a metre of core to work with, correct.

Q. The top row refers to the "High Ash Roof Coal", the bottom refers to the "Low Ash Roof Coal". We will see a photograph in a minute, but was it possible simply with the naked eye to delineate between the two?
A. Most definitely.

Q. Although there is no material I can place before the Board at the moment, we understand from our learned friends at RSHQ that the boreholes referred to were in longwall 108, about a kilometre from the point of interest in longwall 104. Now, on the right-hand side, we see a number of test reference numbers. I will get you to explain in a bit more detail what you did with respect to each test, but what do those numbers refer to?
A. We use a coding system for the type of testing that is

applied to the coal and also of course a coding number as to the sample back to the client, in this case RSHQ. We've used the "GMS" there as Goonyella Middle seam, just the abbreviation for that. Then the other codes refer to the testing type. So if you look at the first one up there, it's RSHQGMS2R. The "R" refers to the fact that there was an R70 self-heating rate test applied to that sample, and the same was applied to the low ash content sample, the low ash roof coal.

We did most of the repeat testing on the low ash roof coal because it would be considered to be the more reactive constituent, and if you do, when we get to the photograph, you will see there is a significant bedding separation plane between these two intervals in this roof coal interval. So when the coal falls away from the roof, it more likely would separate at that particular point.

Q. Just dealing with the other test that was done with respect to the high ash roof coal, it ends in 140CS, but there are some letters before it, which I assume don't refer to a suburb of Brisbane?
A. Indeed.

Q. So can you explain what that refers to?
A. Yes. The "I" coding is used to reference that we are using the newer test method of the incubation test, although it's not that new; it has been in play now for nearly 10 years. "I" refers to incubation testing, and then the other code, the "NALA" bit, refers that it was natural air leakage, so the flow rate that was used was simulating a natural air leakage flow condition, and "A" stands for we were using air passing through the coal to react with.

The "SVA" is a sluggish ventilation flow condition, so it is half the rate of the previous one, and again done in air. And if there is no temperature recorded at the back, if there is no digit at the back of that, that means that it was done at the mine ambient condition.

Q. What was the mine ambient condition that you assumed?
A. Approximately 45 degrees for that depth.

Q. So in relation to the test here, the second test with respect to the high ash roof coal, does the 140 refer to the starting temperature at which you commenced the test?

A. That's correct, yes, the 140, and if you see further down on the low ash, the 120 is a 120 degree start temperature for those.

Q. The "CS"?
A. The "CS" stands for coarse fraction. In this case, the coarse size fraction we used was less than 3mm, which is significantly higher than the normal size fraction we would use. The normal testing we do is done at 0.2mm, less than 0.2mm, or 200 micron, size fraction.

Q. Was there a reason why you didn't test the high ash coal at that smaller size?
A. It was felt that the results from the R70 test would already indicate that it was just going to be slower than the low ash coal.

Q. In relation to the low ash coal, then, we've got the R70 test; the next test below that, the INALA, that started at ambient?
A. Mine ambient.

Q. With normal ventilation; and then the one below that is --
A. Not normal ventilation. Natural air leakage.

Q. Sorry, natural air leakage. I beg your pardon.
A. Yes.

Q. Natural air leakage; and then sluggish?
A. Yes.

Q. And then we see natural air leakage and sluggish with a start temperature of 120?
A. Correct.

Q. And then the same for 140?
A. That's correct.

Q. And then the bottom entry is a coarse fraction with a starting temperature of 140. What size were the coal particles that were used in relation to the other tests of the low ash?
A. They are all less than 0.2mm, 200 micron.

Q. What's the significance, in terms of the potential reactivity of coal, of the size of the particles?

A. The heatings that are going to develop are going to occur in the fine particle size. That's the material that is going to react.

Q. Is that an important factor? Do different coals, when force is applied to them, react differently?
A. They all have different capabilities of producing fines, indeed.

Q. We will come to this in due course, but what would you say about the frangibility, if that's the right word, of this coal?
A. "Friability" is probably the term you're looking for. This coal has a very high friability. It produces fines very readily.

Q. Does this slide show the opened sample?
A. That's correct.

Q. And it was sealed in an airtight PVC liner and duct tape?
A. Yes. It's basically kept in the PVC liner to keep it nice and intact so that it is not getting destroyed in transport, and then the duct tape is securely sealed around the whole thing. That's to exclude oxygen away from the sample.

Q. And you were satisfied that this had been packaged and stored in a way that inhibited the ingress of oxygen into the sample?
A. That's correct. We checked that. We check that with every client when they are sending samples.

Q. Prior to the incubation or R70 testing that you did, you had a look at the coal itself and --
A. Can we just go back to the photo?

Q. I beg your pardon.
A. Yes. There's a couple of key points. You can see what we've done is we've tried to find this point, and it was so clearly demarcated. You can see the bedding separation there, and, as I said, visibly we can identify this as high ash. We've been working with the stuff for long enough to know what high ash looks like, and low ash. The rest of the seam from that point down is a lower ash component, and that's why we separated out those two for the testing on that basis.

Q. Is there a difference between the friability of the high ash and the low ash?
A. There is. The higher ash would have a lower friability than the low ash, in this case.

Q. That's consistent with how it is depicted in that photograph?
A. That's why, yes, it's broken quite readily at that point, yes.

Q. I left that slide too early. Is there anything further we need to talk about?
A. No, those were the key points.

Q. Thank you. Does this slide reflect the investigations that were made about the makeup of the coal?
A. Yes, this is a standard coal quality analysis set of data for both samples taken out of the core.

Q. Can you talk us through what we see here?
A. Okay. These analyses - if you look at the first section, it says it's "air-dried basis". The sample has been sent to the laboratory, which is ALS laboratories. They are one of the standard testing laboratories for coal, and they would do this air-dried basis. It is a standard one according to the Australian Standard. You can see that the low ash roof coal has a much lower moisture content than the high ash roof coal.

Q. Can I ask you to pause there. When you say "air-dried", do you mean --
A. It's basically sat out at a standard condition in their laboratory and allowed to equilibrate for what is called an air-dried condition.

Q. So when we see these figures, this is the amount of moisture that was in the coal prior to it being air-dried?
A. Yes, and it's done gravimetrically, so those are weight per cent.

Q. Sorry, I interrupted you. Please continue?
A. That's good. So you can see there is a difference there, and the ash content shows that clearly: the low ash coal had an ash content of 14.8 per cent and the high ash roof coal 69.9, so clearly showing a lot more non-coal material in the high ash roof coal.

Then the other results show similarly the - if you look at the calorific value, that also is related to that non-coal material. You can see that the low ash roof coal has a very high calorific value - in other words, very good energy for burning, in this case - whereas the high ash roof coal has a much lower energy if it were burnt.

Q. What's the volatile matter?
A. Volatile matter is the organic components of the coal that are liberated at temperatures of around 900 degrees in an inert atmosphere. It's a standard test to give us that particular property of the coal. It is often then used as a ranking parameter. If you skip down to the bottom, that ASTM rank of this coal is medium volatile bituminous, in other words, the thermal maturity. The higher the thermal maturity, the lower that volatile matter value will be. In this case, it fits that particular category.

The other important thing you were talking about before was that the sulphur contents of these samples are very low, so there is no significant pyrite present in these particular samples.

Q. Is there anything significant about the ultimate analysis?
A. The ultimate analysis is another cross-check of the ranking of the coal, to some extent. As the coal rank increases on a dry ash free basis, the carbon content increases to being a major proportion of the coal, and the oxygen content decreases.

Now, you will notice the anomaly there is that the high ash roof coal has a very high oxygen content. The oxygen is actually calculated by difference. So those first four - carbon, hydrogen, nitrogen and sulphur - are determined values, and when you subtract those from 100, you have the oxygen content of the coal by difference.

The reason for the high oxygen content in the high ash roof coal is some of that mineral matter that was present were carbonates, and if you remember, carbonates are CO3. When coal is burnt or processed, you would get a high oxygen content in response to that, and that's what this is reflecting in that case.

Q. Is the oxygen content relevant for the purposes of

assessing the reactivity?
A. We look at the oxygen content in establishing what is known as the minimum self-heating temperature, which is a US Bureau of Mines self-heating index parameter. Based on the oxygen content, you can calculate the SHT value of the coal.

Q. "SHT" being?
A. Minimum self-heating temperature. It's a relative rating scheme. It doesn't mean the coal will self-heat from that minimum temperature, which is a misconception as well.

Q. Now, what are coal rank parameters?
A. The coal rank parameters indicate to us the thermal maturity of the coal. Coal ranges from a spectrum of the low rank, being lignite, so the brown coals we have down in Victoria, all the way through to anthracite, which is the top end of the spectrum, the coal that has been most thermally mature. An example of that would be Yarrabee, which mines a semi-anthracite coal. That's the only one we mine in Australia. A lot of the overseas coals are in the anthracite region just because of their thermal maturity. For these types of coals, of course, then you have to be within a certain rank window to distinguish between coking coals and steaming coals.

Q. I don't want you to go into great detail, but what do the various parameters that you specify on the left mean?
A. The parameters that are used there - we use the volatile matter and calorific value, and I put it on a thing called a Suggate rank, which is the next diagram on, but we will talk to it here first. They give me two axes, values for the two axes on that particular plot. If you see the Suggate rank number there, the higher that particular number is, the higher the rank of coal. So it starts down the lignite end, where the Suggate rank would be 0 to 2 or 0 to 3, and then you come up the other end; it progressively gets into the double digits.

Q. So the higher the number, the more suitable for use as thermal coal?
A. They're all good for thermal coal. It's just the higher the number, the more mature the coal is, and within that higher number region you get a range of coals that fit the window for the metallurgical coking coal.

Q. You have told us about the ASTM rank at the bottom. What was the "MVB" standing for, again?
A. Medium volatile bituminous.

Q. Now, this is not the only time you have looked at coal from the Goonyella Middle seam?
A. No; that's correct.

Q. How do these values compare with other coals from the GM seam that you have seen?
A. The rank of the coal generally fits within that window of medium volatile bituminous.

Q. What about specifically other coal that you have seen from Grosvenor, because we know you looked at it in 2019 and 2014?
A. They would still fit within that rank window.

Q. I will go to the next slide. This is the plot you were telling us about?
A. That's correct. As you see, the numbers go from zero through to 25. It's in a herringbone arrangement because those lines are lines of equal rank. What is actually changing there - if you see, the definition says "high vitrinite coal band" and "low-medium vitrinite coal band". In this case, the coal fits within the high vitrinite coal band. That's where the prime coking coals would fit for this rank, in that particular window. When they fall down into the low-medium vitrinite coal band, that's where a lot of our thermal coals will sit from these coals.

Q. You provided reports to the mine in relation to the exercise that was done in 2014 and 2019, and those reports contained a Suggate rank for the coal?
A. All my reports will contain - yes.

Q. We won't go to them now, but do they show that the coal under consideration - that is, coal from Grosvenor - was roughly the same as --
A. They plot in a very similar field. It's a fairly tight grouping.

Q. I'm going to get you to explain the process that you undertook, and if you can start here by telling us what this is and what it does?
A. Okay. The testing that we do is what is known as adiabatic oven testing. It's a very high, precise oven

that we use. You can still use it to cook up your lunch, if you like, but it's a pretty expensive oven to be cooking lunch with.

It has a number of components to it, and the key components are controlled by this digital controller here, which is the main temperature controller for the unit. What you see at the back here, these are the lines for gases coming in from our warehouse, so it's external to the actual oven room. The oven room is isolated, kept in its own airconditioned environment, so it's the clean side of the lab.

We then have an air or oxygen inlet line, and we also have a nitrogen inlet line. You will see two flow gauges on the front of the unit here. You can see the two flow gauge units there. One is for the nitrogen, and we regularly use the nitrogen to keep the sample in an inert atmosphere before we start the reaction regime, and the other one then monitors the flow rate for the reactant gas coming in.

You can see the temperature controller there. This is actually a test that is under-running at that point in time. It may not be the ones that were in the report, but it is just one for example. The lower temperature reading there, the digital temperature in the red, is the trip arrangement, and I will come back to that, for the unit. But the actual temperature of the coal is measured by the controller, which is shown there in the brown, you will see the brown, 43.1, and if you look at the top, the green, 43.0, that's actually the oven temperature.

So we're not using this oven to force the coal when it is in this particular self-heating mode. We can use the oven to step it to a different temperature, but when we're actually monitoring the reaction that is taking place, it is switched into this mode where the oven is completely controlled by what the coal tells it that its doing.

Q. What are the tubes that we can see on the front door?
A. The tubes on the front door - one is the inlet, so the one there on the right, as you face it, is the inlet going in to the oven; and the one on the left is the outlet coming out of the oven. We use a little moisture collection receptacle, as well, because when the coal is getting to those higher temperatures, sometimes the

moisture comes out readily and we pick it up on the way out.

Q. This is obviously a view of the same --
A. This is the internal workings. As I said, it is not an ordinary oven, by any stretch of the imagination. Basically what you are looking at there is the reaction vessel which sits in the door, in a cradle, and you can see, if you look to the right, the hosing that is there on the right - that's the inlet coming in. It goes into a spindle that goes down into the reaction flask, into the coal. So our less than 200 micron coal is sitting in there. The spindle is going into that, and that's where the reactant gas gets to the coal, and then you can see the tube going out the top goes out.

Now, before it gets to that rubber tubing on the inlet, the actual gas coming in to react goes through that copper coil there in the door. It's 16 metres of copper coil. It is designed because the gas is coming from out in the warehouse, which is sitting at whatever the room temperature is out there - when it comes into here, because the oven is told to keep the oven temperature at the temperature of the coal, the last thing you want is to then just say, oh, well, I'm going to hit it with air at 20 degrees, because you'd just kill the whole thing.

What it is designed to do is make sure the air, when it reaches the coal, is at the same temperature as the oven, which is at the same temperature as the coal. So primarily what you are creating then is the coal now thinks it is sitting in a much bigger pile, and it is that extra insulated environment that allows the reaction to keep doing what it does in creating an event.

Q. Does the oven have a limit in terms of the temperatures to which it can be taken?
A. It does, and that's deliberate. The last thing you want is an ignition in an oven. It's not a nice thing to happen. This particular oven has a - if you saw the red digital down here, that red digital is the other thermocouple in the coal, in the sample, and it is then set at 180 degrees. What it does is, when the 180 degrees is reached, it trips off both the flow of the gas coming in and it also trips out the heating elements. So the oven basically shuts down, and that stops the reaction continuing on to a point where we would have an ignition

source in the oven.

Q. We're going to come to this in some more detail in due course, but we will see some graphs, won't we, where you have plotted the behaviour of the coal at temperatures in excess of 180 degrees?
A. That's correct.

Q. So how are you able to say how the coal behaves at a temperature higher than this oven is capable of attaining?
A. Because at those particular temperatures, the coal is behaving in a manner known as Arrhenius, so it's an exponential increase in temperature. It means it's an exponential oxidation rate that's taking place - standard chemical reactions. By having that information, because we've already monitored the information up to that point, when you plot it appropriately, you can use the line of best fit, which is effectively a straight line with an R squared of 0.9999, and it means the reaction will continue on at that rate.

Q. Is this methodology employed by you something that you have devised yourself or is it something that is used by others?
A. The use of the adiabatic oven has been in play in Australia since 1979, when Dave Humphreys introduced it through ACIRL. He actually did his masters on this work to prove it up, and then they introduced it as a commercial testing primarily to do the R70 test. So that particular test has been in use in the Australian coal industry since 1979. But in 2009/2010 we went to using what we call the incubation test, still using the same apparatus. So the apparatus still holds true, it works appropriately, and we have been able to introduce that use.

Q. The applicability of the results of this testing isn't just confined to underground coal mining?
A. Definitely not. It's applied to anything that will self-heat.

Q. But in terms of coal, for example, we know that coal is stockpiled on the surface, in fresh air?
A. We can use this to look at the behaviour for a coal stockpile situation, for a pillar situation, so blocky, fractured coal, as well.

Q. And, for example, obviously the spontaneous combustion of coal is significant for the shipping industry?
A. That's correct.

Q. Is this methodology applied in that context as well?
A. No, it's not. They have their own devised test arrangement that has been signed off by the various countries. However, it is under severe review at this point in time. There is an ACARP project reviewing the application of that test, primarily because it's creating a few issues for Australian coals.

Q. If we can go to the next slide, this slide summarises the R70 test procedure. You might firstly just explain to us, why is it called R70?
A. The reason it is called R70 - and this was Dave Humphreys' terminology - is because it is determined as the average self-heating rate from the coal at a standard start temperature of 40 degrees until it reaches 70 degrees. So the "70" part relates to it getting to 70 degrees.

Q. Can you explain the process to us, please?
A. The process is that if you think back to the core that we had, the coal core is crushed down and reduced down in size, generally reduced down to sub-12mm initially, in a mechanical process. It's then fed through what is called a cross beater mill, which is the instrument we use - other labs might use another one, but you can get all sorts of crushing units - to take it down through a screening process to get it below 200 micron, 212 micron in this case.

The coal then - we use 150 grams of that fine coal. It is dried in nitrogen at 110 degrees. That's to make sure that it doesn't start reacting and affect the result, because the actual intrinsic reactivity is very sensitive to pre-oxidation. It is dried for at least 16 hours and then cooled back down to the 40 degrees start temperature that is the standard that is used.

It is transferred then into the vessel that you saw in the door, put into the adiabatic oven under nitrogen and then allowed to equilibrate as close to 40 degrees as possible. We try to get away with the test starting at 40 plus or minus 0.2, using the equipment we've got. Then, once it is set down to that starting point, the flow is switched to oxygen, we use 50ml a minute, and then the temperature change is recorded by the computer. The graphs that you have seen in my report show time/temperature graphs, and those are the ones that are used.

Q. How does this test fit with what we know are the real-world conditions, say, in an underground coal mine - for example, is the coal dry in that environment?
A. No, it's not. This is a dry basis test. But like all the other index parameters for self-heating, they are used as rating schemes so that you are comparing coal A against coal B against coal C under a classification that has been routinely developed over time.

Q. When we come to some of the incubation tests, in those cases was the coal dried before the test was done?
A. No. In incubation testing, the moisture is present because that's one of the keys to what happens in the low ambient temperature behaviour.

Q. Ultimately the outcome you get is degrees Celsius per hour?
A. Yes, it's just straight time - temperature divided by time.

Q. You were saying before that this coal ended up with results that were well below half a degree Celsius per hour?
A. Correct.

Q. This slide here, slide 10 - does this show all the results for the low ash coal?
A. Yes, this is the low ash coal. It has an R70 of 0.36 degrees C per hour. If you look at the lines that I've drawn, you can see how the calculation is done. It's just the straightforward temperature rise from 40 to 70, divided by the time it took to get to the 70 degree mark, and that's how the value is obtained.

Q. We can see, though, that beyond the 70 degree mark, and probably, what, about 80-something hours, the curve progressively steepens beyond that point and becomes almost vertical?
A. It is now in what is called Arrhenius behaviour. It is going exponentially, yes.

Q. There is a figure of RIT there. What is RIT?
A. That's another one of the rating schemes. It is

a relative ignition temperature, and in this case it is 172.4. At this point, what is happening is that the coal is self-heating at a rate of 2 degrees a minute.

Q. So does this graph show the actual data - that is, what actually happened to this coal all the way to 180 degrees?
A. That's the actual data at 5 degree increments.

Q. So it is not an extrapolation beyond the 70 degree point; this is what actually happened to this coal?
A. Oh, extrapolation beyond 70 degrees are you saying?

Q. Yes.
A. This one is - I need to refer back to the report whether this one - I think you will find this one went on its own.

Q. We can see that in your report in any event, can we not?
A. Yes, if you go back to the appendix to the report, it should indicate whether we had to use a step heat to get the last bit or not.

Q. We might come back to that.
A. Yes. It is relevant, actually.

Q. This is the same graph with respect to the high ash content.
A. That's correct.

Q. Consistently with what you have told us, there was a slower response --
A. You have a decrease in the R70 and an increase in the RIT, and a significant increase in the RIT, because those mineral matter constituents - which, you know, we didn't assess what they were - if they are clays, they have a higher heat capacity, say, than quartz and so on. So it will push the number up quite significantly.

Q. So this shows the lower reactivity of the high ash coal?
A. It does show a lower reactivity, yes.

Q. Does this slide show the way in which the propensity of coal to spontaneously combust is assessed according to various levels, if you like?

A. Yes. This is the rating scheme that we currently use. It was published back in 2011, and we have used that ever since. You will notice it is divided into ratings going from "low" all the way to "extremely high". It is somewhat semi-logarithmic, and primarily what happens there is that at the lower end you have the high rank coals, so your low volatile bituminous, medium volatile bituminous coals. At the high end, at "extremely high", you would be into sub-bituminous into lignite coals.

Q. We know from the previous graphs that the R70 values for low ash and high ash coal that you tested were 0.36 and 0.24 respectively. So on either the Queensland or the New South Wales scale, the propensity rating would be low?
A. Indeed, yes.

Q. What is the difference, or the reason for the difference between Queensland and New South Wales?
A. The reason for the difference between Queensland and New South Wales, as I said earlier on, if I mine the same mine in Queensland, I am at a different starting temperature.

So when Dave developed the R70, he used the standard 40, which is back in 1979 and, you know, we weren't mining the same range of coals and in the conditions. He saw or envisaged using 40 as a standard. But in New South Wales your starting temperature can be 20 degrees or less in some places in the Lithgow area, particularly in winter, and so the same rating scheme doesn't really apply, so we've just used a different allowance for that change in start temperature for the coal, and kept the same levels, but again using a semi-logarithmic subdivision.

Q. The R70 is not the only way of assessing the spontaneous combustion propensity?
A. No, it is not. There is a number of index parameters available. We routinely look at these other two. They are somewhat of a cross-check, but they can also have some anomalous results to them as well for various reasons, and you can see that in one of the tables here. These are what are called the self-heating temperature, minimum self-heating temperature, which is a US index parameter, and the other one is crossing point temperature, which is more used in the Indian coal industry, although that particular parameter is also determined through laboratories out at Simtars. They will do that.

We calculate these, because the US Bureau of Mines test is no longer available, so it is done based on the oxygen content of the coal. So as you see there, for the low ash roof coal it is 108, which is a low propensity rating. Anything above 100 on an SHT is classified as low. The high ash roof coal I've got "na", not applicable, primarily because, if you remember, it had an anomalous high oxygen content value, but that was due to the mineral content of the coal and therefore the index would be invalid for that particular sample.

In the crossing point temperature values we use the equations that were developed for the Indian coal mining industry, using the ash content and the moisture content of the coal, and again you can see that the higher ash content coal gives a higher crossing point temperature value than the low ash content coal. So that equation works quite well to separate the two out, but they still end up at a low propensity rating because they are above 150.

Q. How do these figures compare with other testing that you have done on Goonyella Middle seam coal?
A. They are all a fairly good match. It's really strong - most of these other index parameters are very strongly rank related, so when you get to the higher rank coals, by definition, they have a low intrinsic reactivity.

Q. We're going to move to the incubation testing now, but perhaps before we do that, the R70 testing and the other indices that you have identified just a moment ago all show that this coal has low spontaneous combustion propensity?
A. They do.

Q. Yet, at the same time, there have been a number of incidents where Goonyella Middle seam coal is believed to have spontaneously combusted?
A. That's correct.

Q. So this exercise, what we're about to talk about, is an effort to understand perhaps why that might have happened?
A. Yes, it is.

Q. Can you explain the incubation testing to us?
A. The incubation testing is designed to create a more indicative mine condition test arrangement. So we actually

test the coal with its as-received moisture. So it has turned up at whatever the moisture content is in the split, and we would do it at that particular moisture content unless the mine tells us otherwise. We use a larger sample mass than the R70 test. So you will notice that the sample mass in the R70 test was 150. 150 would not actually fill that flask. When we do the incubation test we actually fill the flask, so there is a larger mass in there.

We use a lower flow rate than that 50ml per minute, and that gives us then a high mass to flow ratio, and that's more indicative of reality. What you are trying to create is, if you envisage the environment that these things occur in, the sort of velocities you are talking about are 10 to the minus 5 metres per second. So, in other words, it is basically a puff. So when we do the sluggish one, it is half a puff, and that's the environment that these things create or occur in.

The test itself provides us a quantification of the initial coal self-heating from that low ambient temperature start. So, in other words, we do it at the mine's start temperature. Not every mine has the same start temperature, as I pointed out before, and it makes a big difference to the way the coal will behave, because that's where the crux of controlling spon com is, understanding the behaviour from the low ambient condition.

Therefore, it obviously gives us an opportunity to see, by doing it with the moisture present, what effects moisture is having in terms of moderating the self-heating behaviour. Again, getting back to that heat balance situation of, well, they might have this intrinsic reactivity, but if I have a really high moisture content it's going to use up all that reactivity energy to try and get rid of the moisture, and eventually it could go back and lose heat. So you are always trying to establish those circumstances.

Q. How valid an exercise is this incubation testing when you consider the conditions underground as opposed to in the laboratory? Is there a proper basis for criticising what you have done on the basis that, well, it doesn't actually reflect what goes on underground?
A. We're creating the worst case scenario, so it is the environment where a hot spot will form. So what we're assessing is can a hot spot form, given those right

conditions, and, if so, in what sort of time frame? So the actual test is benchmarked. We've got a number of mines in the database. One mine in particular is Meandu open cut, where they open up the coal benches, and we've got time frames that match from the mine to the laboratory. We've got a couple of underground mines as well, where we know that the time frame matches from the laboratory to the mine site circumstance.

Q. We're going to move to the results of your testing now.

There is a matter that requires some attention, Mr Martin. I wonder whether now might be an appropriate time to take the morning break?

THE CHAIRPERSON: Yes, all right. We will adjourn a bit earlier, then.

Mr Telford, do you wish to announce your appearance?

MR P W TELFORD: May it please the Board, my name is Telford, initials PW. I'm instructed by Cantle Carmichael lawyers and I seek leave to appear on behalf of DSI Underground.

THE CHAIRPERSON: Yes, thank you. All right. You will let me know when it is a convenient time to resume?

MR HUNTER: Please.

SHORT ADJOURNMENT

THE CHAIRPERSON: So, Mr Hunter, you informed me at the break that the report from Simtars in relation to the PUR is now available, and you were suggesting that that be distributed to the parties and they be given the opportunity to see the contents, and also Mr Beamish, obviously, and perhaps resume at 2.15.

Mr Holt, would that be convenient?

MR HOLT: Yes, we obviously don't know what we don't know at this point, but I would be very grateful for some time with the report so that we can make an informed submission to the Board.

THE CHAIRPERSON: Everyone is in the same position, I must say. Mr Telford that, suits you?

MR TELFORD: It does, thank you.

THE CHAIRPERSON: Does it not suit anyone? All right. Well, see how we go, but we will resume at 2.15 and hopefully we will be in a position to proceed at that time. Sorry, Ms Holliday, does that suit you?

MS HOLLIDAY: Yes, thank you.

THE CHAIRPERSON: All right. We will adjourn until 2.15.

LUNCHEON ADJOURNMENT

THE CHAIRPERSON: Yes, Mr Hunter, are we right to proceed?

MR HUNTER: As far as I know. I will assume, in the absence of anyone saying anything, that we are.

THE CHAIRPERSON: Thank you.

MR HUNTER: Q. If we can have the PowerPoint, thanks, Mr Operator. Dr Beamish, before we go to the results of the testing, before lunch you said that one of the reasons why you thought that this incubation testing was appropriate was because of a number of incidents that had occurred in mines involving the Goonyella Middle seam?
A. I said that it's not just the Goonyella Middle seam; any coal that has these low R70s, if there's an enigma in that result --

Q. So apparently non-reactive coal, nonetheless, appears to be spontaneously combusting?
A. Correct. In any shape or form, doesn't matter which index parameter you use, it is a reflection of the way the coal is likely to behave.

Q. Can you give us some examples of those sorts of incidents - incidents of spontaneous combustion?
A. The incidents themselves?

Q. Yes. I mean, we know there were incidents at North Goonyella, for example.
A. They are probably about the only ones I'm familiar with.

Q. Which ones are they? There was one in the 1990s.
A. The 1997 one is the most familiar one that I refer back to.

Q. Can we go to the test results, please, and the next slide. Can you explain what we can see in respect of each of these?
A. These are the two test results for incubation testing of the coal from the mine ambient start temperature. So if we start at the left of the graph, over here, this is in the natural air leakage test. The coal initially self-heats slightly, gets up to about 46 degrees or thereabouts, in that region, and then it starts to roll away, and that's because the moisture that's in the coal is now starting to have a bigger effect than the oxidation of the coal itself. Remember, we are using air here, so it's as close to reality as you are going to get.

And then this one over here, in the same pattern, same start temperature, only with half the flow rate, gets up a little bit high in temperature, up to around 48 degrees, and then it starts to roll down again, for the same mechanistic reason. The moisture in the coal is having a more dominant effect in taking away the heat than the coal can produce from the oxidation reaction.

From that point on, then, we did a step-heat to 60 degrees in both cases. If we focus on this one, basically what you are looking at there is that the oven is turned up to 60 degrees and we allow the coal to come up to that temperature. So that's why the dashed line. There is no point looking at what it's doing on the way up; it's what it does when it gets there. You can see that it sits there for the best part of 20 hours and doesn't do anything at 60 degrees. And the same pattern occurs even at the even slower flow rate. So at that point in time, eventually, probably, if we let the test go longer from that point of view, it would start to lose temperature, but there was no point in doing that. If it hasn't started to go from there, the reaction rate is so slow that it's not going to create a problem.

That was confirmed when we took the test up to 80 degrees. It didn't kick away from the 80 degree step - same process. Therefore, it's not going to go from that particular temperature. But when we take them both up to

100 degrees, the coal then goes into the exponential increasing rate, and the temperature, as you see, rockets up right towards the end there quite dramatically.

The difference between the two is that with the higher flow rate, it goes a little bit quicker because there's more oxygen availability, and at the lower flow rate, it takes longer to get to the same temperature point.

Q. This data only goes, in terms of temperature, as high as 180 degrees?
A. That's correct, because then we tripped the oven at that particular point.

Q. Is there any reason to think that it would not continue on the same general trajectory after 180 degrees?
A. Definitely not. It's got the oxygen supply there. It's going to keep reacting at that particular exponential rate from that point on.

Q. So in terms of the speed of the reaction once one gets to 100 degrees, looking at the top graph, it's perhaps difficult to say precisely when it becomes exponential, but it is something in the order of 24 hours; is that fair?
A. That would be close enough.

Q. Whereas with respect to the sluggish ventilation, it is more like, what, five days or thereabouts?
A. It is certainly several days, yes.

Q. So did you then compare those reactions or those results with some known data that you had?
A. With the known data?

Q. Yes, data you had from other mines or other types of coal.
A. From, what, 100 degrees?

Q. No, the incubation period.
A. Well, the incubation period, we benchmarked from the mine ambient condition. In this case, we've step-heated it, so we don't have to benchmark that. That was done in air. So the days are the days. That's actual days.

Q. Tell us, then, what are we looking at here?
A. Okay. This is the test of the R70 test done under oxygen. This is benchmarked against other coals that have

been tested under the oxygen with their ground conditions or their normal conditions. So Kideco, which is a sub-bituminous coal, has an R70 of around 20-ish. Meandu has an R70 of around 3-ish. Metrop, or Metropolitan, has an R70 of around 0.3, plus or minus, fairly similar to the Goonyella Middle seam.

What we've done here, though - they are actually incubation tests, but I've overlaid the R70 test, which does go to thermal runaway because there is no moisture to roll it back, right, there is no inhibitor, natural inhibitor. Looking at the time frames, in the low ash roof coal, it would be 103 to about 122 days for it to reach thermal runaway point, and in the high ash roof coal, it would be about 240 to 275 days, much, much longer.

Q. What did you say that the approximate R70 of the Meandu coal was?
A. It is in the order of 2 to 3.

Q. So it is considerably more reactive, on the R70 at least, than the low ash roof coal?
A. Yes, yes. But the difference there, it's got its moisture content in it, and the moisture content of that particular test was 7.5 per cent.

Q. Does this graph, though, show that despite that R70 being different, the low ash roof coal is more reactive?
A. What was that again?

Q. You have the low ash roof coal - sorry, I will change the pointer, if I can.
A. Oh, compared to the Meandu?

Q. Yes.
A. Yes. At that point in time, yes, it is, and that's primarily because there is no moisture in the test.

Q. Obviously we know that water boils at 100 degrees.
A. Yes.

Q. How quickly does the moisture content of coal boil off once it gets to that temperature?
A. It depends on how much moisture is there. If it is a very high moisture content, it takes a considerable amount of time. You end up with what we call a moisture shoulder, so it could take several days.

Q. We know that you did testing that involved starting the process not at ambient but at 120 and 140 degrees?
A. Yes, at elevated temperature.

Q. What does this graph show?
A. These are the tests from two elevated start temperatures - one at 120 degrees, so that's this one here, and that was done both with the natural air leakage flow and then the sluggish flow at half the rate. So if you look at that, it clearly shows that with the higher flow rate, it goes to thermal runaway much quicker. The test terminates at the 180 mark, here, and then we've used the kinetics information to extrapolate up to the 540 degree mark. So the same process has been applied to all four test runs, the same procedure.

And of course, then, the sluggish ventilation, because of the lack of or lower amount of oxygen available, takes that much longer. Then at 140 degrees, clearly it is further up the chain, it reaches the same finish point a lot sooner, and again with the sluggish ventilation, it takes longer to get there.

The interesting thing was, of course, if you actually went and used the 120 degree test and just took out that first period of time and rescaled it across, they would lay over the top of each other, and that's the kinetics, it sort of proves the kinetics is correct.

Q. This graph shows or demonstrates why or how the fine particles are more reactive than coarse?
A. There is another graph that shows that.

Q. I'm sorry. Perhaps I have misunderstood you.
A. This is all on fine.

Q. This is all on fine?
A. Fine low ash roof.

Q. You spoke about the kinetics, and we referred to the Arrhenius equation this morning. What is this showing us?
A. This is the graph that we use, then, to be able to extrapolate to the higher temperature. So if you see here, that 2.5-ish or just under 2.5 on this axis, which is one over the temperature, and that temperature is in degrees Kelvin - that's the standard practice for doing an

Arrhenius plot - so that's the 120 degree end, and this is the 180 degree end up here. These are 5 degree increments, so it is done equally incremental so that we can then assess the rate properly.

As you see here, these are the two different ventilation rates. The sluggish rate - clearly, the reaction rate is further down the chain here. This is log of dT/dt. Because it is an exponential, we're using the logarithm. By plotting the logarithm against the temperature, or one on the temperature, it should form a straight line if it is an Arrhenius reaction, and that's in fact what it does up here, this higher temperature end.

You can see that the two tests, whether it is the 120 or the 140, they both overlay each other from the different start points, and again at the higher flow rate they overlay each other, so the line fit is exactly the same.

Q. You said it was the log of dT/dt. What's dT/dt?
A. Log of the reaction rate, so temperature divided by time. Normally we work out the temperature divided by time in degrees C per hour, so a bit like the R70 for those 5 degree increments. So it's 5 degrees C per hour, and then we will convert it to the log of that value, which is what is plotted on here.

Q. If we just go back to the previous slide, we know that the oven cuts out at 180?
A. Yes.

Q. So anything above that line is extrapolated?
A. It is extrapolated using that linear fit to the data at the top end of the reaction.

Q. Is that a conventional way of extrapolating that sort of data?
A. It is. It is the conventional way for looking at these types of reactions.

Q. I'm sorry, I confused myself earlier. This is the graph that shows the test results at different particle sizes?
A. That's right. We indicated that in the original table, that we would do the coarse particle size on both the high ash and the low ash roof coal, and so this one captures that. But I've also left on the low ash fines at

both sluggish and natural air leakage to show the difference between them.

The thing to point out is that if we go to the coarse low ash, you can see it takes a little bit longer than the fines low ash, but we're only talking a matter of hours, right, and remember we're using air here, so it's not a fairly huge difference in time frame.

If we go to the high ash, of course, then it is a matter of more days between the two, at that high ash fraction. And the other thing to note, at the start of the high ash test, there was a slight drop in temperature. That is taken to be as a result of some trapped or tightly bound moisture that would have been present in some of those clays, the mineral components in that particular coal interval, because they are bound in the crystal lattice of the clays and it takes a lot more energy to drive that last little bit of moisture out. But once they're gone, as you can see, then the carbon that's left that's reacting now wins out and it continues to go in the same manner.

Q. Can I ask you about the ability of coal to retain heat once it has reached a particular temperature.
A. It can sit there and hold the heat for considerable time, as long as it is insulated by a surrounding of coal.

Q. So can I put a scenario to you. Is oxygen required for heat retention?
A. Heat retention?

Q. Yes.
A. No.

Q. So it is just the coal --
A. And we know that from nitrogen inertisation. When you do the nitrogen inertisation, you don't necessarily take the heat away from the heating.

Q. Obviously you are familiar with the PUR injection scenario that has been spoken of in this inquiry?
A. I am now.

Q. If you assume that a quantity of PUR is injected into the roof at the face and that that is then mined through so that the coal in the roof that had been injected with PUR is then sitting above the shields?

A. That will be the roof beam that's sitting above the shields, yes.

Q. If we assume that the coal is heated initially by the curing reaction associated with that PUR, would that coal that was in the roof beam above the shields retain that heat?
A. It could retain a significant amount of heat, yes.

Q. Now, it wouldn't be exposed to oxygen necessarily in that situation, would it?
A. It could still be in a slight oxygen environment, which would be enough for it to be able to continue to react.

Q. Once the shields move past the place where the coal is, it might then be exposed to the mine atmosphere?
A. Then, if it's moving forward, it's becoming less oxygen rich, so in other words oxygen deficient - I suppose I should have used that word.

Q. But if it were to cave into the goaf immediately behind the shields, there might be oxygen there?
A. There would be some oxygen there, at a level that's higher than what it would have previously been exposed to, yes.

Q. Is it plausible that the sort of effect that we see - I will go back - described in this slide, slide 17, could occur?
A. It is. It's also plausible that it could have reached that sort of temperature before it fell, in that case.

Q. So it could be in the roof at that temperature?
A. It could also be in the roof at some temperature of that order.

Q. Would it necessarily be a large amount of coal that reached that temperature?
A. No, no. It could easily be a very small tennis ball or soccer ball sized piece of coal.

Q. I will go to the next slide, which talks about the implications of this reaction rate. Can you explain what you mean here?
A. What we're sort of saying is that you can see that it is only a short time frame involved for those temperatures

to get elevated, which is what all those tests actually show. And as I said before, they are done in air, so they are actually as close to real time - they are probably minimum time frames. Clearly at the higher ventilation flow rate, it happens a lot quicker, and that's because of that reaction rate behaviour with the oxygen availability.

The one thing that I did note is that something that people tend to forget is that in that temperature range, the coal could actually be glowing and not necessarily flaming. That's well documented. As I said, I looked at the papers back in the early days when they were doing that as a particular test, and it was a well-defined test for glow point, what's called glow point. So it could actually be glowing at that point.

Q. Is there anything that could occur in the goaf that might make coal that was glowing burst into flame?
A. There are a couple of ways that that could possibly happen. If there were a hot spot like that, sitting in the roof, and it did drop down, even just the movement of the hot spot dropping down through the air would create a velocity effect greater than what it had been exposed to. It's now into a more oxygen-rich environment than it was previously, and that could actually exacerbate it into flame. That's one possibility.

If there was an injection of air back into the goaf, if that coal had fallen down and it hadn't quite reached that point, but there was an injection of air from a windblast suck-back effect, then it could also create the same thing. It's like a bellows effect in a blacksmith's furnace.

Q. If it was something as small as a tennis ball or soccer ball sized piece of coal that had reached this sort of temperature, would you expect the products being liberated from that coal to be detectible in the mine's ventilation system by the usual means for looking for spontaneous combustion?
A. They are the hardest type of heating to detect, when you have a small defined hot spot, because of the nature of the dilution effects that take place. It depends on where your monitoring points are with respect to where it is, and so it is much more difficult to detect these sorts of things.

Q. What if your monitoring point was a tube bundle about four kilometres away down the tailgate return?
A. You wouldn't pick up something that small.

Q. Could I ask you about the significance of ethylene, and I'm not necessarily talking about this scenario, a small tennis ball sized heating; I'm just talking about a heating generally. What, in your view, is the significance of the presence of ethylene?
A. The presence of ethylene is normally an indicator of elevated oxidation, but it can also be present from other possibilities. But in the first instance, if I were in an underground coal mine and saw ethylene, I would be investigating its likely cause.

Q. What if the amounts of ethylene were being picked up on a gas chromatograph at sub-1 part per million levels, would that nonetheless concern you?
A. It certainly would. I provide daily advice to a mine in New South Wales, and our routine is any register of ethylene, whether it's just a trace on the trace, gets reconfirmed immediately.

Q. Do you have a view about the reliability or the accuracy of the quantification of the amount of ethylene below 1 part per million?
A. The GCs are reasonably sensitive to picking up the traces. It does come down to some experience in interpreting the traces as well.

Q. Now, you spoke about windblast and suck-back. Can we have a look at slide 21. What are we looking at here?
A. This is a record out of an ACARP project that was done in 2001. It is a record of air movement from a windblast event. What you see initially is that with the windblast, the air velocity comes out from the goaf into the workings at a very rapid rate, in the order of about 3 seconds as shown on the graph there. But then within a space of another second, you get what's known as a suck-back effect, where the pressure differential created by the cavity and so on, creating a vacuum effect, sucks the air back into the goaf environment.

Q. Can we see, though, that after that suck-back --
A. Then you get a bit of bounce around.

Q. -- there is then what we see tailing off to the right?

A. Yes.

Q. What would an event like that do, particularly in the context of this bellows effect that you were describing to us?
A. Well, now you're getting a rush of air, and as we were showing with the different air flow rates at those sort of temperatures, at those sort of temperatures you are not going to create a cooling effect; you are actually creating an exaggerated opportunity for the coal at those temperatures to react, and it's almost within split seconds.

Q. When say it is almost within split seconds, what do you mean?
A. It is going from being in that glowing state to now suddenly flaring up into a flame.

Q. Moving to some conclusions, then, we've got slide 22. This is really a restatement of what you have already said, which is that according to those parameters, the R70 and the others, they all say that this seam has low spon com propensity?
A. They do, yes, all those index parameters. There is an additional index parameter that we didn't go back to or refer to, and that is these coals are shipped around the world under a strict regime using the UN test for shipping certification. Not that I've seen the results for this coal, but I would imagine that it passes that, otherwise it wouldn't be shipping around the world the way it does, which would also come up with the same result.

Q. Having noted that, there is this combination of factors that can lead to the outcome that you describe. Can you talk us through this, please?
A. From using the incubation testing with coal with some moisture present, whether it's the moisture that's there or even a reduced moisture, under the ideal conditions, and we give it the perfect conditions in the test framework that we use - it's perfectly adiabatic, there are no heat losses out of the system, we're using fine material, fine coal; in this case we were using air, and in other cases we will use oxygen, and we've used oxygen in the past on this particular coal - the low ash roof coal is unable to reach thermal runaway, and so under a normal mine ambient temperature condition, without an external heat source, it can't reach that thermal runaway point. Did we miss

a point there?

Q. I'm sorry, I've gone ahead.
A. We were also able to show that self-heating doesn't initiate from temperatures of about 60 or 80 in this particular arrangement or boundary conditions, and that then answered the question about the virgin rock temperature having an impact on an outcome. But at temperatures above 100, in both situations, it didn't matter which flow rate we used - the natural air leakage or the half a puff, the sluggish ventilation - both of them were able to achieve thermal runaway.

When we did the testing again from starting temperatures that were more elevated, in all cases the coal reached thermal runaway, and the time taken to reach 540 degrees also reduced significantly. The shortest time frame was associated with the higher flow rate in that particular case. And again, at that higher external heat source temperature of 140 degrees, even the coarse coal size fraction of both the low ash and the high ash roof coal self-heated up to 540 in a short period of time.

Q. Is the critical temperature, then, 100 degrees?
A. It is somewhere between 80 and 100 degrees, as shown in those tests.

Q. We know that the product that was being used to consolidate the face and/or the roof at Grosvenor mine is a product that, depending upon which document you look at, cured at a temperature somewhere between 110 and 146 degrees. Do those temperatures have any implications, given the work that you have done?
A. They do, in the sense that they are able to take the coal into the region where it is possible to go to a thermal runaway circumstance.

Q. So what are the implications, then, of that?
A. The implications of that are that given the right conditions, it creates the circumstance where a spon com event can take place.

Q. You have seen the report that was provided to us all today concerning the testing that was done by Simtars of the PUR?
A. It has been handed to me, yes.

Q. I'm not suggesting that you have had an opportunity to digest it in any great detail. In your view, should there be more testing of this product, preferably on a larger scale than has been done so far?
A. Most definitely. That was one of the conclusions or recommendations I really came to in my report, that there is a serious need to actually look at more bulk-scale testing. And that was a follow-on from the review I had done of the ACIRL report. They had started to do that sort of bulk-scale testing, but they hadn't pursued it beyond those initial trials that they did.

Q. When you say "bulk scale testing", does Simtars have the capacity to do that sort of testing?
A. Well, they do at the really bulk scale, yes. They have a 16 cubic metre chamber that has been used for ACARP spon com projects in the past to look at heating development and what takes place with the gas evolution associated with heating development.

Q. Presumably some thought would need to go into precisely how it was done, but whatever testing was done, should it, in your view, involve an assessment of the interaction between PUR and coal?
A. Yes.

MR HUNTER: Those are the questions that I have for Dr Beamish.

<EXAMINATION BY MR HOLT:

MR HOLT: Q. Good afternoon, Dr Beamish. My name is Saul Holt. I'm one of the barristers for the Anglo companies, who have been given leave to appear. I just have two topics to deal with with you.

Firstly, just by way of background, I think you mentioned it briefly when being asked questions by Mr Hunter, you have previously been commissioned for your expertise in relation to the assessment of the spontaneous combustion capacity of coal, specifically for the Grosvenor coal mine by Anglo?
A. I've done testing work for Anglo, yes.

Q. Specifically in relation to the Grosvenor mine?
A. I've done some Grosvenor mine testing, yes.

Q. Specifically reports I think in 2014 and 2019?
A. They were reports in 2014 and 2019, yes.

Q. Thank you. I then just wanted to ask you, please, about your - I'm sorry, let's go back a step. In terms of those reports, your conclusion about, firstly, the low reactivity of the Goonyella Middle seam coal at Grosvenor was essentially consistent with the work that you did for the purposes of your report here?
A. It was consistent, yes.

Q. Particularly in terms of that conclusion that you have explained to us today and is on one of the last of the slides, which is, in essence, that in the absence of an additional external heat source, under the closest to real conditions that you could replicate in your testing, you couldn't get to thermal runaway?
A. Correct.

Q. That was essentially the advice that you gave Anglo operations at Grosvenor in 2014 and 2019?
A. Yes.

Q. There's just one aspect of your report that I would like to ask you some questions about. Mr Operator, might we go, please, to Dr Beamish's statement, BBA.001.001.0001. Could we go to page 19 of that report, please, under 4.1. I'm sorry, his page 19. I apologise. Could you call out, please, the second paragraph down.

Obviously enough, Dr Beamish, as indeed this very Board of Inquiry demonstrates, it is critically important, isn't it, that learnings are taken from incidents, from events that occur, that involve spontaneous combustion in underground coal mines?
A. Yes.

Q. You have been heavily involved, in the course of your career, with ensuring that those learnings are taken on board and implemented, so to speak?
A. Yes, I regularly present at industry conferences and Mine Managers Association meetings with advancing the knowledge as it advances.

Q. I want to, then, make sure that we are understanding the dataset in terms of this PUR issue that you have raised. About halfway through, just prior to halfway through this paragraph that's called out, you note:

The use of PUR also introduces significant heat to the mine environment and this has contributed to a number of documented spontaneous combustion events ...

Then in brackets you note "(Cliff, Beamish and Cuddihy, 2009)". Do you see that?
A. Yes.

Q. The point you are making there in brackets is that that is the reference which supports the proposition that the use of PUR has contributed to a number of documented spontaneous combustion events?
A. It is a reference back to where that comment is made in that particular --

Q. All right. Could we then have a look, please, at that paper, of which you were obviously a co-author?
A. I was, yes.

Q. That is in WMA.003.003.0001. Might we go, please, to 0006. On the first page, three paragraphs down, it commences "The use of". Could you call out that paragraph and next one, please, Mr Operator.
A. That particular paragraph?

Q. I'm asking the operator to call it up. I apologise, Dr Beamish. I'm just dealing with ensuring we can all see it. The first paragraph I've called out notes:

The use of Polyurethane Resin (PUR) and explosives can introduce significant heat and these have contributed to a number of events that have been attributed to spontaneous combustion.

Do you see that?
A. Yes.

Q. Was that the reference that you were intending - that you had in mind when you referred to that in your report?
A. Well, it's the paragraph that follows that is the one that it's --

Q. Yes, and that paragraph that follows refers to two

events, doesn't it? The first was at Leichhardt colliery in January 1981?
A. It does, but I wasn't referring to the Leichhardt thing. It was more the one that comes after that.

Q. I understand that. Just let me work it through.
A. Yes.

Q. Because the Leichhardt one relates to explosives, that is, the shot-firing that occurred?
A. Yes.

Q. The next one that is referred to is North Goonyella?
A. Yes.

Q. Three events traced back to the use of significant amounts of PUR, as it is described?
A. Yes.

Q. So was it that North Goonyella which is the number of events that you were referring to in your report?
A. The repeat events, yes.

Q. Are there any other examples that you are intending to refer to in your report of any link between PUR and spontaneous combustion anywhere in your experience, apart from North Goonyella?
A. Not that I've got on record, no.

Q. So when we talk in your report about "contributed to a number of documented spontaneous combustion events", the reference there is only to North Goonyella?
A. To the repeat events, correct.

Q. At North Goonyella?
A. Yes.

Q. Thank you. You have noted there, or it is noted in that report --
A. Could I just point out something for you there?

Q. Yes, of course.
A. This particular section was written by Paul Cuddihy because of Paul's experience at North Goonyella, and so on. So when we were putting this chapter together, he wanted to make sure we covered all the things that we had learnt from the previous experiences, and that's why this was in there.

Q. I understand that entirely.
A. Yes.

Q. I just want to make sure that when we're talking about a history of a certain thing occurring --
A. Yes.

Q. -- which is here said to be a link between PUR and spontaneous combustion, that we all entirely understand the dataset that we're talking about, and here that dataset is North Goonyella?
A. As it stands, yes.

Q. You are not aware, I think, of any other events in Australia or indeed in the world of a link between PUR and spontaneous combustion - of the kind of theory that was just put to you by our learned friend Mr Hunter?
A. Not at this point in time.

MR HOLT: Thank you, Mr Martin.

THE CHAIRPERSON: Thank you. Mr Telford?

<EXAMINATION BY MR TELFORD:

MR TELFORD: Q. Good afternoon, Dr Beamish.
A. Good afternoon.

Q. My name is Paul Telford. I represent the interests of DSI Underground. I've got a couple of questions for you about your report, which is BBA.001.001.0001. I'd also like to ask you some questions about the document that my learned friend Mr Holt took you to, WMA.003.003.0006. Then finally I have some questions or observations I'd like you to comment on concerning the Simtars report that we were all given today, although I appreciate that you have only had a very brief period of time to look at that, and if you are unable to assist us in that regard, I understand completely, and I appreciate that you are not the author of that document.
A. Yes.

Q. As I understand your executive summary in your report and the answers that you gave my learned friend counsel assisting earlier today, it is your evidence, isn't it, that spontaneous combustion of GMS coal is possible, given ideal conditions and sufficient time? I think you used the phrase, "It has a low propensity to occur, but it has happened before"; is that correct?

MR HUNTER: I think the difficulty is that there are a number of propositions --

THE WITNESS: It clearly says for the Goonyella Middle seam. It clearly says for the Goonyella Middle seam.

THE CHAIRPERSON: I'm sorry, doctor.

MR HUNTER: The difficulty is that I think there were a number of propositions in that question.

THE CHAIRPERSON: Try again, Mr Telford.

MR TELFORD: Thank you.

Q. If I can take you, Dr Beamish, to your report and the executive summary, please, Mr Operator. This is page (i), and can we go to the final paragraph.
A. Yes.

Q. Am I to understand that statement to say that under ideal conditions, et cetera, spontaneous combustion is possible?
A. No, it says:

> *Adiabatic oven ... testing shows that under ideal conditions of critical thickness, ample continuous supply of oxygen and minimal heat dissipation, spontaneous combustion incubation is very dependent on the balance between intrinsic reactivity of the coal and moisture content.*

What that's saying is that if they are in the wrong combination, it can't occur. The next statement then clarifies, in the case of the Goonyella Middle seam:

> *... at a mine ambient temperature of ... 45 degrees, incubation to thermal runaway is not possible without an external heat source.*

Q. Regardless of time?

A. Regardless of time.

Q. So your evidence is that we need to elevate the Goonyella Middle seam coal to a starting temperature of something in the order of 100 degrees?
A. 80 to 100.

Q. 80 to 100 degrees. While we have your report in front of us, you did some testing - this is at page 16, please, Mr Operator. The incubation test results show that even at 80 degrees, we have a static heat until an external heat source is applied?
A. Yes.

Q. So it needs to be more than 80, and on your diagrams here, in fact, we don't get to thermal runaway until 100 degrees?
A. That's correct.

THE CHAIRPERSON: Q. I'm sorry, doctor, in relation to the step heat, you heated at 80 degrees, and then you stepped it straight up to 100 degrees or --
A. No, we let it sit there to just see if it would take off, and it didn't take off. It was --

Q. But after that, did you step heat it straight to 100, or did you go in between?
A. No. After that, we take it up to the 100, and you can see it's about a couple of hours to get there.

MR TELFORD: Q. Then your testing goes on to show - and I'm now quoting from page 23 of your report, Dr Beamish - that when coal is exposed to successively higher external heat temperatures at or above that 100 degree thermal runaway point - for example, 120 degrees and 140 degrees - the time taken for that coal to reach 540, 570, 600 degrees reduces significantly?
A. Compared to the 100, yes.

Q. Of course, the heat of 540 degrees is significant for the purposes of this event, isn't it, because we're talking about a heat sufficient to ignite methane?
A. That was part of the premise, I think, yes.

Q. Which is something approaching 600 degrees?
A. For?

Q. Heat sufficient to ignite methane.
A. No, it's 536.

Q. Thank you. In excess of 500?
A. Yes.

Q. So the process you postulate is that a combination of PUR in contact with coal created a spontaneous combustion, and that was the ignition source, potentially, for the event of 6 May 2020?
A. The contact of the PUR with the coal creates the opportunity for the coal to self-heat to get to the stage where it becomes a spontaneous combustion.

Q. You are not suggesting, are you, for example, that the PUR of itself was an ignition source in the same way as a spark or a naked flame; you are saying that the combination of the exothermic reaction with the PUR and the coal heated the coal to the point where it achieved thermal runaway up to a level approaching 500 degrees?
A. In this case, it's the PUR acting as an initiator, and then the coal takes over, yes.

Q. Of course, if we were to translate that to an in-mine condition or circumstance, then we need to accommodate a number of factual and theoretical assumptions that closely replicate what was happening in the mine?
A. Things have to line up.

Q. Yes, and you acknowledge that in your report. So we must have an ignition source in excess of 530-odd degrees Celsius; we need to have an appropriate methane-oxygen mix - correct?
A. But I don't address that in my report. I'm not addressing the explosibility aspect. I'm just addressing the coal behaviour.

Q. In context, though, of the combination of the Goonyella Middle seam coal and PUR being a potential ignition source?
A. Yes.

Q. Is it the case that when you were preparing your report, you were conscious of the time frame that was involved between the application of the PUR and the ignition on 6 May?
A. No, I was never aware of any of that. I was not aware

of most of the background that's been given in these last couple of weeks until I read the transcript from the first day, when there was a summary made of all the witnesses that were coming forward. I had no idea what was coming these last couple of weeks, so my work was done completely independent of any of that information.

Q.   Let's concentrate, then, on this hypothesis that the coal is heated by its contact with the PUR. Mr Operator, can I have that last passage that my learned friend Mr Holt took Dr Beamish to, which is WMA.003.003.0006, please. Now, you have already told us this afternoon that you weren't the author of this?
A.   Correct.

Q.   It was Mr Cuddihy. Do you agree, though, with what is stated in that paragraph, and in particular I'm interested in the sentence halfway in that paragraph that says:

> *PUR cures with an exothermal temperature of 152 degrees C. When coal is encapsulated in a block of PUR, it is raised to 152 degrees C and then both PUR and coal act as insulators ...*

Do you accept that as being accurate?
A.   It has some relevance, but it may not necessarily be the only way that the heat transfer takes place.

Q.   Can I suggest to you that if you have two adjacent masses of different temperatures and you combine them, then neither will retain the same identical temperature as they were before the combination occurred, if that makes sense?
A.   Yes.

Q.   Do you accept that?
A.   From a heat transfer point of view?

Q.   Yes.
A.   Yes.

Q.   So if I can give you a very simple example, if you can imagine holding a cup of hot coffee and you are pouring some cold milk into the coffee, then the coffee never reaches the temperature of the milk to begin with, and the milk will not hit the same temperature as the coffee. Do you accept that? There is a heat transfer process?

A. Heat transfer, yes.

Q. I appreciate that you are not the author of this, but insofar as this purports to say that when coal is encapsulated in a block of PUR, it is raised to the same temperature as the PUR, that clearly can't be correct, can it?
A. It's probably not in the terms of the heat transfer that you are describing, no.

Q. Because in fact some of the energy in the form of the temperature in the PUR will have been transferred to the coal?
A. Yes.

Q. So if we try to translate that to in-mine conditions, I'd like you to assume for these purposes that we have an injection into the coalface ahead of the AFC of a volume of PUR in the order of 200 kilograms, not more than 200 kilograms, and that we have spacings of at least 2 metres across the mine face of about 70 metres, so we've got 35 injection holes each of roughly 4 or 5 metres length. You would agree with me, wouldn't you, that the additional mass in the surrounding coal is going to extract the heat from the exothermic reaction of the PUR but in a way - sorry, I will break it down. Do you agree that that is likely to occur?
A. It depends on what cavities the PUR is going into. If I've got a big cavity in there, then I end up with a big block of PUR there. It's not the same as if it's going down the holes and into little fractures. So then I've got a different heat transfer.

Q. Sure. In fact, one of the things I will take you to in a moment is your example of another situation where you say there was a spontaneous combustion event that involved PUR being injected into what was effectively a cavity. But we're not talking about that here. We're talking about an injection of PUR into a hole which is, as I've said, about 5 metres in length, at 2 metre distances, in a face of coal. You are comfortable with that assumption?
A. Yes, but you're also making the assumption that it's only going in the hole. If there is a big cavity down the hole somewhere that the hole [sic] has come into contact with, then it will go into the bigger cavity.

Q. Sure, but cavities are important for a number of

reasons, aren't they, because in a real mine condition, you are going to encounter significant volumes of water?
A. Only if it's an aquifer.

Q. Can I suggest to you that there are a number of sources of water that would have some impact on this relationship of the heat transfer between PUR and adjacent coal. One would be the inherent water within the coal itself, the fact - and again you accept this in your report - that coal contains moisture inherently; correct?
A. In this particular rank of coal, it's between 1 and 3 per cent.

Q. The very fact that we are using PUR suggests that there is some instability in the coal itself, which is suggestive of fractures within the face, which could be filled with subterranean moisture, water; do you accept that?
A. I don't know whether this was deemed a wet pit. If it's not a wet pit, it's not necessarily the case.

Q. But it can't be excluded?
A. I think that's a fairly - a rare situation.

Q. Are you aware of whether there were any significant faults in the seam that were proximate to the area where the ignition source is said to have occurred at shield 111?
A. No. As I said before, I'm not aware of any of the mine background leading up to this.

Q. Are you familiar with the process of the AFC as it works through the face of the longwall?
A. Yes.

Q. So you would accept that there is a large volume of water that is used in the course of that process? Water is sprayed on to the face of the longwall?
A. That's the face coal, yes.

Q. It's used for dust suppression?
A. Correct.

Q. That water will make its way into any crevices or cracks within the coal?
A. It doesn't go against gravity and go up into the roof.

Q. Does that not depend on, for example, the pressure at

which it is applied?
A. No. It's a spray. You're not putting a hose up in the roof. It's a spray. It goes on the face.

Q. So you are saying that there is no possibility for water to track through crevices in the coalface?
A. It's against gravity. It can't happen.

Q. You do agree, though, that the presence of water would act to suppress heat and, in particular, a heat transfer between the PUR and the coal?
A. If there is additional moisture somewhere, I guess so.

Q. When you do your testing, in order to properly replicate the mine condition, don't you dry the coal?
A. Not for the incubation test, no.

Q. If I can take you to your report, please, in the second paragraph of your executive summary, there is a reference to extrinsic factors such as in-mine ambient temperature and moisture?
A. Sorry?

Q. I am sorry, it is in the introduction at paragraph 2. That's the executive summary, Mr Operator. Could I go to page 1, the introduction. Halfway through that paragraph:

> *The moderating influences of extrinsic factors such as in-mine ambient temperature and moisture (both in the coal and the surrounding environment) have been recognised and studied ...*

That is important, isn't it, for the purposes of replicating in-mine conditions?
A. If you know what the in-mine conditions are in that particular case, yes.

Q. Here, you don't know what the in-mine conditions are for the purposes of this longwall; is that correct?
A. We work on what we are given from the mine at the time.

Q. But you aren't able to assist us with the extent of the moisture that was present in the mine at the time?
A. Well, we're given what we're given. It is not a --

Q. All right, thank you. If we can go back to this notion of heat transfer, I think you have agreed with me that the statement that you attributed to Mr Cuddihy is inaccurate?
A. It's not inaccurate. There are other circumstances. It doesn't have to be encapsulated by PUR; it can come into contact. It sort of gives the impression that it is always encapsulated. It can be the other way around, because it is penetrating, so it doesn't cover all the circumstances.

Q. Sorry, let me be a bit more precise. The notion that a piece of coal encapsulated within PUR means that the coal adopts the same temperature, precisely, as the curing PUR - do you agree that that is an inaccurate statement?
A. Well, it might have been a bit simplistic with the way that Paul wrote it.

Q. Well, is it correct or not?
A. It's Paul's impression. I don't know whether it's correct. It's Paul's impression.

Q. Do you adopt it?
A. In what way would I adopt it?

Q. Well, do you accept that it is correct or not?
A. It's not completely correct.

Q. The extent to which it is not correct is that it doesn't accurately describe the process of heat transfer?
A. Yes, well, in that particular statement.

Q. Sorry, do you accept that proposition or not?
A. In that particular statement.

Q. Yes. So in that particular statement, it is - can we use the term "inaccurate"?
A. If you want to put it that way.

Q. All right, thank you. Can I ask you to consider the Simtars report, please. As I have said several times now, I appreciate you are not the author of this report. Everyone in the room has had it now for less than three hours or so. But you have had a chance to read it?
A. I have had a quick look at it.

Q. Can we go, please, to page 23 of 35. Do you recall, Dr Beamish, what this particular test involved, the

physical circumstances of this test? Sorry, you said you've read this report?
A. I've had a look at it, yes, but I haven't looked at all the data because there is so much there.

Q. Can I suggest to you that what table 5 demonstrates is that in circumstances where you had a sample of coal which had been injected with PUR, the maximum temperature of the coal, which you will see under the column of test conditions, "Max temp external TC15", was 81.5 degrees.

MR HUNTER: Mr Martin, I really wonder about the utility of this exercise, given the witness's lack of familiarity with the material. We can all read the report for ourselves and see what the data is, but it is a little unfair, in my respectful submission, to be expecting this witness to, on the hop, as it were, express opinions about something that is plainly highly technical in circumstances where he hasn't had an opportunity to review it.

THE CHAIRPERSON: Well, I think Mr Telford would be entitled to ask Dr Beamish certain things assuming the accuracy of the testing. Is that what you are trying to do, Mr Telford?

MR TELFORD: I am.

THE CHAIRPERSON: Perhaps if you frame it in that way and see what you want to ask, and we will see if Dr Beamish is in a position to respond.

MR TELFORD: Thank you.

Q. If we assume for these purposes, Dr Beamish, that a test which I have just described for you - so we have a coal sample that is cylindrical in nature and has a hollow centre and has been injected with PUR, tested by Simtars, demonstrated that the maximum external temperature of that coal sample was 81.5 degrees. Let's assume that that is what this test demonstrates.
A. Why are you focusing on that particular temperature with respect to the other temperatures that are there that go up to 109 degrees?

Q. Because those temperatures are not temperatures of the coal; they are the temperatures of the PUR.

MS HOLLIDAY: It's my turn to object now. Mr Telford is putting his interpretation on this table, which may well not be correct at all. It was prefaced on the basis of assumptions. Now it is being phrased as the actuality of what is the contents of that table.

THE CHAIRPERSON: Yes.

MR TELFORD: I have asked the witness to make an assumption, and the witness has asked me to qualify the basis of the assumption. If the witness wants to accept the assumption, we can move on.

THE WITNESS: Can I say something here? I'm not comfortable with talking about other people's data that has just been generated. I'd rather talk to the authors of this particular piece of work so that I can at least interrogate them on a level where they are explaining to me exactly what they have done.

THE CHAIRPERSON: Q. And understand what the data is?
A. And understand it.

THE CHAIRPERSON: Yes. Mr Telford, this problem was likely to arise, given the late arrival of the report. There is no productivity, I must say, in questioning about something that may or may not be correct. Your interpretation may or may not be correct, and I don't think that's a satisfactory basis upon which to continue. Do you have any other questions?

MR TELFORD: I do.

THE CHAIRPERSON: Yes.

MR TELFORD: With your indulgence, can I just ask one more question on this report and then move on?

THE CHAIRPERSON: Well, try your luck. I will hear what it is, firstly.

MR TELFORD: Q. If this report demonstrates that the maximum temperature that could be reached when you apply, in these circumstances of the test that was done, 81.5 degrees, do you accept that, going back to your report and your investigations, that would not be enough to initiate thermal runaway?

A. No, I don't accept that. There are some other qualifiers you need to take into account here, and that's why I need to talk to the Simtars guys to understand how they obtained that data and - I don't even see the thermal curves for this data. It's just a table, it's numbers. It doesn't tell me anything.

THE CHAIRPERSON: Yes.

MR TELFORD: All right.

Q. You were discussing with my learned friend counsel assisting before the detectible products that would be expected in circumstances where coal has been heated to a point where it would ignite methane. Do you remember that?
A. He was actually talking about when the first presence of ethylene comes into play, not when the coal ignites.

Q. Well, I'm going to ask you about ethylene in a minute. Let me recast the question. If coal has been heated to a temperature in excess of or about 530 degrees, would you expect for there to be observable phenomenon, and I think the one that you identified both today and in your report is "glowing" - you would expect the coal to glow; is that correct?
A. The hot spot itself won't be on the surface. You will not see that glow. We have had pillar heatings in the past, in solid coal, fractured solid coal, which is what we're talking about here, fractured solid coal. The glow was sitting in from the free surface, and it was just that someone happened to walk past and was looking at the right direction at the right time, and they saw the glow, so --

Q. So it was observable?
A. No. You can't walk in a goaf. You're not allowed to walk in a goaf environment.

Q. You said someone was walking past and just happened to look at the right position at the right time?
A. That's in a pillar in a roadway in fresh air. Sorry.

Q. I see. That's okay. Would coal that's heated to that sort of temperature also produce smoke?
A. At a glowing stage, not necessarily.

Q. But possibly?

A. In the case of a small hot spot, it would be very minimal.

Q. Would it produce an odour, a discernible odour?
A. Again, you are talking a trace - trace at the best.

Q. So are you saying "yes" or "no"? Yes, but small amounts?
A. Yes, but very small diluted amounts.

Q. And what about a heat haze, Dr Beamish? If coal was heated to a temperature in excess of 530 degrees, would it produce a heat haze?
A. Not if it is in away from the free surface.

Q. So is it a fair summary of that passage, then, that phenomena such as heat haze, possibly smoke, possibly glowing, possibly odour may be present but are unlikely to be observable because, in your scenario, we have a relatively small particle or pocket of coal that's some distance from the face of either the coalface or the roof?
A. It's in an inaccessible area; correct.

Q. Inaccessible?
A. Yes.

Q. In those circumstances, though, what is the exposure of that coal to oxygen?
A. It could be very small.

Q. Could be limited?
A. Limited, yes.

Q. And oxygen is a necessary component, of course, for combustion?
A. For continued combustion.

Q. Yes. So if it's the case that the particular scenario you are envisaging is that you have a small piece of coal that has been heated to that extent but it is not observable, it's unlikely, isn't it, that that is going to be the source for spontaneous combustion, because it's not exposed to mine conditions, it's not exposed to oxygen?
A. If the ventilation were to change for some particular reason, then it will change its equilibrium and it will actually move.

Q. So we have to have an additional condition where the ventilation changes, so --
A. For some reason or other.

Q. For some reason?
A. Yes.

Q. And of course we have to have the absence of moisture, assuming that there is some moisture within the mine?
A. That's a very vague possibility, moisture.

Q. Vague possibility of moisture within the longwall 104 at the time --
A. But the moisture is not going to stop the hot spot doing what its doing if it is up at 500 degrees.

Q. But moisture will inhibit heat, won't it?
A. It is not going to affect - you would virtually have to swamp it.

Q. Is that correct, though, where you say that the trigger point is 100 degrees? I mean, obviously once it gets --
A. It's different for every coal, because they've all got a different reactivity moisture balance between them, so lower ranked coals have lot more moisture in the coal, so that trigger point can be - it's more likely to be 120. When you have a low moisture coal it doesn't have as much moisture to deal with so it can trigger at a lower temperature.

Q. Is it fair to say, Dr Beamish, that the circumstance that you have described is remote, where we've got a very small piece of coal, in the scheme of things --
A. Do you mean remote in terms of inaccessible or a remote possibility?

Q. No, no, in terms of possibility, or both?
A. It's still - it's a likely possibility. When you are doing hazard likelihood, it is a likely possibility.

Q. Assuming that the coal is at that temperature?
A. It is pushed - yes, that's right. Correct.

Q. Putting to one side what our friends at Simtars have done recently, you have agreed with me that a process of heat transfer necessarily means that whatever heat is

generated by the exothermic reaction of the PUR doesn't transfer completely into the adjacent coal?
A. That's a bit of an unknown, yes.

Q. Well, I think you agreed with me earlier that the statement to that effect is inaccurate. The extent to which it transfers is an unknown; is that correct?
A. Correct.

Q. And the extent to which it transfers relates to the comparative masses of the body; do you agree with that?
A. You are getting outside my field of expertise with the heat and mass transfer aspect.

Q. Right. Okay. So you are not comfortable talking about the likelihood of a body that's adjacent to the PUR - and we've heard today that the temperature of the curing PUR is going to be somewhere between 110 and 140-odd degrees - you are not comfortable about giving evidence about the likelihood of that heat transfer to adjacent coal; that's beyond your expertise?
A. It is, because I'm looking at - the testing I've done is at set temperatures, so that we know that if those temperatures are reached, then that's the outcome.

Q. In the laboratory context?
A. That's the outcome.

Q. Thank you for that. We had an exchange earlier about ethylene, and I think your evidence was that even a very small amount of ethylene in this environment would cause you concern?
A. It certainly does.

Q. Do you agree that ethylene can be produced by heating coal to a temperature in excess of 100 degrees?
A. Yes.

Q. Now, this may follow from the concession that you have just made - and I don't want to take you out of your field of expertise, Dr Beamish, so tell me if you are not comfortable answering this question as well. You were asked earlier about the presence of cavities or the possibility of coal falling into the AFC or behind into the goaf. Do you remember that?
A. Not about coal falling into the AFC.

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Q. Sorry. You were asked about the presence of cavities and the possibility of the coal falling into the goaf?
A. Right.

Q. If we assume for these purposes that there were significant cavities in and around shield 111 --

MR HUNTER: Can I just clarify something? I didn't ask the witness about roof coal falling into the goaf in the context of cavities. I simply asked the question about the normal process of coal falling into the goaf - that is, the roof coal falling into the goaf - as part of the goafing process. So the questions I asked had nothing to do with the existence or otherwise of a cavity.

MR TELFORD: All right. Thank you.

Q. If we assume for these purposes, Dr Beamish, please, that there was a cavity in the vicinity of shield 111 as the AFC was moving through the longwall, will you do that for me - in the roof. Let's assume that the evidence demonstrates the existence of that cavity.
A. Mmm-hmm.

Q. Does the presence of the cavity have any impact on the likelihood of there being sufficient conditions in the roof for there to be a spontaneous combustion event through the combination of PUR and adjacent coal?
A. I'm not really sure where you are going with that, because it sort of goes back to fracture mechanics and that's really evidence from one of the other experts. I'm not familiar with even what you are talking about with 111. Like I said to you before, I've got no - you know, I've not been made aware of the event as it exists and what 111 means.

Q. I see. So is it fair to say, then, that your opinions here today are based solely on - well, perhaps not solely, but predominantly on your experimental work in the laboratory as opposed to the transfer of any data or findings from your testing to the actual in-mine conditions as they existed on the day?
A. The testing has been done to try and replicate mine conditions as they exist with the coal as the boundary condition, and therefore it's related to how the coal is going to behave if exposed to those boundary conditions.

Q. Generally?
A. Well, yes, it's done at set steps, yes.

Q. You don't purport to be able to transfer or extrapolate that data into the precise circumstances as they existed in this mine on 6 May or in the preceding days?
A. Not without going back and reviewing whatever it is that you are presenting to me.

Q. Thank you. And, Dr Beamish, you were asked before about the role that PUR would play, in a generic sense, in spontaneous combustion events, and you conceded that it was a matter that required additional investigation - in your report?
A. The recommendations at the end of my report, correct.

Q. Yes. And, in fact, you say, don't you, that it would warrant an ACARP project?
A. Well, it would be a likely way to go, from an industry perspective.

Q. Yes. Which is a significant investigation?
A. A much more detailed investigation, correct.

MR TELFORD: Thanks. Those are my questions.

THE CHAIRPERSON: Thank you. Mr Crawshaw?

MR CRAWSHAW: No questions, thanks, Mr Chair.

THE CHAIRPERSON: Ms Grant?

MS GRANT: No questions, thank you, Mr Martin.

THE CHAIRPERSON: Mr O'Brien?

MR O'BRIEN: No, thank you.

THE CHAIRPERSON: Ms Holliday.

<EXAMINATION BY MS HOLLIDAY:

MS HOLLIDAY: Q. You were asked some questions in relation to your incubation testing. The whole point of your incubation testing, isn't it, is to attempt, as best as you are able, to replicate the mine conditions?

A. It is.

Q. And indeed, that's why there is a purpose-built oven; is that correct?
A. Correct.

Q. And for the purpose of your testing and analysis, you obtained a sample from the Goonyella Middle seam?
A. We did.

Q. And, further than that, you retained the moisture as it existed in that sample?
A. Which is why it's enclosed in the duct tape and it's handled appropriately.

Q. So to your mind, as best as your testing is able, you did replicate the mine conditions; that's correct?
A. The coal was coming from that 450 metres down, whatever the number was - not precisely - but, yes, it is retained at that condition.

Q. In relation to the questions that you were asked by Mr Telford and a number of propositions and scenarios that were put, you were asked about if this coal that had been injected with PUR was sitting at 530 degrees, and you were asked about the moisture content - the boiling point of water is 100 degrees; correct?
A. Yes, there is no moisture going to be there. If the coal - if there is a hot spot sitting there at 500 degrees, it will just go "pffft" - moisture is gone.

Q. You were also asked in relation to the amount of oxygen and you said that it could be small. Do you mean by that that you only needed a small amount of oxygen --
A. No, what I mean by that, the concentration could be small but the volume of oxygen available, if you've got a goaf void - as far as the coal is concerned, it's infinite, as long as there is a percentage of oxygen there to work with.

Q. And indeed, the fact is that goafs have oxygen?
A. They all have oxygen until they have been finally sealed up.

Q. And the goaf fringe in particular has oxygen?
A. There is a gradational arrangement from the face going inbye.

Q. So if this coal that had been injected with the PUR had, through the process of mining, fallen down behind the shields, then it's entirely possible, isn't it, that it was being in an oxygen environment by at least the goaf fringe or the goaf itself?
A. That's correct.

Q. And you only need a small amount of oxygen --
A. Just to maintain the hot spot, correct.

Q. You were asked some questions in relation to ethylene and you mentioned a mine in New South Wales that you are engaged by. In that mine, is it the case that the presence of any amount of ethylene in the goaf stream triggers a level 2 TARP?
A. It is correct.

Q. And that's because, isn't it, that ethylene in any quantity should be treated seriously?
A. Yes.

Q. And indeed, investigated by the mine to determine its underlying cause?
A. Most definitely.

MS HOLLIDAY: Mr Martin, those are the only questions that I have. In relation to what Mr Hunter put on the record this morning about the location of the sample that was utilised by Dr Beamish, it was put on the record that it came from 52 cut-through on longwall 108, which is approximately 1 kilometre from the incident site. The reason why it was taken from there, for the record, is because, on our instructions, that was the borehole in the closest proximity to the incident site.

THE CHAIRPERSON: Yes, thank you.

MS HOLLIDAY: Thank you, Mr Martin.

THE CHAIRPERSON: Mr Hunter?

MR HUNTER: I have no further questions.

THE CHAIRPERSON: Mr Clough?

MR CLOUGH: Q. Dr Beamish, I've just got a couple of

questions. Would you be able to, if it is within your field of expertise, maybe give a brief summary of the effect of gas drainage on moisture content of coal?
A. Yes, that is within my expertise, because we've tested this aspect on a number of occasions.

The effect of gas drainage is to remove two of the most significant intrinsic inhibitors in the coal, and that is, one, the seamgas; and the moisture, because for the oxygen to actually get to the sites it needs to react with, the gas has to leave and come out of the pore structure and the oxygen has to go the other way and get in. The second thing is, then, by doing gas drainage you also remove moisture at the same time. So now, the coal is no longer up at the moisture reactivity that it would be prior to having drainage.

Q. Thank you. The second question is just a little bit of clarity about this conversation about heat transfer. When I look at your graphs - and correct me if I've got this wrong - what I'm reading there is that the critical temperature is 100 degrees. That's where the moisture boils off and where you get a self-heating, according to your lab tests. Is that the way I'm reading it?
A. For this particular coal, yes.

Q. So am I right to say it's actually irrelevant about the coal reaching the same temperature as PUR; all it has to do is actually - the curing PUR, all it has to do is get over the 100 degree threshold?
A. In this case, I think it only has to get over between 80 and 100 degrees, for this particular coal. It is the rank of coal. We're actually trying to do more tests in that range for these sorts of ranks of coal now to see if, you know, is it 85? In actual fact, we determined for the same seam that under a certain circumstance it was 85 degrees - not this particular mine - when we were doing an investigation on other matters.

Q. Thank you. And then just the last question. My understanding is that the portion of the Goonyella Middle seam that was extracted at Grosvenor, there was actually floor coal left as well. Are you aware of that?
A. No, I'm not.

Q. So obviously no testing was done on any floor coal that could have gone back in the goaf?

A.   No.

MR CLOUGH: Yes, I have no more questions, Mr Martin.

THE CHAIRPERSON: Thank you.

Mr Hunter, what's the progress of this matter and Dr Beamish?

Mr Telford, you will have to come back to the microphone, if you don't mind. Are you wanting to take any matter further?

MR TELFORD: We are, Mr Martin. We would like to explore with Dr Beamish the findings of Simtars, particularly in relation to that final exchange.

THE CHAIRPERSON: All right. Mr Hunter?

MR HUNTER: I confess to not having spoken to Dr Beamish about his availability next week. I understand there are witnesses scheduled for Tuesday and Wednesday of next week.

THE CHAIRPERSON: And Monday.

MR HUNTER: I am sorry, and Monday. Consideration of the issue of calling the author of the Simtars report hasn't really progressed terribly far given the recency with which it was delivered, but it might be that there could be some evidence called from the author of the report. It might perhaps be preferable that if Dr Beamish is to be recalled, he is recalled after any evidence is taken from the author of the most recent Simtars report.

THE CHAIRPERSON: Yes. I don't wish to put you on the spot, Dr Beamish, but are you available some time next week?

THE WITNESS: We're moving into Easter aren't we? We've only got four days next week.

THE CHAIRPERSON: Yes. I know how many days there are. I just want to know how you are.

MS HOLLIDAY: Mr Martin, I'm loath to interrupt, but Dr Beamish doesn't know with respect to the availability of the Simtars expert as well. If I can liaise with

Dr Beamish, I'm sure he will make himself available and we will, if necessary, tie in the necessary days. I have had a conversation with Dr Beamish in relation to his availability next week.

THE CHAIRPERSON: All right. Thank you.

With that done, anything else?

MR HUNTER: No. Might Dr Beamish stand down?

THE CHAIRPERSON: Yes. If you don't mind, Dr Beamish, I won't excuse you at this stage, for obvious reasons. We will see you again shortly. But we will adjourn until 10am on Monday.

<THE WITNESS WITHDREW

AT 3.50PM THE BOARD OF INQUIRY WAS ADJOURNED TO MONDAY, 29 MARCH 2021 AT 10AM

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