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 Monday, 29 March 2021 at 10am
(Day 23)

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THE CHAIRPERSON: Yes, Mr Rice?

MR RICE: Mr Martin, I call Dr Ting Ren, who is appearing remotely. Hopefully he will be on the screen.

THE CHAIRPERSON: Professor, are you there? Can you hear me?

DR REN: Good morning, yes, I can.

<TING REN, affirmed: **[10am]**

<EXAMINATION BY MR RICE:

MR RICE: Q. Dr Ren, I want to ask you some questions to begin with. Can you see me and hear me okay?
A. I can only see the wording here "Queensland Coal Mining Board of Inquiry". I don't see the other - I cannot see, you actually.

Q. Let's see if we can arrange that. That's preferable.
A. Yes, I can see the courtroom now. Yes.

Q. Is your name Ting Ren?
A. Correct.

Q. Dr Ren, you're an associate professor at the University of Wollongong where you're situated today; is that right?
A. Correct.

Q. And you're attached to the School of Civil, Mining and Environmental Engineering?
A. Yes.

Q. Have you had that position since 2009?
A. That's correct.

Q. I just want to ask you a few more details about your background. You were tertiary educated in the United Kingdom; correct?
A. Yes.

Q. You gained your Masters in Mining Engineering in 1988?
A. Yes.

Q. And then a doctorate in the same field in 1992?

A. Correct.

Q. And you worked in the UK until 2003 as a mining engineer and also a senior research fellow?
A. That's correct.

Q. You came to Australia and worked for a number of years, I think until 2009, with CSIRO?
A. That's correct, yes, six years.

Q. And you worked there in various capacities - as a research scientist and a senior research engineer, also a ventilation engineer?
A. Yes.

Q. You're the co-editor of the International Journal of Mining Science and Technology?
A. That's correct.

Q. And you've published many papers and technical reports in your field of expertise?
A. Yes.

Q. Relevant to today's topic, you've participated, I think some years ago, in a number of ACARP projects that considered the application of inertisation to active goafs and, in particular, the two projects in 2005 and 2010; correct?
A. Yes.

Q. And have you retained since then a professional interest in that subject?
A. Yes, I do.

Q. Let's start with something basic. We know that an active goaf contains both methane and oxygen to varying degrees and that that's a situation to be managed. Would you tell us, to begin with, what inertisation involves?
A. In my view, the active goaf inertisation basically refers to the action of creating an inert atmosphere in goaf areas and in underground coal mines by means of injecting inert materials such as inert gas to deplete or reduce oxygen concentrations to a low level that would effectively suppress or contain the onset of active coal oxidation or spontaneous heating or potentially a gas explosion situation.

In addition to the use of inert materials, such as inert gas, this process could involve a combination of other actions, for example, ventilation controls, pressure balancing, seals, injection of other materials, depending, like foams, slurries, things like that, to minimise oxygen ingress into the goaf area.

Q. We might discuss some of those as we go along. In terms of reduction of oxygen levels, is there an objective in terms of a percentage to be ideally achieved?
A. I think for any spon com from mines or longwalls or whatever you call it, the goaf inertisation basically - it is used for operating longwalls. The aim is to drop the gas, the oxygen level, to a certain level to contain the onset of spon com. And for gassy mines with high gas emissions, methane - for example, during the longwall seal-off operations - the inertisation will help to minimise the risk of gas explosion by rendering a potential explosive goaf atmosphere.

Q. Can we start with the 2005 project and just speak about the content of that for a while, and then later on you can bring us more up to date. Okay?
A. Yes.

Q. There was quite a lot of time and money spent on that 2005 project; am I right?
A. Yes, that's true.

Q. It spanned over a two-year period?
A. Yes.

Q. According to the abstract from the report, the program was one to develop and demonstrate effective proactive inertisation strategies. Can I ask you, what was the impetus behind a project of that expense and magnitude?
A. I think at that time in Australia we had done quite a lot of goaf inertisation already. It was coming to the point that we need to further optimise the inertisation strategy, and, as a result, I think ACARP supported that project. I can't remember the exact amount of the money, but it's quite substantial, say something like $450,000.

Q. To that point, had there been use made of inertisation beyond its more established use in sealing operations?
A. Prior to this project, there was another ACARP project with the aim of optimising the process of seal-off

operations by injecting some nitrogen into the goaf to speed up the process of inertising the goaf, and therefore you reduce the danger of gas explosion. Yes, there was some study already before this project, but for a different purpose.

Q. Again, the abstract of the report refers to some frequency of goaf heatings and also production losses that can emanate from adverse incidents. Was that part of the figuring behind the conduct of that project?
A. Correct.

Q. The report, I think, makes mention that there have been developments by way of increased awareness of spontaneous heating hazards, some improvement in gas monitoring systems, and perhaps, since then, some greater understanding of gas flow mechanics. If you accept that there have been improvements in those areas, is there still a case for the wider use of active goaf inertisation?
A. Yes, I believe so. At the time, I think, although the industry has been practising inertisation for quite some years, and I think there's a general need of improved knowledge of the science behind this process, exactly what is happening in the goaf and what happens to the inert gas that you inject, and there's a common perception that there's a need to better understand this process, and therefore we are able to improve the practice in industry. I think that's probably the major driver behind that project.

Q. I was wondering if you could comment on the scope of application of this process of active inertisation. Is it, for example, one that has potential for use in all underground coal mines or only some or only where some features are present? Could you comment on that?
A. Yes, sure. I think by referring to that study or that project, ACARP project, I think there's two particular key outcomes from that project. The first one is perhaps the scenario that when the proactive inertisation should be introduced to reduce or contain the risk of spon com in the longwall goaf, and that would include, for example, if the longwall is extracting a seam that is highly liable to spon com or you are mining a particular section with severe geological disturbances, for example, faults or dykes, you might expect a bit of delay of your longwall advance, or you may experience a situation that the longwall stops for a prolonged period - it might be because of tailgate or

face collapse or other reasons, for example, equipment failures; or in certain situations, you might have abnormal CO readings or other gas ratios that indicate something is perhaps happening, or perhaps you're passing an adjacent goaf that in the past has a history of caving and you take some precautions. That's the situation.

Q. In the area of mining that we're particularly concerned with, which is the Goonyella Middle seam - I don't know if you have any familiarity with that. Do you?
A. I'm not into that, honestly.

Q. It so happens that in the ordinary course of mining in this seam, the conventional practice is to leave a beam of coal in the roof, which then caves into the goaf, and, similarly, there may be a section of floor which is not mined, in other words, it's not stone to stone, as it were; there's some coal which is left behind from the process of mining which then forms part of the goaf. In that circumstance, there is a spontaneous combustion hazard to be managed. Is that a scenario to which this active inertisation may be potentially applicable?
A. I think that's correct, because I think it's quite common practice in underground coal mining operations, sometimes you leave roof coals or floor coals, and sometimes you may have a thin seam above your face, and in the process of mining, all these coals will be left in the goaf, and therefore you would have the fuel or the sources for spon com.

I think most of the mines, when they're doing the goaf inertisation, it's not only just the coal they're mining but also, as you say, some of the roof coals are left, maybe some of the carboniferous materials are close to the roof that need to be left behind simply because they're not good quality, or maybe a very adjacent thin seam that is liable to spon com - these are the situations that you would I think consider the use of active goaf inertisation.

Q. Would you see it, in that scenario, as being something which is applicable to be done as a matter of course or only in response to a particular developing issue of spontaneous combustion?
A. I would say the first option, I think. It's action or response that, if you have your mine in that sort of situation, then you should actively consider active goaf

inertisation.

Q. Could we just come back to the 2005 report, and perhaps you might explain something of the methodology involved there. There were, for example, field studies involving two mines. Can you give us some idea of the scope of those?

THE CHAIRPERSON: Sorry, Mr Rice, just before the professor goes on, I think this topic started with his saying that there were two key issues that came out of it, and I thought that he dealt with number one. I was just curious about what was number two. That was all.

MR RICE: Q. Would you mind commenting on that, Dr Ren?
A. Yes, I think the second outcome from that project is very much relevant to the last question. Basically from that project, the second aspect is we produced a set of recommended guidelines for active inertisation, and that included, like, the location, the injection rate and how you operate this process. This actually involves a lot of details, for example, when and where you should inject the nitrogen and at what sort of a rate and what are the controls or systems you should have in place to support that process.

Q. Let's develop that, then. You mentioned a set of recommended guidelines. Do you want to take them one by one?
A. Yes. I think the first thing is the recommendation would be an onsite nitrogen generation unit should be available. If you are mining a seam that is highly liable to spon com, you need to have really good knowledge of your goaf gas flow dynamics, including, for example, what's the gas conditions: you've got compactions, your ventilation, gas composition and also the likely critical oxygen zones in your goaf. We recommended at that time that the inert gas flow should be a minimum of 0.5 cubic metres per second or 500 litres per second, but I think the recent field experience and study indicated that this may be not sufficient, in particular for some longwall panels exceeding 350 metres wide and you're running 2000 metres long. That sort of inert gas rate may need to be increased to a minimum, say, 1.5 metres per second, but dependent on the field conditions.

Q. Does that equate to 1500 litres per second?

A. That's right, 1500 litres per second, and that's probably a minimum for some of the high-production longwall faces. It depends. I mean, we did some studies recently, and it was indicated that that should be the minimum flow rate that the site should provide.

Q. That creates a requirement for a certain infrastructure by way of a means of producing and applying nitrogen at that rate. Is there infrastructure available to achieve that desired flow?
A. I think currently most onsite nitrogen generators will be able to provide 5000 litres per second flow rate, but there are mine sites that do have prepared - they can double that, and I believe that the infrastructure could be upgraded to provide that sort of flow rate. It's a matter of costing, obviously, but I think that is achievable.

The other recommendations, I think as we go - I can go through, for example, where we should inject the inert gas, and we're suggesting a deep injection is better than a shallow one. The shallow injection, say, within 50 metres behind the face, you will not achieve the inertisation effect. You had better do it, say, at least 250 to 400 metres behind the face.

Q. Was that a conclusion that came out of this report, that inertisation near to the face was not effective?
A. Absolutely, absolutely. And also that has been supported as well by some of the field data.

Q. Why is that so?
A. If you see the field data and some of the numerical modelling that we did in the past, basically if you inject the nitrogen too close to the face, basically it's diluted with the high ingress of your ventilation leakage, so therefore it's not going to get into the places where it should be, in other words, the critical zones, and most of the injected nitrogen will just go with the leakage of airflow and report to the tailgate.

Q. You mentioned, I think, the more desirable point of injection was some 200 metres behind the face. How was that conclusion arrived at?
A. That conclusion is based on several things. One is some of the field data and secondly we did lots and lots of extensive numerical modelling using computational fluid dynamics, and also that suggestion is also based on some of

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the site validations and most recent applications, for example, in some of the mines in Australia.

Q. I might just put up a diagram from that report and you might be able to speak to it. It's relevant to what you've just been speaking about. Mr Operator, could we have document BOI.036.001.0001 and at page .0011. Can you see that page, Dr Ren?
A. Yes, I can.

Q. You would be well familiar with it, I'm sure?
A. Yes, yes.

Q. Perhaps, Mr Operator, if it's possible to enlarge the diagram that appears on that page?
A. Better.

Q. In figure (c), we see, do we, the results of gas injection 200 metres behind the face?
A. Yes.

Q. And from the looks of the colouration, the great majority of the goaf appears to involve oxygen at least well under 5 per cent?
A. Yes.

Q. Towards the right of the diagram, we see the colouration reflects the presence of oxygen?
A. Yes.

Q. And I suppose the yellow line, if I can call it that, represents a demarcation of about 12 per cent?
A. Yes.

Q. Tell me, does this activity of inertisation to achieve that kind of result affect the extent of the goaf fringe, which at some point in its zone will contain an explosive mixture?
A. Well, if you see from the top of this model, the top picture basically shows a typical Australian longwall, you've got a maingate and a tailgate, and the modelling shows the oxygen ingress patterns, which indicate the red, the light red, the orangey colour, and then develop into the deeper goaf, which is the blue colour, and that shows where the goaf gas is sitting. In this case, it's methane. Obviously on the top of that picture, close to the tailgate, you will see, as we expected, the goaf gas is

going to report and converge to the tailgate.

The purpose for this study is basically trying to understand that if we do inject inert gas behind your longwall face, at different locations, the best inertisation effect you could achieve.

The second diagram actually shows that if you inject the inert gas at something like 30 metres behind the face, which was quite common practice in the past, and you see that it's not working as it should be, and much of the injected gas or the inert gas will be either diluted with the leakage and then it drifts to the tailgate, or some of the things have actually been pushed and mixed and diffused with the ventilation leakage into the goaf, and it's not doing the expected job, which is to inertise the goaf area.

But obviously if you compare (a) and (b), there are slight changes of the tailgate colours in terms of the oxygen level and perhaps also the gas concentration, but not that significant.

The bottom one basically shows that if you do the inertisation - everything we assume is the same; there's no change of other ventilation or other parameters - and if you do a deep injection, in this case 200 metres, of the same inert gas, you have much better effectiveness of goaf inertisation.

But if you look on the tailgate corner side, there are some changes of the gas levels, but I wouldn't say there's a significant impact, really, on the tailgate gas emissions, because most of the inert gas that we injected at the deep holes will be staying further in the goaf areas and to replace the oxygen that would otherwise penetrate. So in that regard, I don't think the strategy here would impact that much on the tailgate, in particular the tailgate corner, on the gas accumulation, but it depends, you know, what sort of gas emissions that you have in the goaf and other parameters as well.

Q. Is it possible to estimate the size, in diagram (c), of the oxygen zone, if I can call it that, which is below 12 per cent, in terms of distance?
A. Yes, from the modelling, yes, you can. Actually, these three diagrams illustrate some very important concepts. From the top one, from the red into the blue,

there is a band of orange colour, and that is the area that we call the critical zone, and that's where the spon com is likely to occur and the coal oxidation is likely to occur.

So the purpose, actually, is trying to narrow down this area, and therefore you minimise the oxidation process. By doing so, if you see figure (c), actually, that band, that orange sort of colour, light red, has been significantly narrowed. That also means that if you have coal left in the goaf, either from the roof or from the floor, then you have a very limited time to be exposed to sufficient oxygen for oxidation or potentially spontaneous combustion, and that's the whole purpose of an optimised goaf inertisation strategy.

Q. Diagram (c) reflects the modelled result of injection at 200 metres behind the face. Can I ask you first of all, are we speaking about injection on the maingate side or the tailgate side or both?
A. The model here is modelling a situation of injecting from the maingate side.

Q. And why is that?
A. This is because from the first diagram here, (a), we understand - if you see, and we can from the modelling and also from the field data - we know the majority of the oxygen ingress takes place on the maingate side, and also the critical oxidation zones are mostly aligned next to the maingate rib side. That's why we're doing this from the maingate side.

But if, for example, the longwall orientation has changed and you have different goaf gas regimes, for example, that oxygen penetration pattern may change, and you could have, perhaps, on the tailgate side, a deep oxygen ingress pattern, and in that regard you might have to, say, do injection on the tailgate side or on both sides.

Q. The next question, perhaps, is the method of delivery of the gas to the goaf. What is the point of delivery and the method of delivery?
A. I'm not an infrastructure engineer, but my observations normally are you have an oxygen-generating system on the surface, you have compressors, you have pipelines, and typically the main pipeline will be 6 inches and then you could pipe it all the way to the back or the

starting-off line by either a borehole or a drop hole somewhere and all the way to the gateroad, and then you can couple it with - my observation is I think it's 4 inch pipes, and these can be distributed to different cut-throughs. Obviously you're going to seal that, each of the cut-throughs, seals that would have pipes pre-installed for the purpose of inertisation.

Q. Pre-installation of pipes, I think you're referring to, on the maingate side?
A. I think for most of the mines, if they mine a pit that is spon com liable, when they're doing the goaf seals, they would pre-lay a pipe for goaf inertisation.

Q. With the gas to be delivered from the surface via a generator at that location?
A. That's true, yes. Most of the oxygen will be delivered from a nitrogen-generation plant located on the surface.

Q. You're telling us, I infer, that that kind of infrastructure is available to be applied in that way?
A. To my knowledge, yes. Most mines, if they're operating a pit that is mining coal that is liable to spon com, they would have such facilities on the surface.

Q. Is it correct to say that to some degree at least, mines that operate in the fashion I described earlier, where reasonably significant amounts of coal are left in the roof and the floor and then form part of the goaf - are they the kinds of mines that carry a spontaneous combustion hazard to be managed?
A. I would believe so, but it very much depends on the coal they're mining and the coal left behind, and if the coal left behind has a very high propensity to spon com, then that will be the case.

Q. In your answers to date I think you've spoken about the use of nitrogen for this purpose. Are there other options?
A. In Australia, basically the most popular one obviously is using nitrogen. We do in some mines use the Tomlinson boiler, and that delivers 80 per cent of nitrogen and perhaps 12 per cent of CO2. You could also use CO2, for example, but in Australia, in most cases, most of the mine sites would prefer to use nitrogen because the system is simple, it offers a continuity of inert gas supply, and

there's lots of operational experience there already.

Q. What about the fluid properties of nitrogen compared with other options, like perhaps carbon dioxide?
A. Well, if you say nitrogen, which is almost the same, you know, density because the majority is nitrogen, that means the flowability of nitrogen is almost the same as air. So that means that in a goaf space, nitrogen can flow to any places that it can.

But in comparison with CO2, carbon dioxide, because CO2 is a heavy gas, it tends to stay on the floor, and so the flow - in some of the cases, the CO2 will not be able to cover some of the areas, for example, that you want to cover. In particular, for example, if you have roof coal left or a band of carboniferous material or thick goaf left in the goaf, and if you inject CO2 from a higher elevation, it's probably very difficult for CO2 to cover these areas, and therefore you could have a spon com risk.

Q. As I read it, one of the points of emphasis from the 2005 report was that the success or failure of inertisation operations depends on mine-specific design. Did I read that correctly?
A. That's right.

Q. Is that because there's a range of variables associated with all mines, really, including ventilation layout, airflow intake, degree of gas flow emissions, and probably several other factors as well?
A. Yes. I think if we assume that a mine site has the inertisation system available - there are many factors, actually, affecting the design of the inertisation strategy. The first one obviously is ventilation. Are you using two gateroads or three gateroads? Is there a bleeder system or perimeter road? The location of the shaft - is it forcing ventilation or exhausting? All these impact on the goaf, the oxygen ingress into the goaf. And also the mining method - your cutting head, for example, you mentioned, you could be leaving coals, roof coals or floor coals.

The other factor is the gas composition. In this case, the diagram that we illustrated is methane. But if you're mining a seam that is CO2 dominant, the distribution pattern of the goaf gas may be different and may change, because CO2 is heavy and will tend to go to the lower location, and therefore at higher locations you would have more oxygen ingress. Obviously with other systems that you're running, gas drainage systems, in particular goaf drainage, you have different goaf hole locations, operating parameters - all these things will impact on the design of an effective inertisation system.

Q. It raises a question, perhaps, if there are quite a range of variables which are involved in the development of a strategy for an effective program of inertisation, who then would undertake the necessary analysis to devise the optimum strategy?
A. I think the optimum strategy would have to be specific and it has to be an integrated effort, I would say - people working on site, the ventilation officers, mining engineers, because they know the pit better. But also I think there are some really qualified people that could provide some advice in terms of the design of the system and how to better understand the goaf flow dynamics, what are the key factors that will be impacting on a particular pit. I would say it will be teamwork, but it mainly depend on who is operating the site.

Q. It may be difficult to generalise, but I was wondering if the necessary expertise is likely to exist on site or whether outside assistance is likely to be called for to advance a desirable strategy?
A. I think goaf inertisation practice has been used in Australia for quite many years, and there is plenty of knowledge and experience on site. Certainly to my understanding there's quite many people in the industry that have quite a lot of knowledge in terms of goaf inertisation, what sort of system is working or not.

But I think it is always useful to have a third person, for example, seek some additional advice from some specialists in this area. That would help them provide a design for sufficient, effective inertisation design or system.

Q. This report was published in 2005, and I think since then you and Dr Balusu have also published a conference paper in 2009 on a similar subject, or at least derived from the ACARP project?
A. Yes.

Q. Could you perhaps bring us up to date, then, since the

2005 project, since your conference presentation in 2009, as to the take-up of proactive inertisation in the industry?
A. I think since the last project we mentioned and this hearing, quite many of the outcomes from that project have been adopted or at least considered to a certain extent by people on site when they are designing their inertisation system. Obviously it has been quite some years and there are changes in the mining conditions. For example, I believe in Queensland there's lots of high-production mines, they are operating not only a spon com pit but also high gas emissions.

So in facing the challenge of spon com, you deal with spon com on one hand, and on the other hand you have to deal with very high gas emissions. So there are studies, field trials still going on, for example, at the University of Wollongong we continue to do some modelling studies trying to better understand other parameters in the equation, for example, high gas emissions or larger longwalls, what sort of inertisation strategies you could perhaps adopt on the basis of previous studies and things like that.

We also look at the impact of goaf gas compositions - for example, there are pits that are operating in CO2 dominant goaf gas, but the seam is also liable to spon com, and what we're going to do in that sort of situation. We are also adopting other techniques, for example, tracer gas studies, to help this process.

The work is still going. Obviously there are still unknowns. There's still a need for the advance of science and knowledge, and that will be needed for designing a more effective inertisation strategy, in particular for the current high-production longwall panels.

Q. Tell me, to your knowledge, are there any mines that adopt continuous inertisation of their longwalls as a routine practice?
A. Yes.

Q. Or is it more still in response to specific developing issues?
A. To my knowledge, there are mines that are using this goaf inertisation as an ongoing and continued control process. So it's not just on and off. It is a continuous

injection of inert gas into goaf areas.

Q. You've probably touched on this already, but I was going to ask you if you wouldn't mind perhaps commenting on the advantages of doing that?
A. The obvious advantage is prevention. I think we have a saying, "prevention is better than cure". By taking that strategy, in particular working with a spon com management plan, you have the opportunity to suppress or contain a potential heating risk. I think that's the practical purpose, because people onsite know that if you don't do that, there's high likelihood, you know, certain levels of coal oxidation or spon com could occur, and by taking that preventive strategy you could avoid a potential disastrous situation.

Q. Tell me, you've described a method of delivery of gas to the goaf, is there any interruption involved to production in the kind of method of delivery that you describe? In other words, does this process impact on production or not?
A. I'm not aware of any sort of significant interruption to the production process, because the delivery of inertisation is very much independent of your production system. You know, the gas is generated on the surface and in most cases the gas is delivered with pipelines and drop holes or boreholes from behind the longwall, and then it is piped to the goaf seals. So I would say practically it's very much independent of your production system, but there will be some link. You know, there will be certain interactions in certain areas, but I wouldn't say there would be significant interruption by doing so.

Q. Moving forward to the 2010 project, it apparently had the object of looking into the feasibility of foam applications in underground mines to improve the effectiveness of proactive inertisation. Do I understand that correctly?
A. Yes.

Q. Was that to do with assisting with control of particular issues, such as fires or heatings, or was its application to be considered more widely as part of the proactive inertisation strategy?
A. I think the purpose of that project is basically to develop a foaming technology that would facilitate the goaf inertisation process, in other words, it's to enhance the

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effect of inertisation rather than --

Q. How?
A. The purpose for that project is basically developing a foam technology that can be pumped at some distance, you know, through the seals, and to place a foam plug that will essentially increase the resistance of air leakage close to the tailgate side, and therefore you minimise the oxygen ingress and also perhaps the air leakage momentum. Therefore, if you do inertisation inbye the foam injection site, the inert gas will stay there for longer and therefore replace or minimise the oxygen ingress.

I don't think that the technology developed at that time is for the purpose of suppressing the heating or for other purpose. That's not the case.

Q. Was its potential utility, then, as you described, to assist by way of forming a plug at different points; was that the main objective?
A. That's correct, and we did a trial on site, and it demonstrated that it is possible to offer some kind of increased resistance to air leakage, but the problem is the stability of foams. In that particular site, I believe the air leakage from the maingate into the goaf is pretty strong, and the foam only lasted a few hours before basically the bubbles of the foam disappeared.

Q. What would be the strategic location of the kind of foam plug that you've spoken about? Where would it be deployed?
A. In that trial, the foams were injected from the first and second cut-through behind the longwall, and in that case we observed that because of the velocity of the leakage, it is having a significant impact on the stability of the foam. I think the lesson from that trial or that study is the location - if you do use foam in the future, the location is also very important. As I just mentioned, if you do gas inertisation, you would do deep injection rather than shallow, and I would suggest that the foam plug would be the one maybe just next outbye to the injection point of your inertisation, but not too close to the face, because the foam will just not stay there.

Q. You mentioned a question mark about the stability of the foam. Is the technology sufficiently advanced for it to be able to be used in the way that you just described in

your last answer?
A. I'm not aware of that. I do believe that there are some researches still going, I think it's driven by a company, but I do not have knowledge of its latest development.

Q. Could you tell us whether you have any knowledge, since this project was done in 2010, of the use of foams by mines as an adjunct to a gas inertisation program?
A. If we're talking about foams, it might be in a different sort of forum, put it that way. To my knowledge, there are mines that are using a foam plug, so basically it will be fly ash, nitrogen or water, and they can pump it in from a surface borehole to a particular location, therefore not only you produce some sort of plug but also the extent and the stability of the plug will be extended to a level that the conventional foams would not reach - I mean, the height, the shape of the plug.

I think, to my knowledge, there is an ongoing ACARP project supporting the further development of this technology, but I haven't seen the final report yet of this project. I believe it's still going.

Q. Can we turn to the overseas experience of proactive inertisation of active goafs. Can you give us some perspective on the nature and extent of its use overseas?
A. I think goaf inertisation using nitrogen has been reported, I would say, in the early 1950s. I think the first one using pure nitrogen would be in the Czech Republic.

I think since then, nitrogen has been used routinely for firefighting, to my knowledge. In the UK, for example, in some of the pits - I've been there many times. In the Domain colliery, for example, they have been using nitrogen for the prevention of spon com. And in other countries when they have this mine industry, like in Germany, certainly other countries, like Poland and Czech Republic, they have been using this technique for quite many years, and even today, and they are still using this. Countries like the US, South Africa, definitely in China, they are still using goaf inertisation based on either nitrogen or other means or materials.

Q. I was just looking to get some perspective, bearing in mind the delineation, perhaps, between its continuous use

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across a longwall as opposed to its strategic use to deal with heating incidents and fire incidents. Bearing that delineation in mind, would you like to comment further?
A. Yes, most early actions will be responsive. Basically, "Okay, we have a heating incidence", you know, "This is happening, we've got to do something", and that's how this nitrogen is deployed.

But more recently, to my knowledge, the inertisation has been used by several countries, including the Czech Republic and Poland, and they do use it as an ongoing and continuous inertisation strategy to control spon com and heating in their longwalls.

Q. I suppose we should be careful to draw comparisons with mining conditions in other places, but are there conditions in those other countries that make its continuous use more advantageous than in Australia; in other words, is a comparison apt?
A. I wouldn't say that. You know, mining conditions in other countries are different. For example, in Poland or the Czech Republic they are mining in greater depths, overburdens and gassy, lot more complicated geological conditions, and their ventilation system or longwall system is perhaps quite different from others. That can impact on the use, for example, of the inertisation system.

So there is experience and knowledge that we could perhaps learn from other countries, but Australia is very different in terms of the mining system that we're using, in particular ventilation systems that we're using, in comparison with other countries.

Q. You've set out in your report a range of methods that you're aware have been deployed overseas, including a mud slurry, foams of various kinds. Is it the case that nitrogen is still the option of general choice?
A. Yes. These means, as I mentioned, the slurries or gels, and sometimes they use these things in combination. I know these things are being used and applied in quite many mines in China. They use so-called three-phase foams. Basically they have fly ash, they have foam, they have nitrogen. They also combine with, like, other slurries and fly ash, even sometimes, like, clay, and in combination with inert gas.

The purpose for that is by using other means, in particular like the slurries or fly ash, they will be able to seal or minimise the oxygen risk - oxygen ingress to a particular heating site, and therefore by injecting inert gas, they would have a better impact on the potential heating.

Q. In your report, you've noted various of the spontaneous combustion indicators that are used by way of monitoring that particular hazard, and you've made mention that at least a couple of those would be affected by use of nitrogen for inertisation purposes, in particular I think Graham's ratio and Trickett's ratio?
A. Yes.

Q. Can I ask you about the effect of inertisation on those spontaneous combustion indicators. It has been said here that all of the various indicators that you've listed have some flaw or other and that they all have different flaws. Do you agree with that?
A. I would say so, yes.

Q. Arising from that, there is a proposition that given the flawed nature of the various indicators, more is better, as it were, and that it would be desirable, in the interests of spontaneous combustion monitoring, to retain the full suite of indicators rather than reduce their number as a consequence of this inertisation. Do you have a comment about that?
A. That is correct. I think throughout these hearings I believe the experts from Simtars have already provided much information on the different gas indicators and things like that. I don't think that I can add a lot more evidence in this regard, but what I can say is there are a number of well-documented, let's say, spon com ratios or indicators or whatever you call them, that we can use for monitoring and assessing the progress of heating.

The standard indicators for spon com, like CO, hydrogen or ethylene or different trigger levels at different mines, they should be still applicable. So obviously when you do the goaf inertisation, you will disturb the process, the nature of the forming of the goaf atmosphere. You introduce contaminations to some of the parameters that you mentioned, the GR and also the Trickett's ratio, because both GR and the Trickett's ratio need to calculate the oxygen deficiency, to detect oxygen in the oxidation, and this is actually the measure of oxygen consumption.

These ratios are based on two assumptions. The first one is that the supply of air has no contamination. That means the air supply should be 21 per cent of oxygen, 79 per cent of nitrogen. The second assumption is that no nitrogen has been consumed or added to the process.

So the drawback for these ratios is that accuracy will be doubtful if the oxygen that has been consumed is very small or the oxygen deficiency is less than 0.2 per cent. This is actually very common for any gas indicators that - if you need to use the oxygen deficiency.

Having said that, the GR is still the most widely used indicators for detecting heating events. In my opinion, these drawbacks can be overcome, for example, by establishing a normal range for a particular mine, and that will be the case, and according to the textbook, if normal is less than 0.5 per cent, then if there's any per cent deviations from this normal range, that could be an indicator of heating.

The other point that I want to make here is that it is critical that you have a comprehensive picture of your goaf environment, and this can only be achieved by taking samples, ideally continuous sampling, from multiple points. And if you're injecting inert gas from a particular cut-through, I wouldn't suggest you take a sample from that cut-through, because obviously the injected nitrogen could give you a false reading. But gas readings from your adjacent cut-throughs, say, 100 metres away or 50 metres away, should still give you a good indication of what's happening.

As I said and perhaps also as an expert already provided, the most important part is not to look at a particular value at a particular point; it's the trending. It's the trending of different gas ratios, different indicators that will give you the best estimate of what is happening.

Q. Just on the impact that the inertisation would have on the use of Graham's ratio and Trickett's ratio, the disturbance of those indicators by use of proactive inertisation - does that factor, in your view, outweigh the benefits of proactive inertisation?

A. I wouldn't say so. I mean, as I said, that GR is still a very powerful tool we can use. Obviously you wouldn't take a sample for the GR calculation or the other ratios that you will take the sample calculation from the point of the inertisation, but the adjacent sampling locations will give you perhaps a better indication of what's happening.

Q. You touched on the prospect of getting a false reading by doing gas monitoring at a point adjacent to the point of injection. One proposition is that the use of nitrogen injection for inertisation purposes might actually serve to mask a spontaneous combustion event. For example, if there was an injection of nitrogen at one particular point and there was nearby gas monitoring, it might give a false picture of the overall position across the goaf. Is there a method of dealing with that?
A. I wouldn't think so, but there's a potential error there, but this can be overcome, as I say, that you should be taking samples from various locations, I would suggest, you know, five or six sampling points behind the longwall, next to the injection point - some distance from the injection point, and that will give you a better picture of what's happening rather than just depending on a reading from an injection location.

But also, in addition to the GR ratios, the other gas indicators as I mentioned in the report, like CO, hydrogen, ethylene, all these things, all these gases, will still remain good if this event is happening. So the interpretation of the goaf readings must take into consideration not only the GR but also other gas ratios.

Q. Is it a matter of strategic location of the gas monitoring points?
A. Yes, that is very important.

Q. Another proposition has been put that a robust spontaneous combustion management system doesn't need proactive inertisation. Do you have any comment about that?
A. I would say a robust spon com management plan should include an active goaf inertisation system in place, because if you run a pit that is liable to spon com, you do all the monitoring, you do all the controls, you try to minimise the risk, but there's always the chance that you could be going through particular locations, you know,

slowing down your advance or retreat, you have roof failures and things like that, and that could cause potential risk, and that is the time that the active goaf inertisation should kick in, you know, to contain any potential heating events.

So I would say a robust spon com management plan should consider the use of, or at least perhaps an integral part of that system should include a proactive inertisation system. That's my view.

Q. There's one other topic I wanted to just broach with you. It concerns the interaction between inertisation and goaf drainage. I'm talking about post-drainage. What are the implications for the conduct of a post-drainage program of the use of proactive inertisation?
A. Are you talking about the gas inertisation of goaf drainage?

Q. Well, how would they interact with each other? Would there be an adverse or positive impact on the effectiveness of goaf drainage through the use of such a program?
A. I think the key issue lies in the compromise between the goaf drainage and the goaf inertisation. As I mentioned, the primary objective of goaf inertisation is to reduce oxygen ingress into the goaf by filling up whatever spaces or voids that would otherwise be occupied by oxygen or goaf gas, such as methane.

Goaf drainage I believe aims to capture seamgas or methane as much as is needed to reduce the gas emissions reporting to your longwall and to the tailgate, but must avoid sucking excessive air or oxygen into the goaf area and perhaps also the drainage pipelines, or consequently you run the risk of a spon com, of forming an explosive atmosphere.

Those issues can be addressed by better understanding the goaf gas flow dynamics and the knowledge of the goaf gas distribution patterns - what sort of goaf gas you're mining, is it methane or CO2, where is the gas coming from, what sort of rate; and by, as I mentioned, optimum design of the goaf hole locations and structures, so where the goaf holes are located; your elevations; you have a perforated section, how long would that be; and also how you operate the goaf holes in such a way that you could find a balance between the goaf inertisation and gas drainage.

But, having said that, in particular for very gassy mines, in some way the goaf inertisation could assist the methane drainage process or goaf drainage process by chasing out the oxygen and feeding perhaps part of the inert gas that you injected in to the drainage system, and so therefore it's a win:win situation - you contain the spon com and in the meantime you improve the capture efficiency. I believe that the research is still going, supported by ACARP. I'm looking forward to the outcome from this project as well.

Q. You may be aware that Dr Balusu has advanced a theory, subject to some further research, that the displacement of oxygen through the inertisation process might actually assist post-drainage. Is that the kind of concept that you've just been referring to?
A. That's correct, and I'm aware of Dr Rao Balusu's research and I do believe that, as I demonstrated, actually, in the slides, I think the first two slides showed the longwall goaf gas accumulation patterns, so basically we have - when you're injecting the inert gas, it will take over the space, whatever is going to be occupied either by oxygen or methane. So in that way, if we could increase the inert gas flow, it will be able to take much space that would otherwise be occupied by oxygen and also in a way that it would help maximising the goaf gas capture of goaf gas from the system.

Q. In your last answer, you referred to some slides. I think you may have been referring to the first couple of figures depicted in your 2005 report; am I right about that?
A. That's right, yes. That's the diagram, yes.

MR RICE: We haven't gone to those, because your explanations have perhaps been sufficient, but we can all go to that report and look at them if we need to. Those are my questions, Mr Martin.

THE CHAIRPERSON: Thank you. Mr Holt?

<EXAMINATION BY MR HOLT:

MR HOLT: Q. Dr Ren, can you hear and see me okay?
A. Yes, I can hear you, yes. I can see you as well.

Q. My name is Saul Holt. I'm one of the barristers for the Anglo group of companies, just so you know where my questions are coming from.
A. Yes.

Q. Thank you. I'd just like to go back to the 2005 ACARP report which you took us through earlier. You explained that that report involved numerical modelling and the outputs of numerical modelling?
A. Yes.

Q. In addition, and importantly, it also included calibrating that numerical modelling to field data from a number of coal mines?
A. Yes.

Q. And obviously enough being able to calibrate model results to actual field data is critically important for any model?
A. Absolutely.

Q. If we could pull up, please, Mr Operator - and I hope this works, Dr Ren, for you to see it also - the ACARP report, which is BOI.036.001.0001, and might we go, please, to .0017, Mr Operator. If we can just call out the third paragraph down, that commences "The authors ", we can see there an acknowledgment to the management and staff of collieries of Anglo Coal Australia and Xstrata?
A. Yes.

Q. And it was from those sources that much of the field data and the work that could be done in field studies was obtained?
A. Yes.

Q. Thank you. Could we come out of then, please, Mr Operator, and call up the paragraph just prior to that. As well as that access to field data, people from Anglo Coal Australia were also acknowledged for their valuable contributions, support and interest in proactive inertisation research?
A. That is true.

Q. You would be aware also, I imagine, and I'll come to it in a moment, of the ongoing collaborative work between Dr Balusu from CSIRO and Anglo Australia also on this

particular issue and the research and development of it?
A. I am not aware of that.

Q. I'll come to something which might assist with that in a moment. You were being asked some questions by our learned friend Mr Rice about, in particular, where the expertise lies in relation to inertisation, and you noted that inertisation has been going on for a while, and so there will be quite a degree of site-specific expertise?
A. That's correct.

Q. I imagine you would also expect, particularly for a coal miner such as Anglo, that they would have centralised expertise also to assist the individual, separate coal mines with these kinds of issues?
A. Well, I'm not sure of that. I don't think I can comment on that, but I'm pretty sure there's quite some people, and I know in Anglo Coal they have quite good knowledge and experience in this regard.

Q. And Dr Bharath Belle you would be familiar with, I imagine, who has done quite a lot of work with Dr Balusu also?
A. I know Dr Bharath Belle.

Q. On that question that Mr Rice was asking you about toward the end about the relationship between goaf gas drainage and inertisation strategies, you referred to the fact that this is an ongoing, important developing field of knowledge?
A. I do believe so, yes, yes.

Q. And you are working in that field and Dr Balusu is also working in that field?
A. Well, I know that I am doing something, some research in this field, but I can't speak for Dr Rao Balusu --

Q. But I think a moment ago you indicated in an answer to Mr Rice's questions that you were aware of some of his research in this area?
A. That's right, yes. That's right.

Q. And particularly are you aware of a 2018 piece of collaborative work between Anglo American and CSIRO called "Development of goaf gas drainage and inertisation strategies in 1.0 kilometre and 3.0 kilometre long panels"?
A. I have seen a paper and a report, I believe - I think

it's a paper published by Dr Rao Balusu and his colleagues.

Q. And also including - and you might have to accept this from me - Dr Bharath Belle from Anglo also in a collaborative project between those two organisations?
A. Yes, that's correct.

Q. Thank you very much. In that sense, you were being asked some questions about overseas experience with continuous proactive inertisation. Are you aware that continuous proactive inertisation has been practised at the Grosvenor coal mine through its longwall development right through from 101?
A. Say it again, please? I missed that question.

Q. I'm sorry. Are you aware that continuous proactive inertisation has been practised at the Grosvenor coal mine right through from its first longwall panel?
A. No, I am not aware of that. I'm not in contact with any people in that mine.

Q. No, I understand. Thank you. In any event, moving out from the specific to the general, part of the development of thinking around continuous proactive inertisation is around the use, for example, of multi-point injection strategies; that's right, isn't it?
A. Yes, ideally, I think injection from multiple points, at least two, is better than a single point.

Q. Indeed, in fact a sophisticated inertisation strategy would see, effectively, a nitrogen - if that was your chosen gas - pipeline with multiple injection points that can be ramped up or ramped down as circumstances require?
A. That's correct.

Q. In addition, another way in which those who are at the forefront of thinking about goaf inertisation are operating is moving from direct injection into the goaf into what are called balance chambers; you would be familiar with some of that advancing technology and work?
A. I wouldn't say I'm familiar with that. I'm aware of the application of that balance chamber.

Q. Can we then, just on a final topic, please go back to .0005 of that same document, Mr Operator, and the abstract. Might we call up the first paragraph, please. Dr Ren, when I put documents up like this, are you seeing them okay?

I obviously can't see your screen.
A. Yes, okay, pretty clear. That's good. No problem.

Q. If you need them in any other format or size, please just ask.
A. Sure, no problem.

Q. What's noted there in the abstract from the second sentence is:

> *Review of oxygen ingress patterns into longwall goaf at various mines has shown that in some cases the oxygen concentration in the goaf was well over 17% even at 300 m to 400 m behind the longwall face.*

A. Yes. That is correct. That is dependent on some of the sites. Obviously the review, the report, is based on some observations, some data from the longwall face, and the data tells us that even at 300, 400 metres behind the longwall, you could have a gas reading of oxygen that is greater than 17 per cent.

Q. And that was part of - not all of, but part of - the motivation for this increased research and development and deployment of goaf inertisation strategies in order to try to reduce those oxygen concentrations in the goaf for the purposes of managing spontaneous combustion and ignition risks?
A. Correct.

Q. I have the benefit of another paper that you've written. I just want to read something which I think should be pretty straightforward, but if it's an issue, please let me know. I'll just read what you've said:

> *The specific objective of inert gas injection operations is to reduce the goaf oxygen levels below the safe limit of 8 per cent (ie with a factor of safety of 1.5 on the explosive nose limit of 12 per cent) before methane concentration reaches the lower explosive limit of 5 per cent.*

I'll break that down, but in essence what's being said is that the specific objective of inert gas injection is to

reduce goaf oxygen levels below 8 per cent, which gives a factor of safety of 1.5 on the explosive nose limit of 12 per cent. Would you agree with that?
A. Yes, but that is for different purpose. The purpose of injection for this active longwall is to suppress the onset of spon com.

Q. Yes.
A. That data that you mentioned reference to is referring to the seal-off operation.

Q. Yes.
A. So when you finish off a longwall, you're going to seal that off, and that purpose for injecting inert gas is not for suppressing, say, the onset of spon com; rather than - it is the purpose to render an explosive atmosphere. That's why we say --

Q. I understand that. Thank you. Can you explain what the explosive nose limit of 12 per cent is in relation to oxygen?
A. Well, I think in the public hearing in the past few days - and I've been watching this - so the nose point is basically you have this Coward's triangle, and that's the point of 12 per cent oxygen, and above that you have a sample, you could be drifting - say, a sample between 5 to 14 or 15 per cent of methane, you could drift into the explosive atmosphere, and therefore you run the risk of an explosion.

Q. That's why, albeit in a different context, and I understand that, you describe 8 per cent as giving a 1.5 factor of safety --
A. A safety factor.

Q. -- to that 12 per cent?
A. That's right.

MR HOLT: I'm conscious of the time. I have only a few minutes.

THE CHAIRPERSON: Carry on.

MR HOLT: Thank you, Mr Martin.

Q. Could we pull up that figure that we were looking at before of the three longwalls, which is BOI.036.002.0001 at

0004. That's the specific page, Mr Operator. Could we call out the colourful diagram. I just want to be clear about a couple of things you were talking about, Dr Ren, if I can. The top figure we can see there is the base model, and of course there will be variations in individual longwalls --
A. Yes

Q. -- but that's designed to represent the situation in the absence of inertisation?
A. Correct.

Q. What we can see there is that classical sort of air-wash zone shape down towards the maingate where there's more oxygen in the sort of semi circle shape as it comes around to the left?
A. Yes. On the maingate side, the oxygen.

Q. I understand. The point that you were making is that part of the strategy here of inertisation is to reduce that orangey zone effectively where you're in that problematic range of oxygen concentrations?
A. For the purpose of suppressing oxidation and spon com, yes, correct.

Q. But the point is that on any of these renderings - that is, on the second or the third - we still see, of course, the high level of oxygen close to the face, and the idea is simply to limit the length or the width of the zone which is problematic to as small as it's possible to do so?
A. That is correct.

Q. And with the added benefit in the third rendering towards the bottom, where we see the 220 metres behind the face injection represented there by the green arrow --
A. Yes.

Q. -- the effect is also to drop the oxygen concentrations down well into the blue zone for the majority or almost all of that goafed area?
A. Yes.

MR HOLT: Thank you, Mr Martin.

THE CHAIRPERSON: Thank you. Mr Crawshaw?

MR CRAWSHAW: No questions, thanks, Mr Chair.

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THE CHAIRPERSON: Ms Grant?

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

THE CHAIRPERSON: Mr Trost?

MR TROST: No questions, Mr Martin.

THE CHAIRPERSON: Mr O'Brien?

MR O'BRIEN: No, thank you.

THE CHAIRPERSON: Ms Holliday, do you have questions?

MS HOLLIDAY: Yes, I do.

THE CHAIRPERSON: All right, we might take the morning break, then.

Professor, we're just going to have the morning break. We'll be about 15 minutes, if that's all right.

THE WITNESS: Yes, sure, no problem.

SHORT ADJOURNMENT

THE CHAIRPERSON: Yes, professor, are you there?

THE WITNESS: Yes, I'm here.

THE CHAIRPERSON: Good, thank you.

<EXAMINATION BY MS HOLLIDAY:

MS HOLLIDAY: Q. Dr Ren, my name is Deborah Holliday. I'm appearing for Resources Safety & Health Queensland. I just have a couple of questions for you. In an answer to Mr Rice earlier this morning, you indicated that you were aware that there were mines that are using proactive goaf inertisation as a continuing control process?
A. Yes.

Q. Can you assist with whether those mines are, firstly, in Australia?
A. Yes, some of the mines are in Australia, some overseas. When I say the mines in Australia, I believe

some of the mines are in New South Wales and in Queensland as well.

Q. In relation to those mines that are using proactive goaf inertisation continuously as a control process rather than as reactory, are they high production rate mines with high gas emissions?
A. Yes, some of the pits are. To my knowledge, some of the mines, the pits, for example, producing 5 million tonnes of coal are pretty gassy, yielding not only methane, in some cases CO2 as well.

Q. You indicated in response to another question by Mr Rice that there needed to be more research done in relation to how your theoretical approach to active goaf inertisation could be practically implemented, particularly in high production rate mines.
A. That's correct.

Q. So you still stand by that as a statement?
A. Yes.

Q. Indeed, that is because of the intricacies and nuances that exist when there are advancing longwalls in high production rate mines?
A. Because we are operating in a changing mining environment, and we're getting deeper, it's getting gassy, our longwall mines are getting perhaps bigger and highly productive, that actually presents a lot more challenges, for example, ventilation, dealing with gas, and of course spon com. That can, to some extent, change the goaf atmosphere or the goaf gas dynamics, and therefore we will need further studies to better understand exactly what is happening and so that we can do a better job in containing the potential heating or gas events.

Q. Would you agree that that further research should also include as to how traditional spon com indicators can be better understood with proactive inertisation?
A. I do believe so, and as was mentioned I think also by some of the experts in these public hearings, there are limitations for all the gas indicators, and it has always been an ongoing study in how, in particular, a set of gas indicators can be improved to improve their reliability.

In the case of inertisation, you introduce additional alien gas, such as nitrogen or CO2, and this actually disturbs the natural formation of the seamgas, and as I mentioned and also the other experts mentioned in this hearing, it could cause other issues with some of the gas indicators. So I do believe that further research is needed to study the impact of inertisation on these gas indicators or ratios.

Q. In response to one of the questions asked by the Board, you ran through in your brief response how ethylene, for example, could still be used. But there's the difficulty with ethylene, isn't there, that whilst it's a good indicator of an advanced heating, if it's present, it nonetheless means that it can't be used to detect a heating?
A. Well, if you detect ethylene, in most cases we would say the heating has developed to an advanced stage, and sometimes I would say some of the online monitoring systems will not be able to give you a timely response or reading, and we sometimes rely on bag samples.

It is an important parameter, but, as we said, we would not wait until you detected the occurrence of ethane or ethylene or other unsaturated hydrocarbon gases; we'd rather focus on other parameters, other indicators, and try to contain the heating before it advanced to that stage.

Q. Any mine that's currently using proactive goaf inertisation would have to make sure, wouldn't they, that their TARPs take into account the fact that they are using the inertisation?
A. Yes, they have to. They have to consider the impact of potential inertisation on all these TARP systems that they're using, and that's why they have TARPs for different locations, for example, the goaf stream or the returns, the intake, the goaf seals, the gas drainage plants and things like that. So there are considerations built in the TARP systems to address these issues.

Q. You expect that to be the case. You can't comment specifically on, for example, Grosvenor mine, as to whether they did or they didn't?
A. No, I have no idea. I would expect a mine operated by Anglo Coal, they would have done such a thing in their system, but I am not aware of the exact system, things like that.

MS HOLLIDAY: I have no other questions, thank you, Mr Martin.

THE CHAIRPERSON: Thank you. Mr Rice?

MR RICE: Nothing from me, Mr Martin.

THE CHAIRPERSON: Yes, Mr Clough?

MR CLOUGH: Good morning, Professor Ren. Andrew Clough here.
A. Good morning.

Q. I do have a couple of questions. The first question - I understand that your studies were primarily directed at controlling or preventing the development of spontaneous combustion. However, I wonder if you have any comment on the other effect, which is the impact on the total volume of explosive gas mixture sitting in the goaf, whether or not the proactive inertisation - one of the other potential benefits is it will actually reduce the size of the zones within the goaf that contain an explosive gas mixture?
A. I think that will be the add-on bonus for goaf inertisation. You are injecting inert gas into the atmosphere of the goaf, and that inert gas, if you're using nitrogen, is ready to diffuse and mix with the goaf gas or oxygen. In that manner, if you provide sufficient inert gas in that environment, then you will be able to render the goaf atmosphere out of the explosive range in addition to containing spon com.

Q. The second question is in relation to the importance of other measures to reduce oxygen ingress into the goaf. Correct me if I have this wrong, but I was left with the impression that unless you do other things to try to prevent oxygen getting into the goaf, then you may actually compromise the ability of the inert gas to reach its maximum effectiveness. In particular, I wanted to ask about the maingate corner of the longwall as a source of oxygen getting into the goaf and any comments you might have on the importance of managing that part of the longwall face?
A. If we talk about the injection rate of inert gas, nowadays lots of mines are perhaps pumping nitrogen at a rate of 500 litres per second or, you know, maximum 1500 litres per second, and that in comparison with your ventilation or your ventilation leakage into the goaf is pretty small. So in that regard, it is very important to

take whatever controls, in particular like ventilation controls, the seals, your mine layout, to minimise oxygen ingress into the goaf area.

Now, coming back to the maingate corner, if you see most of the longwalls, we run quite high ventilation to the face, so when the ventilation is entering the longwall through the maingate corners, it has very high momentum, so therefore a part of that ventilation will tend to penetrate into the goaf. If that happens, it will compromise to a great extent the inertisation effect. To minimise that sort of impact, we will need to minimise the oxygen ingress from that point by - for example, in most cases, we would have a goaf curtain. I have seen most of the mines will have these things in place.

Further to that, I would suggest it's not only just a curtain next to the first chock and second chock, maybe extending that a bit further along the longwall face, I would say maybe to the fourth or fifth longwall chocks, to maximise the impact of stopping oxygen or air ingress into that position.

This could be also combined with other techniques, for example, a plug you could drop in or put in through a cut-through just outbye of your injection point. All these things will come together, and that will help you to have the inertisation system work better and more effective.

Q. The next question is on similar lines, but it's in relation to goaf drainage. What I'm seeing is that the management of the goafs is an integrated approach. Do you have any comment on the importance of making sure that you extract as much gas as possible with pre-drainage versus relying on post-drainage and that impact on the effectiveness of inertisation?
A. Yes, if you're operating any mine or longwall panels that extract a seam that's pretty gassy, we are trying to pre-drain the gas from not only the seam that you're going to mine but also adjacent seams, for example, in the roof, in the floor, to reduce the gas content below the threshold - in most cases, we're talking about outburst. Then whatever is left in the seam will have to be dealt with by post-drainage.

So there is a balance there. For the post-drainage, you try to drain as much as you need; I wouldn't say as much as you "can", because you don't want to drain too much, and then you run the risk of introducing significant oxygen or air into the goaf and therefore you bring in another risk, your spon com and potentially an explosive atmosphere somewhere.

So, as you say, it's an integrated strategy. It's a compromise. The design has to make sure that the two systems work together and offer the best benefit of ensuring that you control the gas emission reporting to your ventilation systems but also with due consideration of oxygen ingress and therefore spon com risk.

Q. I have a final question. It's in two parts. The first question is, if you can ensure or you're quite confident that you have less than 5 per cent oxygen within your goaf, would this not be a better indicator to measure, rather than Graham's ratio, because Graham's ratio assumes you've got an oxygen flow through your goaf. So if you had the choice of not having oxygen in your goaf versus having oxygen in your goaf, is it really such an issue that you lose Graham's ratio in those two scenarios?
A. Well, I would never suggest that you're just looking only at a particular ratio, such as Graham's ratio. We always need to look at other gases together. For example, you mentioned oxygen. You know, an oxygen level of less than 5 per cent is something that we consider in the goaf, in terms of spon com, is a pretty safe level, because there were some tests done before that if you ran at an oxygen level of less than 7 per cent or even 5 per cent, then the coal will be pretty dead, there's very a low oxidation rate.

I wouldn't say the GR ratio is - that you don't need to look at that, but it's just another factor or another parameter into the equation. By looking at not only just the GR but also other gas indicators, certainly your oxygen level would give you a confidence, perhaps better idea or knowledge of what is happening in the goaf area.

Q. The second part of that question: based on your recommendations of injecting nitrogen on the maingate side of the goaf through the seals some couple of hundred metres behind the face, running concurrently with gas drainage with goaf wells, would not the goaf wells themselves be one of the best sampling points for actually determining the

oxygen content in your goaf? They're on the tailgate side of the goaf. You're injecting on the maingate. So if you were controlling your goaf wells so that you had less than 5 per cent oxygen, that would be a very good indicator that you've actually to a large extent controlled the majority of your goaf in terms of oxygen content. Is that a fair enough proposition?
A. I would say so, but certainly you've got to monitor what is coming out from your drainage holes and certainly the oxygen levels, and your oxygen level will definitely tell you what is happening and perhaps how effective that inertisation is.

But also bear in mind that the oxygen could be coming from your tailgate side as well, because your goaf hole could be located quite close to your tailgate side, and if it's just next to a seal, depending on the goaf gas compositions, there are possibilities that oxygen could be penetrating from the tailgate side or maybe through some seals close to the tailgate or from the adjacent - the goaf. That's all possible, but certainly monitoring oxygen levels in your drainage system would give you a very good indication of what is happening in that particular location of the goaf.

MR CLOUGH: That's very helpful. Thank you very much. I have no more questions.

THE CHAIRPERSON: Mr Rice, might Professor Ren be excused?

MR RICE: Yes.

THE CHAIRPERSON: Professor, thank you for your evidence today. You are excused.

<THE WITNESS WITHDREW

MR RICE: The next witness was scheduled for tomorrow, Mr Martin, which raises another subject.

THE CHAIRPERSON: Ladies and gentlemen, as no doubt you've heard, it seems that there will be a COVID lockdown certainly in this area from 5pm today, which will interfere with the hearings for tomorrow and Wednesday.

Consequently those witnesses will be rescheduled for next week, which will be hopefully Tuesday and Wednesday, but no doubt counsel assisting will be in touch further this afternoon.

In any event, parties will be notified by letter or email of rescheduling, and the public will be notified via the website of any rescheduling that has been arranged.

However, the Board is still very keen to receive written submissions as soon as possible. A list of issues to be addressed in submissions will be provided to the parties today. As I mentioned I think last week, these submissions will be required by 5pm on 9 April 2021. A somewhat extended period will be allowed in respect of topics which will be the subject of hearings next week, but hopefully they can be met.

Mr Holt, how are you travelling?

MR HOLT: Up until the COVID lockdown, we weren't going to seek an extension or anything of that kind, but what you have indicated in terms of some leeway potentially on topics where the evidence will address that, I suspect we will deal with any issues, and if we have any other concerns, we will raise them immediately.

THE CHAIRPERSON: Thank you. And Ms Holliday?

MS HOLLIDAY: Similarly.

THE CHAIRPERSON: Thank you for that. It's much appreciated.

Is there anything else at this stage?

MR RICE: No, Mr Martin, not at this stage.

THE CHAIRPERSON: So we adjourn until 10am next Tuesday. Thank you.

AT 12.12PM THE BOARD OF INQUIRY WAS ADJOURNED TO TUESDAY, 6 APRIL 2021 AT 10AM

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