

DAY 8

NOVEMBER 20, 1995

WESTRAY MINE

PUBLIC INQUIRY

HEARD BEFORE: The Honourable Justice K. Peter Richard,
Commissioner

PLACE: Stellarton, Nova Scotia

COUNSEL:

Solicitors for the Commission: Mr. J. Merrick, Q.C., Ms.
J. Campbell, and Ms. Ena MacDonald, document coordinator

Solicitor for the Department of Justice Canada: Ms. Lynn
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Solicitors for the Department of Justice Nova Scotia:

Messrs. R. Endres, Q.C., J. Traves, and Wm. Wilson, Q.C.

**Solicitors for the United Steelworkers of America and the
Nova Scotia Federation of Labour:** Mr. David Roberts

Solicitor for the Westray Families Group: Mr. B. Hebert

Representing the Town of Stellarton: Mr. Art Fitt and
Mr. John Murphy, Town Councillors

Representing the Canadian Union of Public Employees: Mr.
Robert Wells

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1 November 20, 1995 - 9:32 a.m.

2 COMMISSIONER Good morning.

3 ALL Good morning.

4 COMMENTS BY THE COMMISSIONER

5 COMMISSIONER Just before we start with the formal
6 proceedings, I beg your indulgence, Dr. McPherson, for
7 just a couple of minutes. You've heard a lot of evidence
8 over the last couple of days about the presence of
9 methane in coal mines and the presence of coal dust in
10 coal mines. It's very difficult to visualize the
11 different effects of these combinations or the
12 synergistic effect of the combinations of these
13 materials. So in order to illustrate that and to give
14 greater depth and greater understanding to the
15 discussions on coal dust, methane, et cetera, the CANMET
16 people in Sydney who operate the Cape Breton Coal
17 laboratory, have agreed to stage a demonstration here at
18 the Transportation Museum on Wednesday at 2:00 p.m. Now
19 that demonstration will graphically illustrate the
20 explosive potential of methane, the explosive potential
21 of methane and coal dust and the sort of, if I may use
22 the expression, the suffocating effect of the application
23 of rock dust to that combination of materials. It's a
24 very graphic demonstration. I hesitate to use the word
25 "frightened," but when I experienced it a couple of years

1 ago, I was frightened. But in any event, the CANMET
2 people are going to put that on for us at two o'clock on
3 Wednesday, and I think those present would find it not
4 only interesting, but quite graphic and quite
5 educational. So I just make you aware of the fact. It
6 takes between half an hour to an hour, so that will be at
7 two o'clock on Wednesday. Thank you. Mr. Merrick?

8 MR. MERRICK Thank you, Mr. Commissioner. The lead
9 witness this morning is Dr. Malcolm McPherson.

10 COMMISSIONER Good morning Doctor.

11 DR. MCPHERSON Good morning.

12 **DR. MALCOLM JOHN MCPHERSON**, sworn, testified as follows:

13 THE CLERK Would you please state and spell your name for
14 the record.

15 A. My name is Malcolm John McPherson. M-A-L-C-O-L-M.
16 John, J-O-H-N. McPherson, M-C-P-H-E-R-S-O-N.

17 EXAMINATION BY MR. MERRICK

18 MR. MERRICK Dr. McPherson, what is your occupation?

19 A. I'm a Professor of Mining Engineer at the Virginia
20 Polytechnic Institute and State University in Virginia,
21 United States.

22 Q. And what particular area is your specialty?

23 A. Mine ventilation.

24 Q. I see in your report which is marked Exhibit 56 and
25 your resume which is in the first tab, that you

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1 acknowledge the fact that you were retained as a
2 consultant by this Inquiry. Your report indicates that
3 you were retained by a Roy MacLean of Devco. I just
4 wanted to make it absolutely clear, he retained you
5 acting as an agent acting for the Westray Public Inquiry
6 and you were retained on behalf of the Inquiry, is that
7 right?

8 A. That is correct.

9 Q. All right. Let me take you through your background
10 if I can for a minutes. I note from your resume that you
11 received your B.Sc. in 1962 in Mining Engineering. Prior
12 to that had you had experience in the mines?

13 A. Yes, sir. I joined the mining industry in the
14 United Kingdom in 1953.

15 Q. How old were you at that time?

16 A. I was 16.

17 Q. And what did you do and for how many years before
18 you went to university?

19 A. For several months I worked as an accounts clerk in
20 the local National Coal Board area headquarters.

21 Following that, I commenced work underground. This was
22 in the Derbyshire coalfield of England. I worked there
23 for, again, several months. The family moved down into
24 Leicestershire, and I spent the following four years
25 working underground in the Leicestershire coal mines.

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1 Q. What kinds of things did you do underground?

2 A. During that period I undertook and was occupied in
3 virtually all of the conventional occupations
4 underground; that is, including work on the coal face,
5 longwall faces, development headings in coal and in rock
6 and in many ancillary duties. For example, concerned
7 with enlarging roadways that had become crushed,
8 installing pumps in districts that had become flooded, a
9 complete range of duties.

10 Q. And I take it that following that you decided you
11 would go to university?

12 A. Well, one more thing I might add to your previous
13 question, Mr. Merrick, is that during that four years or
14 so in Leicestershire, I also became a member of the Mines
15 Rescue Organization and worked part-time as a mines
16 rescue brigadesman as part of a colliery team, colliery
17 rescue team. I undertook my training at the Ashby Rescue
18 Centre in Leicestershire and was involved in rescue
19 operations during that period.

20 Q. What types of rescue operations were you involved
21 in?

22 A. The Leicester --

23 Q. An example, if you would.

24 Q. The Leicestershire coalfield is not a gassy
25 coalfield, but it does have a lot of problem with

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1 spontaneous combustion. You ask for an example. The
2 last time I was personally involved in mine rescue work
3 which involved wearing breathing apparatus was during my
4 first year at university. At that time one remained
5 certified for a period of not more than 12 months after
6 your last formal refresher training. So I was able to
7 continue my rescue work during my first year at
8 university. And during that time I was involved in a
9 substantial recovery operation at Bagworth Colliery in
10 Leicestershire. This was a spontaneous heating in an
11 area of the mine which was quite extensive and involved
12 sealing off that area of the mine in a number of
13 locations. That was the last time that I was involved
14 personally in rescue operations.

15 Q. I take it that the sealing off operation would be
16 somewhat tricky in that if you didn't seal off all areas
17 at the same time, what might have happened?

18 A. This is indeed quite a skilled operation. When an
19 area of a mine has become involved in a fire, then the
20 ventilation, obviously, is disrupted. Gasses build up,
21 particularly the explosive methane gas. And if the
22 methane is allowed to progress into the explosive range
23 which is five to 15 per cent by volume, mixed with air,
24 in the presence of a fire, then there is obviously a high
25 risk of an explosion. In order to prevent that, when

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1 seals are put on, it is important that the final seals be
2 put on simultaneously. If that is not accomplished, then
3 we have the danger of the mixture within the area which
4 is being sealed entering that explosive region before the
5 seals are completed. If an explosion occurred in those
6 circumstances, then clearly that explosion could
7 propagate into the active parts of the mines.

8 Q. Now just one other thing before I leave your
9 experience in the mines pre-university. At that time
10 when you entered the mines, what sort of training
11 requirements were there before you became a certified
12 miner, if I can use that terminology?

13 A. The training comes in in two segments: before one is
14 allowed, was allowed at that time, to operate underground
15 at all, one had to undergo a 16-week training period at a
16 training centre. I undertook that as a pre-requisite to
17 working underground.

18 Secondly, to involve oneself in individual
19 operations such as work on the coal face, one has to
20 undergo additional training for that specific occupation.

21 Q. Would that be on-the-site training?

22 A. That would be on-the-job training, yes.

23 Q. But your initial 16 to 18 weeks was a formal
24 training program?

25 A. Yes, sir.

DR. MCPHERSON, EXAM. BY MR. MERRICK

1 Q. That wasn't just on the job with your fellow
2 employees or supervisors showing you what to do?

3 A. That was a formal, structured training in the
4 accompaniment of other trainees.

5 COMMISSIONER Dr. McPherson, would that be exclusively
6 in underground coal mining training or just underground
7 mining generally?

8 A. That was underground coal mining training. This was
9 a requirement of the National Coal Board.

10 COMMISSIONER Okay. Thank you.

11 MR. MERRICK Now that brings us to your university
12 training. You took your B.Sc. and you then took a Ph.D.
13 in Mine Ventilation in 1965.

14 A. Yes.

15 Q. Can you tell me, as part of that, what work you
16 became involved in in computer-assisted ventilation
17 design?

18 A. My Ph.D. research was concerned with a theoretical
19 and practical, that is, experimental, investigation of
20 the thermodynamic processes that are undergone when large
21 mine fans are dealing with a mixture of air, water
22 vapour, and liquid droplets. This is of particular
23 concern in deep mines which are usually hot and humid.
24 When the air ascends to the surface from those deep, hot,
25 and humid workings, water vapour will condense, just like

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1 it does in the clouds above our heads, so that the air
2 going through main exhausting fans is this mixture of
3 air, water vapour, and liquid droplets. Testing of mine
4 fans under those circumstances is very difficult. It's
5 difficult, for example, to measure the air flow. Think
6 of a heavy thunderstorm. Trying to measure the velocity
7 of the air when you have large liquid droplets present at
8 the same time.

9 We were able to develop a method that allowed mine
10 fans dealing with that situation to be tested in situ.
11 This was particularly applicable to South Africa at that
12 time where the deepest and hottest mines of the world
13 occurred and do occur.

14 That involved a tremendous amount of numerical
15 calculations. At that time, digital computers were just
16 beginning to be utilized in engineering and scientific
17 work, and I was able to use those then new devices to
18 assist in that work.

19 The use of computers and my developing knowledge of
20 computer programming then allowed me to go on and apply
21 that knowledge to other fields of mine ventilation.
22 During my last year of my Ph.D. studies, much of my time
23 was taken, not by working on my Ph.D. work, but by
24 travelling around the coalfields of England, Scotland,
25 and Wales demonstrating the use of digital computers for

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1 ventilation planning purposes, what is now referred to as
2 "ventilation network analysis." That work resulted in
3 the development of programs, the modern versions of which
4 are now used throughout the whole world of mining.

5 Q. So that the computer modelling for network analysis
6 that's used today in the mining industry basically arose
7 out of the work that you were conducting during your
8 Ph.D. days?

9 A. To be absolutely accurate on this, Mr. Merrick.
10 There were three, at that time, young men, working along
11 parallel lines in different parts of the world. One in
12 Germany, one in the United States, and myself in
13 Nottingham. We didn't know until several years later
14 that we were working along same -- similar lines. But
15 that was the work that certainly resulted in the United
16 Kingdom and the Commonwealth countries of the United
17 Kingdom utilizing and further developing this method.

18 Q. All right. Following your Ph.D., and I assume based
19 on your exposure to industry through this technique that
20 you had been developing, your subsequent years were
21 involved both with industry and teaching?

22 A. And research.

23 Q. Yes. All basically in the field of mine
24 ventilation?

25 A. Yes.

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1 Q. And in what areas of the world would you have been
2 called upon to use your expertise?

3 A. My initial travels were to the United States. The
4 countries of Europe, east and west Europe, and then
5 extensively in South Africa. I spent a considerable
6 amount of time in South Africa in the 1970s, Australia,
7 India, Canada, and then subsequently South America.

8 Q. Have you in fact be called on here in Nova Scotia
9 previously?

10 A. Yes, sir.

11 Q. When and where was that?

12 A. This was also during the 1970s when I was asked to
13 undertake ventilation and design work for Devco.

14 Q. And you did that and completed it?

15 A. Yes.

16 Q. I see from your resume that you moved to the States
17 and took up a position with the University of California?

18 A. At Berkeley. Yes.

19 Q. Yes. At the same time, you were continuing your
20 work with the industry itself?

21 A. Yes.

22 Q. That's when you established your own consulting
23 company?

24 A. In 1982, yes.

25 Q. Yes. And you've continued to do both?

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1 A. Yes.

2 Q. The research project that you have listed, and
3 you've referred to a number of them, it would appear to
4 me that your main focus on those has been on methane
5 research, ventilation relating to methane, and gasses in
6 coal mines. Is that correct?

7 A. That was one of them. The fields of, what is
8 broadly referred to as "mine ventilation" are quite
9 numerous. Methane gas, the problems of methane gas,
10 dusts, including but not limited to coal dust, heat, and
11 humidity. These are all associated with hazards in the
12 underground environment. Ventilation, that is the study
13 of the processes of air movement in the subsurface, is
14 the primary, but not the only means of dealing with those
15 hazards. I've been involved in all of these problems and
16 solutions to those problems.

17 Q. Your consultancy work, and I won't take you through
18 all of it, but you have a fair list -- quite a list of
19 industrial consultancies. I take it that in the course
20 of those various assignments you've actually been
21 involved in doing planning for mines and mines of various
22 degrees of complexity or problems with gas?

23 A. Yes, sir.

24 Q. Any particular ones that you would highlight for us,
25 particularly in relation to your work for the Inquiry

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1 here?

2 A. We have done ventilation design and planning work
3 for virtually all forms of mining with respect to the
4 situation here, planning and design work for coal mines.
5 Much of my early work in the '60s and early '70s with the
6 National Coal Board was all concerned with coal mining.
7 So my earliest work as a consultant was dominantly in
8 that field of coal mining in gassy mines. More recently,
9 work that we have done for gassy coal mines in Alabama,
10 work that we have done for coal mines throughout the
11 Appalachian coalfield, in Colorado. We are -- when I say
12 "we" I'm referring to Mine Ventilation Services, the
13 company that you referred to, Mr. Merrick, are called
14 upon to undertake exactly that kind of work. That is the
15 major type of work that we're involved in -- ventilation,
16 planning, and design.

17 Q. You have also, I take it, in your assignments, been
18 asked to come in and review other plans that have already
19 been prepared or to deal with problems that have resulted
20 from existing mine layouts and ventilation systems?

21 A. Yes.

22 Q. All right. Let me come to the question of gas, and
23 particularly methane, in a mine. We've heard some
24 evidence that methane is an inevitable feature of coal
25 mining. Briefly, tell me about how gas is made in a mine

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1 and gas make. That, I assume, is your first and primary
2 criteria in deciding how to plan for ventilation in a
3 mine?

4 A. One of the first requirements, indeed, as you
5 suggest, is to look at the pollutants of major concern in
6 that mine which one is examining. In coal mines and in
7 some metal mines, methane gas is a hazard that has to be
8 contended with. It's not the only one, but it is a major
9 one in coal mining. So a knowledge of the mechanism of
10 release of that methane from the strata into the actual
11 or proposed mine workings is knowledge that one should
12 acquire. You ask about that mechanism -- how does gas --

13 Q. Yes.

14 A. -- get into the ventilation airstream. Methane gas
15 is held within carbonaceous strata in two forms. The gas
16 is held within the pore structure of the coal. These
17 pores are exceedingly small. They cannot be seen with
18 the naked eye, and they cannot normally be seen with an
19 optical microscope; one has to use an electron microscope
20 to see these pores, they are so small. Gas is held
21 within those pores in the two forms I mentioned.

22 One form is the so-called "free gas" and this is the
23 methane molecules, the molecules of the gas, behaving as
24 a gas normally does and that is moving about within those
25 pores. It cannot move very far because of the small size

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1 of the pores, but nevertheless moving much as the -- in
2 exactly the same way as the molecules of the oxygen and
3 nitrogen around us in this room are moving.

4 Most of the gas, however, is retained in the second
5 form and that is as an adsorbed, A-D-sorbed, layer of
6 molecules coating the inside of these small cells or
7 pores.

8 It is analogous to condensation on the window on a
9 cold day. Condensa -- a film of condensation, water
10 vapour condensing to liquid water on the cold window
11 surface. It is not the same physical mechanism, but it's
12 analogous to that. So one can imagine the molecules of
13 methane now getting much, much closer together than they
14 normally do when they're moving about in the space and
15 compacted onto those internal surfaces.

16 Now the majority of the gas that's held in coal is
17 in that adsorbed form. That is the way that gas is held
18 within the coal.

19 Now with respect to the mechanism of release. One
20 has to have two features available for that gas to start
21 to move towards the mine workings from its geological
22 environment.

23 First of all, there have to be fractures through
24 which the gas can migrate. This is measured as
25 permeability, is the normal technical term. As the

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1 permeability increases, that is, the number of flow paths
2 open up, then that allows the gas to move out of the
3 pores into these micro and then macro, larger fractures,
4 towards the mine workings. That gas which migrates will
5 initially be the free gas I referred to, the molecules
6 which are free to move about. As soon as that occurs,
7 then the gas pressure inside those pores clearly will
8 fall, because it's -- gas is being lost from them, and as
9 the pressure falls the adsorbed gas begins to dissolve;
10 that is, the molecules which have been quote, unquote
11 "condensed" on those internal surfaces will become free
12 just like the liquid film of water evaporating again,
13 come back into this space and contribute towards that
14 migration of gaseous methane, free methane, towards the
15 workings.

16 So we have two things so far. We have the gas
17 content of the coal held in those two forms, free and
18 adsorbed gas.

19 Secondly, we have the permeability of the coal, the
20 fracture paths that allow the gas to move through towards
21 the mine workings.

22 There is a third one and that is that if that gas
23 migration is going to occur then, clearly, there has to
24 be a pressure gradient, a gas pressure gradient. The gas
25 pressure in the coal has to be greater than the

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1 atmospheric pressure in the mine workings. There has to
2 be that driving force in order for the migration to take
3 place, and that gas pressure gradient is normally in
4 existence; that is, the gas pressure in the coal is
5 invariably, I would say, higher than the atmospheric
6 pressure in the workings.

7 Q. And does that pressure differential have to exist
8 for both the free gas that's in the tiny, I forget what
9 you call them, the pores --

10 A. Pores, yes.

11 Q. -- as well as the adsorbed gas?

12 A. The gas migration, Mr. Merrick, will be the free gas
13 only. Let me recap on what I said. The gas molecules,
14 before they are able to move, have to leave the adsorbed
15 state and come into the free gas state before they move.
16 But it is the free gas that is moving that is being
17 reinforced, added to all the time, because of the
18 decreasing pressure within pore structure which allows
19 desorption to take place.

20 Q. I would assume that in a case where mining
21 operations are going on or perhaps geological changes are
22 happening so there are -- there's movement in the strata,
23 that the initial release of gas, this would be the free
24 gas, would be relatively quick depending on, I guess, the
25 amount of movement or fracturing of the strata. But I

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1 assume that the release of the adsorbed gas, the
2 molecular, that the gas that is coating, if you will, the
3 coal cells would be at a slower rate, is that right?

4 Q. If one takes any sample of coal, freshly exposed,
5 freshly taken from a borehole or from an underground
6 location and measures the rate at which gas is released
7 from that piece of coal, then it will decay with time.
8 Expedientially. That is because the sample of coal is
9 being degassed. It's losing its gas, therefore, there is
10 less there to come out afterwards. And, secondly,
11 because the gas pressure within those pores that we have
12 referred to is clearly decreasing with time. So there is
13 a decay process, yes.

14 Q. I take it as well then that the amount of gas being
15 released, particularly in the context of a working mine,
16 will be influenced by barometric pressure. As pressure
17 drops, there would be an increased desorption of that
18 gas?

19 A. The gas pressure in the coal is normally
20 considerably higher than the atmospheric pressure in the
21 workings, typically, 10 times higher. There's large
22 variations, but I'm using a typical mid-range value.
23 With that degree of pressure gradient, 10 atmospheres in
24 the coal, one atmosphere pressure in the workings, then
25 small variations in the barometric pressure will have

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1 very little effect on the rate of desorption and
2 migration of gas through the coal, number one.

3 There is another feature which is more potent and
4 that is that if we have, as we do in all mines, areas of
5 voidage; that is, areas which are not ventilated, such as
6 abandoned workings, such as the separation that takes
7 place between strata in mined out areas, such as the
8 large fractures on coal ribs or in pillars, areas which
9 are open, available, connected to the ventilated part of
10 the mine, but those areas themselves not being
11 ventilated, then gas will build up in a gassy mine. This
12 is -- gas will build up in those areas of voidage, in
13 those old workings, in those bed separation cavities, in
14 those large fractures.

15 Now if you are old enough to remember the old
16 gasometers, those big areas, potentially large volumes of
17 voidage gas, act like gasometers. Those areas contain
18 that gas at pressures which are very close to the
19 atmospheric pressure in the ventilated areas of the mine.

20 Now, in those circumstances, quite small variations
21 in barometric pressure will have an effect on the
22 expansion or contraction of those gases in that big
23 gasometer that you referred to. It is in those terms.

24 So, for example, if the atmospheric pressure on the
25 surface and all the way through the ventilated workings

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1 of the mine reduces so the pressure exerted on those
2 voidage gases also reduces, then just like letting the
3 air out of your automobile tire, those voidage gases will
4 expand and flood into the working areas of the mine.

5 Q. I take it that, and we will hear evidence and have
6 heard evidence, that checking the barometric pressure is
7 a very important or critical thing to do in coal mining
8 and it's for that reason then, I take it?

9 A. Exactly.

10 Q. Because the changes that we experience on a daily
11 basis in barometric pressure can have that kind of an
12 effect if you have an area in your mine where you have
13 these voids where gas has built up.

14 A. Yes, sir.

15 Q. And I assume that you're actually able to calculate
16 the amount of gas that may be drawn out of an old worked
17 out area by giving barometric pressure drops?

18 A. Yes.

19 Q. And this would be applicable in a situation where,
20 for example, in Westray, we had an old worked out area
21 known as the Southwest District One where gas would have
22 been filling that void.

23 A. Yes.

24 Q. All right, and we'll come back to that in a little
25 more detail in a few minutes. I assume that, coming back

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1 to the general question as to how much gas is a coal mine
2 likely to make as you're planning it, in addition to
3 looking at the gas content of the coal, you would have to
4 then look at the permeability of the coal seam that
5 you're working in, is that fair?

6 A. Yes.

7 Q. And I would assume that permeability could be
8 determined or you'd have a rough idea by looking at
9 whether you were in disturbed ground, if it's an area
10 where there are a lot of known faults. For example, that
11 would add to the permeability?

12 A. That is the usual circumstance. In areas of
13 geological disturbance, it is quite often the case that
14 the permeability of the ground does increase.

15 Q. All right.

16 COMMISSIONER Mr. Merrick, just to get this clear, if I
17 add a little bit, Doctor. I read in one article where
18 they referred to a deposit of coal as like a rigid sponge
19 which contains the methane. Also they referred to pools
20 or rivers of methane. How do I equate pools and rivers
21 to this sort of adsorption and so on that you've been
22 discussing?

23 A. Think of the cells within the sponge as being the
24 pores that I referred to, with the difference that the
25 pores in the coal are very much, very, very much smaller

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1 than the pores in the sponge that you could see with your
2 naked eye. The rivers of methane that you referred to,
3 these are the fracture paths that exist within the coal.
4 I had referred to them as micro and macro fractures. The
5 micro fractures may well have existed before mining takes
6 place, micro fractures that exist in the natural state
7 that are being produced through geological processes over
8 hundreds of millions of years.

9 COMMISSIONER Through time or whatever.

10 A. Yes. The large fracture patterns, and these are
11 probably the ones you're referring to as the rivers, are
12 those fracture paths that have been opened up or induced
13 by the mining processes themselves. As mining takes
14 place, stressing of the ground around the workings
15 occurs. Very close to the interface between the solid
16 coal and the airways, that stress drops to near zero.
17 De-stressing takes place and that results in the
18 production of fractures, addition of fractures and
19 opening up of those fractures into the larger rivers of
20 methane.

21 COMMISSIONER Okay, thank you very much.

22 MR. MERRICK But your answer, Doctor, I take it then
23 that when we look at a roadway that's being cut for a
24 coal mine, that in the vicinity of the cut itself, the
25 roof, the sides, the floor, if it's all in the seam, that

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1 the coal surface near those cuts may well be disturbed,
2 if I can use that word.

3 A. Yes.

4 Q. For some depth. So you don't just look at the cut
5 and say that's a clean cut there and everything from that
6 cut in is still solid and the gas is still entrapped in
7 there. There's considerable depth into the coal where
8 there are now very minute fractures that have been caused
9 by the cutting action going through. Is that fair?

10 A. That is correct, yes.

11 Q. For what depth in the coal would that de-stressing
12 and thus fracturing, which we may not be able to see, but
13 for what depth would it actually occur? Are you able to
14 tell us?

15 A. This is not a question one can put a numerical
16 answer to because it depends on a number of variables.
17 First of all, it depends upon the inherent strength of
18 that strata, what is referred to as the compressive
19 strength of the material. And, secondly, it depends upon
20 the mining layout. If the edges, the sides of these ribs
21 that you're referring to have been heavily stressed
22 because of the mining that has taken place, then that
23 heavier stressing will have produced a greater degree of
24 fracturing than would be the case if they were more
25 likely stressed. So it does depend on the layout, the

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1 amount of material that's been removed and the actual
2 strength of the coal.

3 Q. The key point being is that it isn't just the actual
4 cut surface that is releasing this gas at a higher rate
5 now; it's for some depth into that surface.

6 A. Yes.

7 Q. All right. I take it from your evidence that the
8 gas that's entrapped; adsorbed into the coal, that can be
9 measured. If we were to take a block of coal and put it
10 on from wherever we cut it, we can take a measurement as
11 to the amount of gas that's actually entrapped in that
12 coal, is that right?

13 A. Yes, sir.

14 Q. That gives us the first bench mark or the first
15 indicator as to the kind of gas that will be released
16 with mining processes in that seam of coal?

17 A. Yes.

18 Q. And that is a requirement if we are to sit down and
19 decide how much air we've got to flow through that mine
20 in order to accommodate that methane?

21 A. That is correct.

22 Q. Now let me take you through the records as we
23 understand them to date on tests that were done of the
24 coal seam that the Westray Mine was actually mining and
25 as to the gas content. This is the basic figure that

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1 we're looking for this morning. Are you aware of a test
2 done by Algas Resources back in the early 1980s?

3 A. Yes.

4 Q. Can I refer you to Exhibit 47, which has not been
5 copied because it's one of the bulk documents, but tell
6 us what the numbers were that Algas Resources determined
7 was the gas content. I'm told it's the second document
8 in your pile, the yellow binder.

9 A. Did you say "47" or "7"?

10 MS. MACDONALD 47.

11 MR. MERRICK 47, with the yellow binder.

12 A. Okay.

13 Q. And I'm told that at pages 49 to 51, their results
14 are there.

15 A. Uh-huh.

16 Q. And these documents are available for review. When
17 was that test done?

18 A. The report is dated March, 1981.

19 Q. Can you tell me what they determined was the gas
20 content of this gas -- this coal?

21 A. They refer to a range of six milligrams per gram.
22 Other reports refer to cubic meters per tonne.
23 Numerically, these are the same. So if we use the units
24 of cubic meters per tonne, they report a range of six
25 cubic meters per tonne down to zero.

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1 Q. So that if we were to take a tonne of coal and
2 extracted all the gas from it that we could, we would get
3 approximately six cubic meters of gas. Is that right?

4 A. Yes, sir.

5 Q. That's at the high end of their reading.

6 A. Yes, the range was zero to six.

7 Q. All right, did that report make other comments that
8 were of significance to what you might anticipate for
9 planning purposes if you were to mine that seam?

10 A. The report does make the comments that the coals in
11 this area, I'm quoting, "Appear to be quite permeable
12 relative to western Canadian coals."

13 Q. And that's at page?

14 A. Page 51.

15 Q. So that has to be taken into account as well in
16 planning a ventilation system in a mine.

17 A. Yes.

18 Q. All right. Can you take me to the next test that we
19 are aware of and this is tests by the Jacques Whitford
20 consulting firm, which is Exhibit 73, tab 1? We've had a
21 technical problem on the weekend in that our
22 photocopiers, I guess, decided to pack it in and take a
23 day off. That exhibit will be reproduced for other
24 parties as soon as we can get them up and running again.
25 You have Exhibit 73 in front of you?

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1 A. Yes, I do.

2 Q. And what is it? It's a report from whom and dated
3 when?

4 A. This is a report by Jacques Whitford & Associates
5 Limited of Halifax. It's dated August 10th, 1984.

6 Q. What does it report on?

7 A. Again, converting the units to cubic meters per
8 tonne, they give a range of three to nine cubic meters
9 per tonne of methane.

10 Q. That's quite a range.

11 A. It is, indeed.

12 Q. Do they explain the range or give any back-up detail
13 on it?

14 A. I could comment on that myself. It is quite common,
15 indeed it's usual, for tests done on coal samples for any
16 purpose to give a large range of results. The reason for
17 this is that coal is not a homogenous substance, even
18 within the same seam. There will be stratification of
19 different types of coal. Even zones where there's very
20 little coal, ash bands, dirt bands. And, because of
21 this, one does find large variations in results of
22 permeability, gas content, strengths, whatever of coal
23 samples.

24 Q. All right.

25 A. So this is not unusual.

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1 Q. Do you also have a Suncor 1984 test that's attached
2 to the back of a Jacques Whitford Report that would form
3 part of that same exhibit?

4 A. Yes.

5 Q. What and when was that test done?

6 A. I'm looking at a Suncor inter-office correspondence
7 memo headed "Preliminary Results of Methane Gas Content
8 Testing" dated September 11th, 1984.

9 Q. Yes, and what were the findings?

10 A. Again, let me quote, Mr. Merrick: "To date in our
11 program the highest methane content we have encountered
12 is approximately 5.7 milligrams per gram." Again, one
13 could read that as cubic meters per tonne. "The majority
14 of samples range from 2.5 to 4.5 cubic meters per tonne."

15 Q. All right, any other comments in there that would be
16 relevant?

17 A. They also refer to the Algas Resources Report of,
18 they quote, 1980.

19 Q. All right, do you have a later Suncor test as well?
20 I'm thinking of the test that Suncor apparently did in
21 1986 which is in Exhibit 7? That's part of the Kilborn
22 feasibility study. Sorry, it's in Exhibit 7, they did
23 their own geology, at page 84.

24 A. Yes, I have that.

25 Q. When was that done?

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1 A. This report by Suncor headed "Pictou County Coal
2 Project Feasibility Study, Volume One." July '86 is the
3 date.

4 Q. All right, and what were the results?

5 A. Again, let me quote directly. "The gas content of
6 samples measured ranged between zero and 6.2 cubic meters
7 per tonne. However, only six percent of samples analyzed
8 exhibited dissolved gas contents exceeding five cubic
9 meters per tonne. The average value for dissolved gas
10 was 2.4 cubic meters per tonne."

11 Q. And do they consider that those results compare
12 favourably with the first Algas test results?

13 A. They do, indeed.

14 Q. All right, I'll take you to the Norwest Study that
15 was then done, and this is in Exhibit 8 at page 13-1.

16 A. Yes.

17 Q. What do they conclude as far as gas content of the
18 coal in this seam?

19 A. They defer to a large number of tests on core
20 samples conducted by Suncor and they quote the results of
21 those tests as follows: The maximum value reached was
22 6.6 cubic meters per tonne and, again, only six percent
23 of all the samples tested exhibited dissolved gas
24 quantities in excess of five cubic meters per tonne.

25 Q. What did they take to be the average?

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1 A. The average they took to be 4.25 cubic meters per
2 tonne.

3 Q. All right, and the last actual test that we are
4 aware of from our document base, the Pictou Feasibility
5 Study, apparently a study conducted by AMCL in 1987 in
6 Exhibit 10, tab 1, at pages 131 and perhaps 139, if I can
7 direct you to there.

8 A. Yes.

9 Q. What do they describe as to the testing and what the
10 results were?

11 A. They refer to the gas content of samples ranging
12 between zero and 6.2 cubic meters per tonne. Again, they
13 indicated only six percent of the samples exhibited
14 dissolved gas contents exceeding five cubic meters per
15 tonne. The average value for dissolved gas was 2.4 cubic
16 meters per tonne.

17 Q. All right, what do they make, if any, on comments
18 about whether this was a gassy coal, whether it's a high
19 or a low methane content?

20 A. The comments that are made in this report, Mr.
21 Merrick?

22 Q. Yes. Take a look at page 139 as well.

23 A. At the top of page 139 includes the comments: "That
24 although the methane testing is not truly quantitative,
25 it does indicate that the Foord seam has a low methane

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1 content."

2 COMMISSIONER Release of gas there.

3 MR. MERRICK All right. Now we know that the Kilborn
4 studies were very significant in the planning of this
5 mine and that the Kilborn studies were submitted as a
6 significant part of the mine plan package. In that
7 Kilborn Study, we know and we've already looked at it and
8 I won't bother referring you to it, but it was in Exhibit
9 35-A at page 83 where they took the content of the gas to
10 be 6.2 cubic meters per tonne. So the Kilborn, and we
11 don't have any evidence that they did any independent
12 testing themselves, appear to have basically taken their
13 assumptions for gas content somewhere in the range of all
14 of these tests that were carried out, and based on what
15 you've seen from the tests, would their number appear to
16 be a fairly reasonable one to be working with, purely for
17 gas content?

18 A. As a maximum value, yes.

19 Q. All right. Now based on the test results that
20 you've seen, we can't quantify whether those are or are
21 not significant, but you can. In your opinion, would
22 those test results indicate a gassy coal or a low gassy
23 coal? How would you quantify it?

24 A. I would put these in the middle range, medium.

25 Q. And I take it that they are relatively consistent

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1 with each other, although within a range of zero to six.

2 A. The ranges are consistent with each other, yes.

3 Q. All right. But I also assume -- Let me back up. In
4 order to arrive at those values, they would have actually
5 taken a sample of coal and how would they have arrived at
6 those numbers?

7 A. They have put the sample of coal into a container,
8 indeed the sample of coal should be put into a sealed,
9 hermetically sealed container immediately on its
10 withdrawal from the borehole, the sampling hole. They
11 would then bleed off the gas at intervals of time, which
12 would be fairly short initially as the higher part of the
13 dissolving curve has gone through, and at increasing
14 intervals of time thereafter, and they would plot -- May
15 I use the board?

16 Q. By all means, please.

17 A. They would plot the volume of methane emitted from
18 the sample against the square root of the time and this
19 would give some points which would initially be a fairly
20 straight line on this plot against the square root of
21 time and then curve over at later times.

22 This straight line part of the curve would give the
23 rate at which methane was emitted during that initial
24 part. There obviously would have been some methane lost
25 between the time when the coal seam was actually

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1 penetrated by the sampling drill rig and its the
2 placement of the sample into the hermetically sealed
3 container. That is sometimes referred to as the "lost
4 gas," and it is the part of the gas that is indicated by
5 this subzero area of the curve. This is the mechanism
6 through which the gas content is arrived at.

7 Q. And if I can say it in relatively simplistic terms,
8 basically it's a method of just measuring the amount of
9 gas that's given off from that coal over a period of
10 time.

11 A. That is correct. That is one method. There are
12 others, but this is the method that seems to have
13 predominantly been used by these investigators.

14 Q. All right. Now is that all that you should do in
15 assessing the gas content of your coal seam if you come
16 to plan the ventilation requirements for a mine?

17 A. You recall, Mr. Merrick, that we identified three
18 important parameters in governing the rate of gas
19 emission from seams into the workings. One was the gas
20 content. The second one was the permeability. The third
21 one was the gas pressure actually within the coal seam.
22 So what we are looking at in terms of gas content is one
23 of those three measured parameters.

24 This gas content is particularly important with
25 respect to the gas which will be emitted during the

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1 fragmentation process at a coal face. As the machine
2 bites into the coal, fragments it, then those are the
3 locations where you are going to get the peak emissions
4 of gas because of the high degree of fragmentation. In
5 those circumstances, the gas content is certainly the
6 most important of those three parameters. If, however,
7 one is concerned also with the make of gas from the rib
8 sites, from the old workings, then the other two
9 parameters, the permeability and the gas pressure
10 gradient, then become important.

11 Q. Because they would be more significant in the amount
12 of gas that would be made over a period of time from
13 those sources?

14 A. From those standing surfaces, yes.

15 Q. I would assume that in planning a mine you would
16 realize that you would have sides or ribs exposed for
17 some time and you would also probably get areas that had
18 been worked out so that you should plan for those gas
19 sources.

20 A. Yes, there are a number of gas sources which one can
21 identify and one should plan for each of those.

22 Q. The permeability of your coal seam, I assume you
23 would determine or you would account for based on
24 whatever evidence you had available as to how disturbed
25 that seam was, how many faults there were, records of

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1 other mines in the area, that sort of thing.

2 A. The permeability can be and is measured directly.

3 There are a number of means of doing this. The commonest
4 method is to measure the permeability in situ on site by
5 tests carried out on the sampling boreholes that are put
6 down to intersect the relevant seams. That is the
7 dominant method. There are other laboratory methods, but
8 the in situ method is the common one.

9 Q. So that you can get a pretty good idea that way?

10 A. Yes, sir.

11 Q. Are you aware of any permeability tests or analyses
12 being done based on the records that we've been able to
13 make available to you to date?

14 A. I have not seen any permeability values measured or
15 quoted. There are several references to the concept of
16 permeability, but I have seen no actual numbers.

17 Q. And one of those references would have been the
18 Algas Report earlier on saying that this may be a
19 significant factor.

20 A. Yes.

21 Q. The gas pressure, that would be not just the gas
22 content, but the pressure at which it is in the coal and
23 thus likely to be released once it was possible for
24 release, is that right?

25 A. Uh-huh.

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1 Q. Have you seen, based on any of the documentation
2 that we have been able to make available to you to date,
3 any indication that anybody actually tested for gas
4 pressures?

5 A. Not that I have seen.

6 Q. Just while we're at this, and because it will
7 probably come up in discussions later on, I take it you
8 can also make some determination as to the likelihood of
9 a particular coal from a particular coal seam being
10 subject to spontaneous combustion?

11 A. There are tests one can carry out for that purpose,
12 yes.

13 Q. Just briefly tell me about spontaneous combustion
14 and the mechanism of it in a working coal mine.

15 A. The majority of organic substances and some
16 inorganic substances are capable of being oxidized. The
17 common process of burning something is rapid oxidation.
18 Slow oxidation can and does take place. Coal is an
19 organic substance and is therefore liable to such
20 oxidation. The oxidation processes, and there are several
21 of them that proceed one after the other, result in the
22 production of heat.

23 I'd like you to imagine an area of crushed coal in a
24 mine.

25 Q. Such as in an old working?

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1 A. Such as in an old working. But it could be also in
2 those crushed rib sides also that we talked about,
3 through which there is no passage of air, entirely
4 sealed. There can be no oxidation. There can be no heat
5 produced because of oxidation. That is a safe condition.

6 Now I want you to imagine the other extreme in which
7 we have the same area of crushed coal and we are allowing
8 air to pass through that zone at a rate which is great
9 enough to remove efficiently the heat that's being
10 produced because of the oxidation which, invariably, is
11 going on. In that circumstance, the temperature will
12 rise because of the oxidation process. It will then
13 level off when it reaches an equilibrium point at which
14 the heat being produced by the oxidation is being taken
15 away at the same rate by the air flow -- also a safe
16 condition.

17 Q. You'll be getting oxidization, but you will not be
18 getting the heat of ignition because of the build-up of
19 heat?

20 A. The temperature will rise to an equilibrium point.

21 Now let's take a circumstance between those two
22 extremes where we have sufficient leakage of air, and
23 this will be a slow leakage, but a sufficient leakage of
24 air, to enable the oxidation process to proceed and the
25 temperature to increase, but not enough air to take the

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1 heat away at the same rate that that heat is being
2 produced. In that case, the temperature of the crushed
3 coal will continue to increase, and as the temperature of
4 the coal increases, so the rate of oxidization will
5 increase. Chemical processes normally increase their rate
6 with temperature. And in that circumstance the
7 temperature will continue to accelerate upwards until the
8 material becomes, eventually, incandescent, white hot,
9 and that is the spontaneous heating.

10 Q. And then you get a mine fire?

11 A. That is a mine fire, yes.

12 Q. That is a mine fire.

13 A. That is a concealed mine fire, a hidden mine fire.

14 Q. And I take it that different coals from different
15 seams will have different characteristics as to their
16 vulnerability to this process?

17 A. Yes.

18 Q. And how do you determine, for example, the coal from
19 Westray and whether it is more or less likely to be
20 subject to spontaneous combustion?

21 A. There are two sets of factors involved in this, Mr.
22 Merrick. One is the petrology -- the mineralogical make-
23 up of the coal itself. So the first set of tests would
24 involve taking samples of that coal, crushing them to a
25 defined size of particle, passing air or oxygen through

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1 that sample of crushed coal in a test chamber or test
2 tube, and measuring the rate at which the temperature
3 increases. A factor which is quite important in that
4 kind of test is actually the moisture content of the air
5 or oxygen, and the moisture content of the coal. The
6 difference in the moisture contents of the coal and the
7 permeating gas, air or oxygen, is quite an important
8 factor.

9 So carrying out that kind of test, one can plot
10 rates of temperature rise for different rates of oxygen
11 or air flow and different degrees of humidity, moisture
12 content of the air and the coal, and then compare -- the
13 results of coal samples taken from various places. And
14 if one achieves a result for your particular coal sample
15 that is similar to an area where we know spontaneous
16 combustion is a problem, then that is something we should
17 look to. That is one set of tests.

18 There is, however, a second set of tests you may
19 want me to speak to?

20 Q. Please.

21 A. The second set of tests is not concerned with the
22 coal material itself so much as the mining layout
23 underground. The propensity to spontaneous combustion is
24 not only a function of the type of coal but also of the
25 ventilation system of the mine, in particular, the air

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1 pressure differentials across worked out areas or areas
2 of crushed coal. Remember we talked about that critical
3 zone, Mr. Merrick, where we have enough air but not too
4 much? That is controlled by the rate at which leakage
5 can take place through those areas of crushed coal.
6 That, in turn, is determined partially by the pressure
7 differential, the ventilating pressure exerted across
8 that area. It depends also on the degree of crushing of
9 the coal, so if we have a method of working which leaves
10 a large amount of highly divided crushed coal in old
11 worked out areas, then that is going to increase the
12 probability of spontaneous combustion.

13 A third factor is time. It takes time for the
14 temperature to build up in the oxidation process, so if
15 we have areas of crushed coal through which leakage is
16 allowed to occur for a longer period of time, then that,
17 again, increases the probability over a system where the
18 mining process is occurring quickly. It is often the
19 case, for example, that spontaneous combustion occurs
20 during periods when the mine is not working for a week or
21 two weeks, because of this. And there are other factors
22 also. But the point I'm making here is that the
23 propensity to spontaneous combustion depends not only on
24 the type of coal but also on the mining layout and the
25 mining processes.

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1 Q. And let me just go back to the type of coal itself
2 and the first test that you described to us where you
3 would compare coal from one seam with coals from another
4 area where perhaps they had had continuous spontaneous
5 combustion problems.

6 A. Yes.

7 Q. And if the test results came out the same, you would
8 know that you had a coal that may well be subject to
9 spontaneous combustion depending on a series of other
10 factors?

11 A. Yes.

12 Q. From your review of the documents, you are aware of
13 the testing that was done on Westray coal for spontaneous
14 combustion, and I'm thinking particularly here of the
15 report that was done in July, I think, of '86. In any
16 event, it's Exhibit 8, at Section 13-4 and maybe Section
17 13-2. And that is --

18 A. Can you give me those page numbers again, please?

19 Q. Check 13-4 or 13-2.

20 A. Okay, yes, I have it.

21 Q. And that refers to a test called the Hazen test?

22 A. Yes.

23 Q. Carried out by Hazen. What can you tell us about
24 the test and what the results were and what coal it was
25 being compared to?

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1 A. Tests were compared with the Powder River coal. And
2 this is a coal from the United States that is known to be
3 prone to spontaneous heating. The tests that they
4 carried out were, indeed, of the type I mentioned, the
5 passage of moist oxygen over a sample of the coal. The
6 comments by Hazen Research themselves were that the
7 results of their own tests should not be used to predict
8 the behaviour of run-of-mine coal. It was very
9 difficult... I'm quoting "It is very difficult to draw
10 any useful conclusions." We're looking at this report as
11 referenced by the Norwest report. And the Norwest
12 authors themselves had further comments to make about
13 these tests.

14 Q. Just before we deal with that, the tests themselves,
15 how did the Westray coal compare to the Powder River
16 coal? I'm assuming that the Westray coal did not ignite
17 when the Powder River coal did?

18 A. Yes, I'm looking at the graphs referred to as Figure
19 13.4. it follows 13.6. The curve that was obtained from
20 the test on the Foord seam is referred to on this graph
21 as curve 301.

22 Q. Yes.

23 A. You found that? And that curve is one of the family
24 of lower curves on that graph which indicates that this
25 coal is less liable to spontaneous combustion than those

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1 curves which are shown higher up on the graph.

2 Q. So their tests indicated that the Westray coal was
3 less liable to spontaneous combustion than Powder River
4 coal, but they went on to say that you can't really draw
5 any conclusions from these results. And that the
6 possibility of spontaneous combustion should not be
7 dismissed too readily.

8 A. That is correct.

9 Q. We have heard and we will hear evidence about the
10 fact that the old Allan Mine workings just adjacent to
11 Westray apparently had a number of incidents of
12 spontaneous combustion, generally the same type of coal,
13 I would assume. What is your rationale -- let me back up
14 and ask it another way. Have you seen any indications
15 from the short history of Westray as to whether the coal
16 seam, as being mined by Westray, was in fact subject to
17 spontaneous combustion problems?

18 A. I've seen no such indications.

19 Q. And in fact, have you seen a particular area of the
20 mine that indicated to you that if it was likely to be
21 subject to spontaneous combustion, you would have seen it
22 there?

23 A. Yes, indeed.

24 Q. And what area was that?

25 A. Southwest 1.

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1 Q. And why do you look at that as a particular
2 indicator of the tendency to spontaneous combustion?

3 A. That was an area that had been recently mined. Some
4 degree of pillar extraction had taken place in there.
5 Other thin pillars had been left which were, both by
6 design and also because of withdrawal from the area,
7 would clearly be subject to crushing, so in there we
8 would have a very large surface area available for
9 oxidation. Also, following withdrawal of active mining
10 from that area, and there was a period when there was,
11 indeed, a low flow of air going into and out of that
12 district, if the coal had been liable to the rapid onset
13 of spontaneous combustion, then it would probably have
14 been shown on the carbon monoxide traces during that
15 period.

16 Q. So the conditions in the Southwest district were
17 such that if this coal was subject to spontaneous
18 combustion, those conditions likely could have caused
19 that?

20 A. If it had been subject to rapid spontaneous
21 combustion.

22 Q. What do you say as to -- you said one of the
23 criteria as to whether spontaneous combustion could occur
24 is the amount of air that would be going through the area
25 and its ability to carry away heat. What might you draw

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1 from the amount of air that was going through the old
2 Southwest district? It was supposedly a sealed off area.
3 Is one of the conclusions the possibility that
4 notwithstanding that there was still so much ventilation
5 going through there that it was preventing spontaneous
6 combustion because it was taking away the heat?

7 A. This seems to have varied through the month or six
8 weeks before the explosion. There was a time, I believe
9 it was the April 2 set of air flow measurements, when a
10 volume flow, a measurable volume flow of air was
11 progressing into and out of the old Southwest 1 district.

12 Later on, towards the time of the explosion, the
13 ventilation around the old Southwest 1 would appear to
14 have been very small.

15 So between these two levels, if we were going to
16 have rapid spontaneous combustion, it would have probably
17 have shown during that period.

18 Q. Bearing that in mind, how do you reconcile that
19 conclusion with the fact that, as I was saying a moment
20 ago, there are a number of anecdotes or allegations that
21 the old Allan Mine was very subject to spontaneous
22 combustion?

23 A. Yes, this almost certainly due to the second set of
24 circumstances as I referred to you, and that is the
25 mining processes themselves. I have not studied -- I

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1 have not looked at the rates of mining or the methods of
2 mining that were conducted in the old Allan Mine, but if
3 they, indeed, did expose large areas of crushed coal for
4 long periods of time; in other words, if the mining rate
5 had been slower, significantly slower, than is usual with
6 modern coal mining, then this would have given that added
7 time factor for spontaneous combustion to occur. This is
8 why I have, I think, twice referred to rapid spontaneous
9 combustion, rather than spontaneous combustion per se.

10 Q. So that an assessment that Westray coal was not
11 particularly vulnerable to spontaneous combustion can be
12 reconciled with experiences in the old Allan Mine by
13 looking at these other factors of mining method, times,
14 et cetera?

15 A. Yes, indeed.

16 Q. All right, thank you. Now having looked at those
17 background topics as we have, let's now come to the
18 actual process of planning ventilation in a mine. Can
19 you tell me the modern, and by "modern" I mean methods
20 since the eighties, method by which you would go about
21 actually determining how to ventilate and the adequacy of
22 ventilation for an intended mine.

23 A. Yes, it is a fairly sophisticated procedure for
24 modern mine ventilation planning. One starts off at an
25 early stage by assessing the degree of pollutants that

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1 are likely to be emitted into the mine. The pollutants
2 of primary concern with respect to Westray were clearly
3 the methane gas that we talked about, and also coal dust.
4 All mines have some degree of dust problems. On the
5 basis of those assessed pollutants and rates of emissions
6 of pollutants, one can make a judgment on the amount of
7 ventilation, air flow, that one requires. First of all,
8 to meet mandatory, legal standard, threshold limit
9 values.

10 Secondly, to ensure that the personnel underground
11 can work in safety and in a healthy and reasonably
12 comfortable conditions.

13 That set of exercises will allow one to make a first
14 assessment on the amount of ventilation, cubic meters per
15 second, quantified, required in the working areas of the
16 mine. So we know what we are looking for in terms of the
17 air flow requirements at the working faces.

18 We would add to that air flow requirements in other
19 parts of the mine, for example, ventilation of equipment,
20 underground power centers, pumps, compressors, make
21 allowance for those. Then we would liaise with the team
22 that is planning the production of the mine. One has to
23 mine, obviously, where the minerals, in this case, coal
24 exist. So an initial layout of the mine will be produced
25 in terms of production of the mine. Where the faces are

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1 going to be at intervals of time into the future.

2 So we shall have schematics, we shall have mine
3 plans for those intervals of time into the future.

4 We would then produce what is referred to as a
5 ventilation network schematic, which is analogous to an
6 electrical circuit diagram. It's a circuit diagram, not
7 showing electrical currents, but showing air flows around
8 the major circuits of the mine at these time phases,
9 periods of planned time ahead. That will enable the mine
10 to be portrayed as this circuit diagram, this network,
11 which will consist of a series of branches, a series of
12 entries, connected from junction to junction and
13 interconnected, according to the plan production of the
14 mine into the future.

15 Each single one of those branches has to be
16 allocated a value of resistance to air flow. Again, just
17 as electrical conductors offer a resistance to electrical
18 current, so mine entries offer a resistance to air
19 movement through them. Again, if I might use the board
20 here.

21 Q. Yes.

22 A. Let's consider just a single mine entry for the
23 moment. There is an air flow progressing through it, and
24 I'm going to use the symbol "Q" for air quantity volume
25 flow, cubic meters per second.

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1 COMMISSIONER Could you put an appropriate title on that
2 schematic, Doctor, so that when we refer to it later,
3 we'll know what to look for?

4 A. Okay. Mine entry resistance.

5 COMMISSIONER Thank you.

6 DR. MCPHERSON Okay, now if we are to induce this number
7 of cubic meters per second to flow through this entry --
8 This is true, incidentally, not only for mine entries but
9 for pipes, for ducts, any closed system, apart from the
10 open ends. Then we have to apply a pressure difference
11 across there. We'll call that "P." In order to produce
12 that air flow that, let me say it again in order to be
13 clear, in order to induce this air flow, then we have to
14 apply a pressure difference. It's like having a straw.
15 There's no air going to flow through that straw unless
16 you blow through it. You're giving a pressure difference
17 from one end to the other. That will induce the air to
18 move. So that's a pressure difference that we measure in
19 metric units, pascals. There's a relationship between
20 the pressure difference exerted to give this value of air
21 flow and that relationship is often referred to as the
22 square law of mine ventilation. And it is a very simple
23 equation. It states that the pressure differential one
24 has to apply to obtain an air flow Q is given by P equals
25 a constant for this entry R times the square of the air

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1 flow. This value of R is referred to as the, not mine,
2 airway or entry resistance.

3 Q. If I say it in very simple terms, if you want a
4 certain amount of air to go from one end of your entry to
5 the other, you have to blow on it with a certain pressure
6 and that pressure will be determined by the amount of
7 resistance that that air will have in that entry as it
8 goes through.

9 A. Yes.

10 Q. Thank you.

11 A. Okay, so this is, to carry on with my answer to your
12 question, Mr. Merrick, the determination of resistance
13 for every entry in this schematic, the circuit diagram
14 that we're building up, has to be ascertained. When this
15 is done at the stages of feasibility study or planning
16 before any physical mine exists, then the manner in which
17 those resistance values are obtained is by a
18 consideration of the geometry, the planned geometry of
19 the entries; that is, their length, their size, cross-
20 sectional area, the perimeter, the length of the distance
21 around the entry, and also by consideration of the
22 internal roughness, the predicted internal roughness of
23 the entries. There are equations. I'd be happy to put
24 them on the chalkboard for you, if you wish, but there
25 are equations one can use to turn those geometrical and

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1 roughness considerations into values of resistance.

2 So we now have our circuit diagram, our ventilation
3 network. We have a value of resistance for each of those
4 entries shown on the circuit diagram. What we then have
5 to do is to use all of that data to work out two things.
6 One is the distribution of air around all those various
7 branches. We considered just one single branch here but
8 now we're looking at a whole network, maybe hundreds of
9 branches, all interconnected and we have to calculate
10 what the distribution of air flow throughout all of those
11 branches in the mine is. Secondly, we have to determine
12 the duties; that is, think of it simply as the pressures
13 to be developed by the fan or fans to induce that air
14 flow, to produce these pressure differentials. So two
15 things we have to determine, recapping, the distribution
16 of air flow around the mine and the fan pressures and the
17 positions, the preferred locations of those fans to best
18 produce that distribution. Now this is a series of
19 calculations which are very complex. They require the
20 simultaneous solution typically of many hundreds of
21 equations and the modern way of doing that is by computer
22 simulation. In fact, it is the only practical way of
23 achieving what I've requested there -- distribution of
24 air flow and the fan pressures.

25 There were older methods, traditional, approximate

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1 methods, before the days of computers but those have --
2 are certainly outmoded, outdated, so in the 1980s that
3 you refer to, the method of network analysis by computer
4 simulation would be the way to go.

5 Q. And if I got it correctly, the objective, I guess,
6 of this planning process is to determine how much air you
7 need in each of the areas of your mine to accommodate, in
8 the case of methane, the amount of methane that you
9 anticipate that you will meet there. And using your
10 formulas and calculating the network and the resistance
11 in the network, that will give you the amount of fan
12 pressure that must be applied to get that amount of air
13 into each of those areas of the mine?

14 A. That is correct.

15 Q. And with a computer model you can do these
16 calculations much easier. But even if you aren't using a
17 computer model, you still have to do many of these
18 calculations, albeit by hand?

19 A. The way it was done before computer network
20 analysis, the old traditional method, was really quite
21 simplistic. And again let me use the board here. Let's
22 call this the traditional, the old method. The
23 traditional method of mine ventilation planning. Before
24 the days when we were able to do this properly and
25 accurately.

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1 What would be done typically at that time would be
2 to, again, draw a schematic. Let's draw a schematic of,
3 and I'll use a cartoon of Westray, if I may, to
4 illustrate this, of an intake slope and a return slope
5 with areas of mine workings going off at various
6 locations. Okay. The traditional method was to assume,
7 assume, a distribution of air flow. So you'd have an air
8 flow going down, you'd have an assumed air flow going up.
9 You would write down your assumed air flows. In fact,
10 you usually start at the working faces. This is how it
11 was done, by putting down here what you would like the
12 air flow to be in order to handle the methane and the
13 dust and so on, the desired values. Okay.

14 Then using the method of, that I referred to on the
15 previous diagram, again, a value of resistance would be
16 ascribed to every single one of these individual
17 branches. We have got this assumed distribution of flow.
18 All these Q values are different because it's being split
19 and there's leakage allowed for and so on, through the
20 crosscuts and stoppings. So for every branch, we have
21 got the value resistance and the desired or assumed value
22 of air flow. So a pressure differential can be
23 calculated for every single branch. So they would
24 calculate the pressure differential, B1. They'd
25 calculate. B2. Branch by branch. B3. All the way

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1 around the complete mine circuit, do this calculation and
2 have a value of pressure differential.

3 Then once I've got this, the -- once they've got
4 this they would take the longest route from surface to
5 the most outbye or inbye working back to surface, the
6 longest possible route, and they would add up all those
7 pressure drops. All these pressures. And then they
8 would say this is the pressure that we have to have on
9 our fan.

10 Q. So this is the size of fan we need, and this is the
11 amount of air that we've got to push down that mine at
12 that point?

13 A. Right.

14 Q. All right.

15 A. That was the traditional method. It is not the
16 method we use nowadays.

17 Q. Perhaps that might be an appropriate point to take
18 the mid-morning break?

19 COMMISSIONER Fine. Thank you. Shall do that.

20 INQUIRY RECESSED (TIME: 11:04 a.m.)

21 INQUIRY RESUMED (TIME: 11:20 a.m.)

22 COMMISSIONER Mr. Merrick?

23 MR. MERRICK Thank you.

24 COMMISSIONER Just one question, Doctor, to see if I can
25 clarify something in my head. The term, I even forgot

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1 the term now. There's another term that's synonymous
2 with resistance in the flow of air in a mine. "Static
3 head." Is that interchangeable with "resistance"?

4 A. No, sir.

5 COMMISSIONER It isn't. Okay.

6 A. The static head is another means -- the term "head"
7 is an engineering term sometimes used synonymously with
8 pressure. The "P."

9 COMMISSIONER Oh, I --

10 A. The resistance is a different --

11 COMMISSIONER Okay.

12 A. -- concept.

13 COMMISSIONER Thank you. Thank you, I was confused on
14 that, as with a lot of things.

15 MR. MERRICK Doctor, just picking up from where we left
16 off prior to the break. One would expect, therefore, to
17 see in the case of a mine such as Westray that was being
18 planned in the later 1980s, either a computer modelling
19 or a computer circuit network, a series of calculations.
20 Or the hand-equivalent, if you will, the layout with the
21 individual calculations of the pressure drops across each
22 of the headings in some detail prior to the construction
23 of the mine if it had followed the normal planning,
24 development route. Is that fair?

25 A. I would go a little further than that. I would

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1 expect in the second half of the '80s for there to have
2 been a fully qualified network analysis done indicating
3 the ventilation design and planning for the projected
4 life of the mine --

5 Q. All right.

6 A. -- divided into time periods.

7 Q. And I'll come back in a few minutes as to the
8 significance of that. You have talked about this kind of
9 planning should be done at various stages through the
10 mine life, the anticipated mine life. What would
11 designate or what would dictate when you would do it?
12 What would divide each of the phases?

13 A. They're often referred to in the literature as "time
14 phases." That is something of a misnomer because time
15 schedules have a nasty habit of slipping. A more
16 accurate way of defining it would be to look at stages of
17 development throughout the life of the mine. So an
18 initial time phase, for example, would normally consist
19 of the early drivages, the shaft sinking, or in this
20 case, the drivage of the slopes connecting across the
21 bottom into the first development of coal extraction.

22 And then looking into the future, periods
23 immediately before and immediately after major changes
24 such as the closing of a mined out section, the opening
25 of new sections, any period, in fact, during which the

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1 ventilation structure of the mine is being significantly
2 changed. So the so-called time phases I would prefer to
3 look at definitive phases in the development throughout
4 the life of the mine.

5 Q. And that, of course, would be -- you could do that
6 if you were properly planning because you would know when
7 those things were and what they were going to be?

8 A. Yes.

9 Q. For example, in the case of the Westray Mine layout
10 that was submitted at the time of the application for
11 approval of the mine plan, this is basically the Kilborn
12 layout, we know that it showed that they intended to take
13 coal initially from a series of panels at the far
14 northern end of their layout?

15 A. Yes.

16 Q. So that might be one of your phases. And then if
17 they had planned two to three years down the road to open
18 up a series of panels over to the Northeast, if you will,
19 that might be the time when you would do a second
20 calculation of your ventilation requirements?

21 A. Yes. And I would add one more rider to that, Mr.
22 Merrick. And that is that as part of these chosen
23 periods on which to conduct the network analysis, it is
24 prudent to take those times of heaviest demand on the
25 ventilation system. So, for example, in the case that

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1 you cite of workings at the far north end, one would take
2 the situation where the faces have extended to their
3 maximum extent, the entries are at their greatest length,
4 the resistances are at their highest value, and that is
5 the time of maximum -- those are periods of maximum or
6 high demand on the ventilation system. One has to ensure
7 that your infrastructure of entries, how they're joined
8 together, sizes of the entries, fan locations and duties,
9 that is, the pressures and volume flows through the fans,
10 are such as to give an efficient ventilation system,
11 giving those air flows that are required in the working
12 areas.

13 COMMISSIONER So just so I have this straight, Doctor,
14 then, when you are planning for mine ventilation, you
15 plan the total development of the mine before you decide
16 on the appropriate fan?

17 A. You plan as far ahead, Mr. Commissioner, as the
18 mining itself can be planned. For example, some mines,
19 some very large mines are over 100 years old.

20 COMMISSIONER Yes.

21 A. One would normally not attempt to plan that far
22 ahead.

23 COMMISSIONER No.

24 A. But one would plan for as far ahead as the mining
25 feasibility, the production and the forecasted markets.

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1 COMMISSIONER A 15-year plan?

2 A. Yes. Typically, I've seldom see it go more than 20
3 years into the future.

4 COMMISSIONER Okay. Thank you.

5 MR. MERRICK For example, Dr. McPherson, I'm not sure
6 if you've got Exhibit 45 up there. That's the map volume
7 that's right on the far left-hand corner of the desk. If
8 you can turn --

9 COMMISSIONER What number is it, Mr. Merrick?

10 MR. MERRICK Turn to tab eight under Exhibit 45.
11 That's the exhibit version of the large map that we have
12 looked at over the first two weeks of our hearings and
13 which shows three different layouts, colour coordinated,
14 that took place over time. But the one that I'm
15 particularly interested in is the blue which was the
16 initial mine layout that was submitted at the time of the
17 plan approval and which was planned out over a
18 considerable period of time.

19 So what you're telling us is that you would -- if
20 you were doing proper ventilation planning, you would
21 look at your anticipated mine layout as far off into the
22 future as you could see it and you would then calculate
23 your requirements for each of the phases that you would
24 know would be happening according to your plan?

25 A. Yes.

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1 Q. And you would be looking for the maximum or peak
2 ventilation requirements which would occur at some point
3 in that plan. And I assume that that would be because
4 you wouldn't want to get into year six and discover that
5 your fan was not adequate or your main entries were not
6 sufficient sized or whatever?

7 A. That is precisely the reason and the importance of
8 planning ahead in that way. So that the capital
9 expenditure involved in driving these major entries,
10 installing those fans, that that expenditure will be
11 usefully employed for those future years and not simply
12 in the first two or three years.

13 Q. All right. And I'm going to come back to that in a
14 little more detail in a moment. Let me just finish off
15 the planning process. I want to go back and just look at
16 it in a little more detail.

17 As I understand it, we start with the basic
18 assessment or calculation of how much air the mine will
19 require in various areas to handle, in the case of
20 methane, the methane gas. And I'm assuming that to do
21 that in today's -- with the facilities available to us
22 today, that one of the first things you look at is the
23 content of the methane in the coal, the permeability of
24 the coal, the pressure of the gas in the coal, and that
25 gives you a number that will indicate what amount of

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1 methane is likely to be produced during the mining
2 process. Have I got that right?

3 A. Yes.

4 Q. Once you know how much methane is likely to be
5 produced, what do you have to first do with that methane?

6 A. It has to be diluted to concentrations that are both
7 safe and also within legal threshold limit values.

8 Q. All right. And I take it then that's a relatively
9 straightforward calculation? That if you've got this
10 amount of methane, you need much greater volume of air in
11 a certain quantity in order to allow the one to dilute
12 into the other and bring it down to below five per cent
13 concentration?

14 A. One will design to produce concentrations that are
15 very much lower than that. That is the lower limit of
16 flammability and one designs for a very much lower
17 concentrations than five per cent.

18 Q. Quite right. These would be the concentrations that
19 are either mandated by your regulatory authority or that
20 are the safe operating limits at which equipment would be
21 shut off, that sort of thing?

22 A. Yes, sir. For design purposes, again, one would not
23 design to dilute the gas simply down to mandatory limits.
24 One will design for, again, considerably lower
25 concentrations than those mandatory limits.

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1 Q. So if your cutoff points were 1.25, you would design
2 to do it significantly less than that?

3 A. Yes.

4 Q. Perhaps .05?

5 A. Yes. The law does vary a little from country to
6 country. The 1.25 per cent electrical cutoff that you
7 have referred to in Nova Scotia, I would take my
8 guideline, my personal guideline on this is to take the
9 concentration at which one is required to cutoff
10 electrical power and then design to dilute to half of
11 that. So here we're looking at approximately .6 as a
12 design value.

13 Q. And is that generally the way that the industry, the
14 same guideline that the industry generally uses?

15 A. That is -- individual ventilation engineers have
16 their own little rules of thumb, but all of them
17 invariably will design for considerably less than
18 mandatory limits.

19 Q. All right. So if we know a number, and we'll come
20 in a minute to the numbers that were used for the likely
21 amount of methane to be released in the workings of the
22 Westray Mine, there's a standard formula that's referred
23 to in your report to determine how much air you must put
24 into that area to dilute down to that level?

25 A. Yes, sir.

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1 Q. Is that all you have to do?

2 A. No.

3 Q. As far supplying air to that area?

4 A. No, sir.

5 Q. When we left the question last time of the use of
6 network analysis programs, we had arrived at the stage
7 where we had produced an air flow distribution pattern
8 and we had produced a required set of numbers for fan
9 locations and duties. If I may move on --

10 Q. Please.

11 A. -- in answer to your recent question now, as part of
12 that. There are other checks one does make. Having
13 achieved the air flows that you require -- well, let me
14 back off a little.

15 Having produced a distribution pattern from your
16 computerized network analysis, you would look at that
17 distribution pattern and you would then ask yourself a
18 series of questions. First of all, are the air flows,
19 those that I have decided I require in the face areas,
20 have those been achieved? Very often in the first
21 stages, they're not achieved so then one must look at
22 ways of improving those face air flows.

23 And what one does on the computer is the way it used
24 to be, had to be done, pre-1970s, actually in practice,
25 by trial and error. Now you can do this on the computer.

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1 You can increase your fan pressures. You can increase
2 the sizes of entries. You can drive new entries. All
3 simulated on the computer. This is a tremendous
4 advantage. One of the tremendous advantages of using the
5 modern methods, that you can actually simulate on the
6 screen and on paper, what will actually happen in
7 practice if, and you provide the "ifs": where the entries
8 are going to be, the sizes of them, the fans, and so on.
9 None of this was possible in this older method. So
10 through that series of, let's call it "game playing"
11 exercises, one can examine alternatives and then look for
12 most economical ways, alternatives, of achieving those
13 required air flows.

14 Now coming to you last question, Mr. Merrick. One
15 of the important things that I've just referred to is not
16 only the quantity, not only the air flow at cubic meters
17 per second, entry by entry, but the actual speed of the
18 air passing through those entries one by one. The
19 velocity of the air is an important parameter.

20 Q. I just want to stop you there because that's where I
21 had some difficulty and I want to make sure I've got it
22 finally. Your first measurement is the quantity of air
23 that must come into that face to dilute the methane
24 that's produced there, and you measure it in cubic feet
25 per minute or whatever. So that to me, that indicates a

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1 flow. But that first measurement is purely a volumetric
2 flow; you're not focusing on speed or velocity there.
3 You just want to make sure that a certain quantity passes
4 that point in a given period of time?

5 A. Yes.

6 Q. You're now talking about something different?

7 A. Yes.

8 Q. You're talking about the velocity of that air?

9 A. Yes.

10 Q. All right. Tell me about that and why.

11 A. Again, if I may use the board here.

12 COMMISSIONER If you might put a title on it for us,
13 Doctor.

14 A. Let me ask you a question, Mr. Merrick. By --
15 talking about how volume and flow, "Q", is actually
16 measured.

17 MR. MERRICK All right.

18 A. Let us take a cross section of the airway, and we'll
19 draw it larger than we had before. This is part of an
20 airway. We're looking at one single cross section. The
21 way in which volume flow is measured, the predominant
22 method, is to use an instrument that measures air speed.
23 It's called an anemometer. And the most widely-used type
24 of anemometer is like a little windmill, about four
25 inches in diameter with blades. And if one holds an

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1 anemometer in a moving airstream, then just like a
2 windmill, the blades will rotate, actuated by the
3 movement of the air. And the speed of rotation is an
4 indication of the speed of the air. Okay? Right.

5 One takes the anemometer and you start off by
6 placing that anemometer down in one corner of the entry.
7 You use a stopwatch. You zero the anemometer. Set the
8 dial on zero. And then start your stopwatch and with the
9 watch running you move the anemometer. The anemometer is
10 on the end of an extension rod so the body of the
11 observer doesn't get in the way and also because it
12 enables one to reach high places. You traverse the
13 anemometer at a steady rate, up and down. The anemometer
14 is running all of this time. The person with the
15 stopwatch is -- should be calling out every 10 seconds.
16 And what you attempt to do is complete this traverse in a
17 certain time period, usually one minute or 100 seconds,
18 depending on the size of the entry, to complete the
19 traverse at the opposite corner. Lean forward, stop the
20 anemometer rotating, take the reading. That reading will
21 indicate the number of feet or meters of air that have
22 passed through the instrument during this time period of
23 one minute. It actually reads a length, meters or feet.
24 Now that has occurred in one minute. Let's assume that's
25 the time period we're using. So you know how many meters

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1 or feet of air have passed through your instrument in
2 that short time period. That gives you the velocity,
3 number of meters per minute or per second or number of
4 feet per minute or per second. This is a measure of the
5 velocity of the air just as you measure the velocity of
6 your automobile with the speedometer.

7 Okay, now let us call that velocity. Let's give it
8 a symbol U , meters per seconds. That is the mean
9 velocity, this is the integrated or mean velocity over
10 this cross section. The actual velocity there is from
11 place to place. That's why we do it a traverse.

12 That is the mean velocity over this cross section,
13 and let us say the whole of this cross section has an
14 area of a square meter. If we then multiply the mean
15 velocity measured in meters per second by the cross-
16 sectional area, which is in square meters, that is how we
17 arrive at -- See what the units are? Of volume, cubic
18 meters per second.

19 So recapping on your question again, the velocity is
20 just a simple measure of the mean speed of the air going
21 through this cross section. Multiply that by the cross-
22 sectional area will give us the volume flow. The number
23 of cubic meters. Here's a cubic meter. The number of
24 those that have passed through that cross section in the
25 time period per second.

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1 Does that answer the question?

2 Q. Yes, but I now want to come to why it becomes
3 important to determine not only the volume of air that
4 goes through for dilution purposes, but why we must now
5 be concerned with the velocity at which it passes
6 through?

7 A. Right. Let me give you three reasons why we have to
8 be concerned with the velocity. Why we look at velocity
9 in addition to volume flow. Volume flow is the important
10 one with respect to dilution; we've established that. If
11 the velocity is too high, then dust particles will be
12 carried much farther than they otherwise would be in the
13 ventilating air stream. Dust particles that have already
14 been settled out by gravitational settlement may be
15 picked up again, re-entrained. So too high a velocity
16 will give rise to problems with dust concentrations,
17 number one.

18 Number two, if the velocity is again too high, then
19 the cost of ventilation, we've not talked about economics
20 yet, but the cost of ventilation will also increase
21 rapidly. The actual dollars of power that you pay to
22 pass air flow along one of these entries is proportional
23 to the velocity cubed. So if you double the velocity in
24 a given entry, the number of dollars of electrical power
25 that you're using on your fans will go up two cubed,

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1 eight times. So this is a very important consideration.

2 And the third one is with respect to dilution of the
3 pollutants, particularly the gaseous pollutants. Not
4 only is it a matter of diluting the methane gas in this
5 case, it's a matter of mixing that gas efficiently into
6 the air stream. If the gas is not mixed into the air
7 stream, then it will clearly remain in a concentrated
8 form, maybe in the explosive range, five to 15 percent,
9 and the dominant method of insuring that that mixing
10 process, in order to achieve the dilution, occurs
11 efficiently is to insure that there is a sufficient
12 velocity and, therefore, a sufficient degree of
13 turbulence, vortices within the air to enhance that
14 mixing process. So it is important in gassy mines where
15 gas is being emitted into the workings that not only do
16 you have sufficient volume flow to dilute it down to our
17 point six percent, or whatever the number one chooses,
18 but also that the mixing process to achieve that dilution
19 is also sufficiently developed by a high enough velocity.
20 Q. So it's not sufficient that we plan our ventilation
21 system to put enough of a volume of air into the faces
22 over a given time to allow to hold the dilution of the
23 methane gas, we have to also insure that it goes through
24 at sufficient velocity to mix that gas into the general
25 body of the air.

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1 A. Exactly.

2 Q. For example, you could have a very large cross
3 section of your heading that is moving sufficient volume
4 of air through that it would be adequate to dilute the
5 gas, but if it is moving so slowly that it doesn't mix
6 the gas, then you are not accomplishing your purpose.

7 A. That is correct.

8 Q. So you have to do something to the perimeters of
9 your formula or your situation, you have to reduce the
10 cross sections, possibly, you may have to increase the
11 velocity of the air, whatever, or you may have to put in
12 artificial turbulence generators, I guess.

13 A. Yes.

14 Q. Now tell me, and we've heard evidence already, that
15 as long as you can get that mixing, once methane is mixed
16 with the general body of air, it does not then pool out
17 of the air. Once mixed, it stays mixed.

18 A. That is true.

19 Q. But you have to get that initial mixing?

20 A. Yes.

21 Q. And that's where we get into layering because if the
22 gas is not mixed, then it will layer or stay concentrated
23 to itself, if I can put it that way. Tell me about
24 layering, because that's a very significant phenomenon
25 that we have to deal with.

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1 A. I'd like to imagine that, I'm going to use an
2 analogy again, initially, that we pour water onto a
3 sloping surface, sloping ground. The water will flow
4 down that sloping surface. The reason that it flows down
5 is because it is significantly heavier than air. It does
6 not float in the air. It descends to the floor. The
7 reason that it runs down is because of the gravitational
8 effect. Water runs downhill like anything else drops
9 when you let it go free. So a fluid like water, which is
10 heavier and denser than the fluid above it, which is the
11 air, will run downhill.

12 Now there are fluids, there are gases, many of them,
13 which are lighter than air. This is why party balloons
14 which are lighter than air, this is why party balloons
15 float up to the ceiling because we fill them full of
16 hydrogen or helium. They're lighter than air so they
17 move up, just like the water runs down, gases which are
18 lighter than air will move up.

19 Methane is approximately half the density of air.
20 It is a light gas. Therefore, it will move up, just like
21 the water flows down; the methane will move up. So if we
22 now have a sloping surface which is sloping upwards and
23 we have a release of methane at this point, then the
24 methane will flow up the roof of the workings, just like
25 water flows down the floor of workings. That streaming

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1 of the methane along the roof we refer to "methane
2 layering."

3 Q. You show that in your diagram figure A-4 in your
4 report, which is four pages in from the back of the
5 report, under the third tab.

6 A. Yes, sir.

7 Q. All right. Now just before we -- I've got some
8 questions for you about what that diagram shows, but just
9 before we get to it, am I correct then in assuming that
10 this layering occurs not only at the roof in a sense, or
11 at least the streaming effect of methane occurs not only
12 at the roof but could also occur on the sides of your
13 roadway as the gas is emitted from the coal on the side.
14 It would stream up the sides and form again in a stream
15 or layer or river, I guess the terminology was, along the
16 roof.

17 A. That is correct.

18 Q. Unless you mix it.

19 A. That is correct, just like water running down a
20 window or a wall, runs down the surface and does not come
21 out into the room, so the methane will stream and cling
22 to those vertical or near vertical surfaces until it
23 reaches the roof.

24 Q. And looking now at the diagram that you've given us,
25 tell me a few of the characteristics of that methane

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1 stream or layer. For example, in your top diagram, you
2 show that from the given point where it's being emitted
3 into the roadway, it streams or flows along the roadway
4 and thickens.

5 A. Yes. This is where our analogy with the water
6 flowing downhill begins to depart. The liquid of water
7 or any other liquid will maintain its integrity and not
8 mix rapidly with the air above it. It does mix a little
9 because of evaporation but will not mix rapidly because
10 of the very great density difference between the air and
11 the water. In the case of methane, that density
12 difference is not so pronounced. Methane is only, I
13 repeat, approximately half the weight of air, and it is a
14 gas, like air, not a liquid like water. For that reason,
15 mixing will take place along the under surface, referring
16 to the diagram that we have in front of us, mixing will
17 take place along that interface between the high
18 concentration of methane, right at the roof, and the
19 general body of the air where the gas concentration
20 should be much, much lower. So that between those two,
21 high concentration/low concentration, we are going to go
22 through a region of decreasing concentration and that
23 implies going through the region of 15 percent down to
24 five percent, which is the flammable region of methane in
25 air.

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1 Now a degree of mixing is going to take place all
2 the way along that interface, and because of that degree
3 of mixing, the amount of gas being diluted along the
4 fringes, along the under surface of the layer necessarily
5 implies that the thickness of that layer will increase as
6 shown in the diagram as we progress away from the point
7 or points of emission.

8 Q. Looking at that diagram then, the layer that you
9 have depicted there, the line that distinguishes between
10 the layer and the general body, below that line would be
11 methane but mixed down to the concentrations that should
12 exist in the general body of air. The layer that you're
13 referring to there depicted would be a mixture of methane
14 and air at higher concentrations. It would continue to
15 get higher concentrations of methane the closer to the
16 roof you got.

17 A. Yes, sir.

18 Q. So that as the methane mixes in that range from
19 whatever concentration it comes into the roadway to
20 wherever the percentage is that should be in the general
21 body of air, that zone will continue to increase as the
22 mixing goes along.

23 A. Yes.

24 Q. Am I correct then in assuming that the layer or the
25 section of that methane layer that is in the explosible

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1 range, five to 15 percent, that also will tend to get
2 bigger or thicker.

3 A. That is correct, yes.

4 Q. All right, so that you can have an increasing
5 explosibility zone with a stream of methane going along
6 your roadway.

7 A. This is the danger associated with methane layering,
8 that that explosive band does extend along the length,
9 the extent of the layer itself and also has this tendency
10 to move down into the entry as you've described, yes.

11 Q. Tell me about the impact of the velocity of the
12 general body of air in relation to how far and how long
13 that methane layer is likely to extend.

14 A. Again, let me use two extremes to illustrate my
15 answer. Let us start off with an entry in which there is
16 no air movement at all. If that entry has a roof which
17 is completely level and we have methane coming in from
18 whatever source accumulating at that roof, then the
19 methane layer will spread out in all directions in this
20 level roof nonventilated entry. Just like water will
21 spread across the floor if we pour it into the room here.

22 Now let us look at two things. First of all, let's
23 keep the entry unventilated, no air movement, but instead
24 of having the roof level, we'll have the roof inclined,
25 just like water would run down the slope, so the methane

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1 will stream. It's called a free-steaming layer, in these
2 circumstances, will stream by its buoyancy, its reduced
3 density effect, up that slope. That's one effect, the
4 inclination effect.

5 Let's go back to our level airway. This time we
6 will start to allow air movement to progress in one
7 direction. This is, in fact, the diagram we're looking
8 at at the top of the page there. Then the methane will
9 be induced to move as a layer, as a streaming layer.
10 That movement will be induced by the air pulling it by
11 viscous action from underneath.

12 So we get movement of the methane layer by these two
13 phenomena. One, because of its buoyancy on an inclined
14 surface; and, secondly, because of the movement of air
15 underneath it pulling it along.

16 Q. And does the velocity of air, general body of the
17 air, have an impact, once you get it moving along, either
18 a level entry, or even if it's an inclined one where
19 there would be a natural tendency to stream, to what
20 extent does the velocity of the general body of air have
21 an impact on how far that layer of methane will stream?

22 A. Right. If the air velocity is sufficiently high
23 and, therefore, the turbulence, the eddies -- Air does
24 not move along an entry in straight lines. It moves in
25 coils and vortices and one can look at this in the mine;

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1 you can observe it. And because of that natural mixing
2 phenomena, that is going to increase the rate at which
3 this dilution we spoke of at the interface takes place.
4 If the velocity is sufficiently high and, therefore, the
5 turbulence is sufficiently high, then the rate of mixing
6 can be and is great enough to prevent the formation of a
7 methane layer in the first place. In other words, as the
8 methane comes out of, let us say, roof sources, it is
9 immediately met with this turbulent air which rapidly and
10 efficiently mixes that methane into the air flow and you
11 don't get a methane layer at all. Now as we back off
12 from that high velocity which will prevent the formation
13 of a layer, if we back off from that and start to slow
14 down the air, then we have the tendency for the methane
15 layer to begin to form and the slower you bring the
16 velocity down, the greater will be the extent, the
17 length, the propagation of that methane layer.

18 Q. So that under certain velocities of air, all it will
19 really do is extend that layer further and further down
20 your roadway.

21 A. That can occur particularly in ascensional entries
22 where the methane is, in any case, streaming uphill.
23 That will occur if you start, Mr. Merrick, from a very
24 low or zero velocity and let the air velocity increase
25 until it's moving at the same speed as the methane layer

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1 itself. That will give the maximum extent of the methane
2 layer. So, yes, in those circumstances, the methane
3 layer will be lengthened by that increasing velocity.
4 But this is increasing from essentially zero to a still
5 low velocity. As you continue to increase beyond that
6 velocity, then the turbulent mixing begins to take over
7 and will, therefore, reduce the length of the layer.

8 Q. I take it from your second diagram, the B diagram on
9 that page, that even if you have a sloped entry with
10 methane coming out at a low point, that it will tend to
11 stream, I guess, up that entry even if it's going against
12 the air flow.

13 A. Yes.

14 Q. And it would then, although it's going against the
15 air flow, it will have more turbulence at its interface
16 and there will be, I guess, sort of the kind of
17 phenomenon that we see described in your second diagram,
18 vortexes of methane moving up that entry.

19 A. Yes.

20 Q. All right.

21 COMMISSIONER Doctor, can I assume or conclude from
22 everything that you've said that (a) the ideal is to have
23 no methane on the roof of your mine; (b) even if you do
24 have a little bit, it's going to be layered so that some
25 portion of it is going to be in the explosive range?

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1 A. If the air velocity is sufficiently high to prevent
2 the methane layering taking place, which is one of the
3 examples I gave, then that mixing process will occur
4 rapidly and efficiently and you won't get any methane
5 layer at all. It will be efficiently diluted at the
6 point of emission.

7 COMMISSIONER But I'm saying even if it's a little less
8 than 100 percent efficient, you're going to have a layer
9 which will be comprised of a measure of explosive
10 methane.

11 A. Okay, let me back off a little bit in this. Methane
12 is produced, as we discussed earlier, from the coal
13 substance at very high concentrations, typically over 95
14 percent methane. Now if that methane comes into the
15 ventilating air stream and gets diluted to .5 and .6,
16 then obviously somewhere between the emission and the
17 general body, it is going to pass through the explosive
18 region. That is clearly the case.

19 The objective of an efficient ventilation system is
20 to keep the zone through which it passes through the
21 explosive region as small and as short lived as possible.
22 Now if we have that roof emission coming out into the
23 roof here at 95 percent methane, then, yes, it is going
24 to go through that explosive region. But if your
25 velocity is sufficiently high, that mixing process is so

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1 efficient that you don't even get a layer formed in the
2 first place. It sits right there at the spot.

3 COMMISSIONER Okay. Thank you.

4 MR. MERRICK But there is always, I guess, a theo --
5 not a theoretical, an actual point at which that methane
6 has to go through that explosive range.

7 A. Yes, sir.

8 Q. In a very well -- with good velocity, it will be a
9 very small area.

10 A. Yes.

11 Q. And do I take it from your answer to the
12 Commissioner that generally methane as it's released is
13 in a 95 percent concentration?

14 A. Typically in coal mine strata, the strata gases, the
15 quantity of mixture of gases, Mr. Merrick, may contain
16 many of the things as well. But it is commonly the
17 situation that 95 plus percent of that gas is methane.

18 Q. But I take our discussion then has taken us to the
19 point, though, that we now realize that we've got to have
20 that air moving past any possible sources of methane at
21 sufficient velocity to mix that methane as efficiently as
22 possible.

23 A. Yes, sir.

24 q. Preferably right at the source.

25 A. Yes.

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1 Q. And the sources of methane will, of course, be the
2 exposed faces of coal as well as the working face itself,
3 and there may be a number of other sources, like old
4 workings, et cetera.

5 A. Yes.

6 Q. So that we know the quantity of methane that may be
7 released from any particular point in the mine based on
8 our information as to the content of methane in the coal,
9 permeability of the coal, et cetera. How do we arrive at
10 the velocity of the air that we have to put by there to
11 accommodate that given number, whatever it may be in
12 case?

13 A. I'm going to give you two methodologies, one which
14 is more precise than the second. The first one arose out
15 of developments in the late 1950s and through the 60s in
16 the United Kingdom, Safety in Mines Research
17 Establishment in the U.K. We have in the exhibits a
18 paper by Drs. Baake and Leach and they devised what has
19 become a very widely used and accepted measure of the
20 tendency to methane layering.

21 If we are going to measure some entity, then we have
22 to have a tool for measuring that entity, and also we
23 have to have units of measurement. Let me come from the
24 abstract to an example. Supposing I wanted to measure
25 the length of this table. The tool I would need is a

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1 measuring tape. The unit I would use would be feet or
2 meters, units of length. Now throughout science and
3 engineering, other less obvious things have to be
4 measured or it is useful to be able to measure them.

5 The investigators, Baake and Leach, devised a means
6 of measuring the tendency to methane layering. Whether a
7 methane layer will form and, if so, the likely extent of
8 it. This measure was termed the layering number by those
9 authors, and if I may refer you to the same appendix at
10 the back of my report, page --

11 Q. Last page from the back?

12 A. Three pages from the back. Do you see an equation
13 numbered Equation No. 1?

14 Q. Yes.

15 A. And midway down the page, the actual numerical value
16 is put in there for methane, Equation No. 3. Let us
17 refer to Equation No. 3. Upper case "L" is this unit of
18 measure that I've referred to as the layering number.
19 The tools through which we make that measurement are
20 three parameters. In that equation, we have lower case
21 "u," which is the same symbol I use for velocity. This
22 is the velocity of the air in the entry. "W" is the
23 width of the entry in meters. "Q" subscript "g" is the
24 rate of emission of methane in concentrated form and,
25 therefore, capable of layering. If one puts those three

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1 parameters: velocity, width of the entry and gas
2 emission rate into that formula, you can calculate "L,"
3 the layering number. Now once you've achieved it, I
4 would ask you to move on two pages to the last page in
5 the appendix. Once you've calculated your layering
6 number, then refer to this table at the top of the page
7 there. We have three lines in that table. The top line
8 is the inclination or the angle to the horizontal of the
9 roof, naught degrees, five degrees, 10 degrees, et
10 cetera. The two lines underneath refer to the
11 recommended minimum values of this measure called
12 "layering number" for those particular inclinations for
13 ascensional entries, where the air is moving upwards, and
14 descentional, where the air is moving downwards. We're
15 going to refer to the somewhat different patterns of
16 methane layering in an ascensional and descentional
17 airway. This is why we have these two lines.

18 So having calculated the layering number for your
19 specific values of velocity, width and gas emission, you
20 then refer to this table, and it's also available in
21 graphical form on the page just before. You refer to
22 this table and you say is my layering number less than
23 these minimum recommended values? If it is, you're
24 likely to get a methane layer.

25 If your calculated layering number is greater than

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1 these minimum values, then you will either not get a
2 methane layer or will get a very short methane layer.

3 Q. All right, let me see if I've got it. When you look
4 at a particular heading in your mine and you want to
5 determine the velocity of air that you've got to put
6 through there to avoid layering of the methane, and this
7 would be methane coming out of whatever sources would be
8 in that heading, the three factors that will make up the
9 determination as to the tendency of methane to layer will
10 be the ones that you gave us: the velocity of air, the
11 width of the airway, and the rate of gas emission. So
12 using those given in your circumstance, and I would
13 assume you would take a number. You would say I'm going
14 to try this velocity of air, in this width of airway,
15 with this anticipated gas emission and it gives you a
16 layering number?

17 A. That is correct.

18 Q. And you then go and you check whether it is higher
19 or lower than the number that's given in this table. And
20 this table is an industry-wide accepted set of numbers
21 that have been calculated?

22 A. Yes, sir.

23 Q. And if you're --

24 A. May I just correct one thing there? The numbers on
25 this table and the graph that encompasses it, before, are

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1 a combination of theoretical and also empirical
2 experimental results.

3 Q. So it is a number that -- based on both theoretical
4 and actual observe --

5 A. Yes, sir.

6 Q. -- situations is what the industry has pretty well
7 settled upon being the layering number?

8 A. Yes.

9 Q. And if you come back with your calculation as to how
10 you intended to, or the velocity that you intended to put
11 through that passageway and the layering number is too
12 low, then you've got to go back and do something to get
13 that layering number up? You've got to do something to
14 the width of the roadway. You probably can't do much
15 about the rate of gas emission or you've got to do
16 something about the velocity.

17 A. [No audible response]

18 Q. And I --

19 A. The answer is "yes" to those questions with one
20 rider: There is very often something one can do about the
21 rate of emission by techniques of methane drainage, pre-
22 draining the area of methane so that there's less gas to
23 come in. This is a widely-used technique nowadays.

24 Q. All right. And we'll have -- we'll come back to
25 talk about that a little later on in the hearings. Now I

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1 assume as well that you would have to do this kind of a
2 calculation to get your velocity in any areas that you
3 anticipated particular problems. For example, you would
4 have to do a calculation like this as to what velocity
5 you required in the Southwest 2 headings, but you would
6 also do that kind of a calculation in any area that you
7 thought you might have particular problems with methane
8 such as headings going into old workings, that sort of
9 thing.

10 A. Where there was any suspicion that a methane layer
11 might form, then this is a calculation that should be
12 done.

13 Q. Yeah, all right. You would do a standard
14 calculation for your main roadway, I take it, in a
15 particular area because you would assume that the methane
16 emission would be relatively constant through that piece.
17 But you would certainly do a separate calculation at
18 working faces and at anywhere else that you thought you
19 might have a particular methane emission?

20 A. May I go on and refer to the second method? I said
21 there were two methods. This --

22 Q. Please.

23 A. We've described the precise method. One might call
24 it the "scientific method." There are uncertainties in
25 achieving the data for planning purposes.

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1 And the greatest uncertainty in the layering number
2 equation is the rate of gas emission coming out at
3 concentrated form from rib sides from old workings.
4 Because that is an area of uncertainty, there is a less
5 precise, but nevertheless, widely-used second method.
6 And this is quite rudimentary, and that is simply to
7 state that in the entries where layering might occur,
8 there should be a velocity proposed below which one
9 should not go.

10 For example, in the mine safety and health
11 administration legislation governing mining in the United
12 States, it is required there should be a velocity of not
13 less than 60-feet per minute minimum velocity. That is,
14 .3-meters per second in metric units.

15 And the background to that specified minimum
16 velocity is as a degree of insurance that methane
17 layering will be inhibited. It is not an absolute
18 guarantee because it depends on these other factors: the
19 width and emission rate. But it does give a form of
20 rudimentary safeguard against layering.

21 Q. Am I correct in taking it then that the industry has
22 in practice, and based on, I suppose, empirical as well
23 as the research, developed sort of general guidelines for
24 velocity that should accommodate most circumstances?

25 A. Exactly.

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1 Q. All right.

2 A. And --

3 COMMISSIONER Would you use that calculation of velocity
4 relative to the layering numbers? Like, I don't know
5 whether I'm -- is there any correlation in your
6 calculation of velocity? Like, if you find you don't
7 have the proper layering number then you can apply a
8 formula to increase the ventila -- or increase the
9 velocity to --

10 A. I'm not quite sure I understand the question, Mr.
11 Commissioner.

12 COMMISSIONER That's probably because I don't either, I
13 guess. Is there any relation between the two methods of
14 determining whether or not you're clearing out all the
15 methane?

16 A. The second imprecise method, purely based on
17 velocity, is a guideline and no more than that. If one
18 produces a velocity of 60-feet per minute, that is no
19 guarantee that there will not be layering. Because one
20 can look at heavy gas emissions, widths of airways which
21 will give layering in velocities considerably higher than
22 that. It is simply a rudimentary safeguard which, in the
23 case I've cited, is actually built in to U.S. law. It
24 does not guarantee that there will not be methane
25 layering, but it does ensure we don't get into the very,

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1 very, low velocity regions which will certainly increase
2 greatly the probability of layering.

3 COMMISSIONER Okay. Thank you.

4 MR. MERRICK Do I take it, Doctor, that if you were to
5 do a design based on this general minimum velocity that
6 is established as a, almost as a bottom-line or a minimum
7 standard, you could then, if you could assume a rate of
8 gas emission in a particular heading, run that through
9 your formula to see if it really does give you the right
10 layering number --

11 A. Yes.

12 Q. -- in those particular circumstances?

13 A. One can -- could indeed do that, Mr. Merrick. Let
14 me indicate to you how it is more usually applied in
15 ventilation planning. And that is that in working
16 headings on the working faces where an uncertainty is
17 certainly the rate of gas emission at concentrated form,
18 then in those cases I would simply use the imprecise
19 method of asking that there be a velocity of not less
20 than .3 or .4 meters per second. Number one. Number
21 two, for those applications such as emissions from old
22 workings, not working faces, from old workings, where one
23 can perhaps make a little more reliable estimates of
24 methane emission, particularly when those gas emissions
25 are going to come into active workings, the active

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1 ventilation infrastructure, then I would feel much
2 happier to fall back on the more precise methods of
3 examining layering numbers.

4 Q. I think I follow you. And I'll try this on you to
5 make sure I've understood it. Because if your -- if one
6 of the factors in this equation is your rate of gas
7 emission, and if you really are not comfortable that you
8 have with any degree of exactness, that you know how much
9 gas is going to be made, for example, right at the face,
10 then you're going to have to estimate that anyway to run
11 your formula. And rather than estimating it and
12 therefore running your formula and coming up with a
13 generalized number, you'll just pick the one that's been
14 -- the industry-accepted generalized one, or may be
15 mandated in that jurisdiction?

16 A. Yes. And let me, perhaps, explain why further. Why
17 the -- it is difficult to estimate that rate of emission
18 of concentrated gas. You notice I keep using the word
19 "concentrated" gas. It's not the total gas emission into
20 that working heading that is relevant here; it is the
21 proportion of that gas, the amount of that gas which
22 remains undiluted. Once it's diluted by turbulence, by
23 movement of the cutting drum, by dust suppression
24 techniques, by dust extraction, once it has been diluted,
25 then it is not any longer a problem with respect to

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1 methane layering. It's only that part of the methane
2 which does stream up the sides, which does come in from
3 the roof, and remains in a concentrated manner. It's
4 that part that gives a methane-layering problem. So this
5 is an indication of why it's so difficult to get that
6 rate of emission of gas which still remains in the
7 concentrated form.

8 Q. All right. So that the exact method loses its
9 exactness once you are not sure of that rate of emission,
10 but that if you got an area where you can comfortably
11 have an idea as to the rate of emission, such as the
12 amount of gas that might be emitted from old workings,
13 you can do the calculation using the formula for the
14 velocity that you should have in that area?

15 A. Yes, sir.

16 Q. And that will be more precise to those particular
17 circumstances than using some general number that's been
18 legislated or accepted in the industry?

19 A. Yes.

20 Q. I understand. And you're planning, I take it, to
21 determine the velocities of air that you need in various
22 areas of your mine, might be composed of using both
23 methods?

24 A. Yes.

25 Q. All right. I think I've got that. Let's look at

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1 the planning that was done for this mine and the steps
2 that were taken to determine the velocity that would be
3 needed for ventilation in this mine. Let me start with
4 the Norwest Study.

5 Just give me a second while I do my page reference
6 here. Actually, you can assist me, Doctor. It's the --
7 in your report, in fact, I'll take you to your report,
8 that's adequate for my purposes. If I can turn you to
9 page four of your -- tab three of your report.

10 A. Yes.

11 Q. You refer there to the 1986 Norwest Study.

12 A. Yes.

13 Q. Let's go through it and first determine how much air
14 they felt was needed in order to dilute the gas. Can you
15 tell us that?

16 COMMISSIONER Page three? What page?

17 MR. MERRICK Page four.

18 COMMISSIONER Oh, okay.

19 MR. MERRICK Tab three.

20 COMMISSIONER Tab -- okay.

21 A. Okay. Let's take it from the third paragraph up
22 from the bottom. On the basis of the gas content
23 studies, that we went through earlier, Norwest chose to
24 assume an average content of 4.25 cubic meters per tonne.
25 There is, you'll notice, a typo on that line. I've got

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1 it as "4.5," it is -- should, in fact, be 4.25 cubic
2 meters per tonne.

3 Q. All right. So we should correct that number in your
4 report to read "4.25 cubic meters"?

5 A. That is the value that Norwest chose and the value
6 they gave in their report.

7 Q. All right.

8 A. On the basis of that average gas content, they
9 assumed that 10 per cent of that gas content would be
10 emitted into the working face. You recall earlier we
11 said that the rate of methane emission from any piece of
12 coal or any surface of coal decays with time. There
13 would be a limited amount of time for which the fragments
14 of coal will be in the heading. They are removed from
15 the heading to the transportation system. And Norwest's
16 estimate is that 10 per cent of this gas content would be
17 emitted into the working headings.

18 They based that on a desorption curve which is a
19 rate -- which is the rate of methane emission that I
20 referred to with respect to time. I checked that curve
21 and found that the gas emission, the percentage of gas
22 emitted in 10 minutes, was, to my reading, closer to 14
23 per cent rather than 10 per cent. They took no further
24 account of methane emissions from the rib sides or
25 standing faces.

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1 Q. So then for the purpose of their calculation, their
2 initial assumption that the gas content was 4.25 may well
3 have been reasonable based on the studies that were
4 available to them --

5 A. Um-hmm.

6 Q. -- and which we've looked at this morning, but that
7 it may have been somewhat low -- their amount of gas
8 emission might have been lower than their calculations
9 because of these factors you've just identified?

10 A. Yes, sir.

11 Q. All right. Nevertheless, using that, perhaps, lower
12 than it should have been estimate --

13 A. Right.

14 Q. -- what did they come up with?

15 A. Let's move on from there to the next paragraph.
16 They then considered that methane to be diluted to a
17 concentration of .9 per cent.

18 Q. That was their goal?

19 A. That was their goal.

20 Q. And to do that what did they need?

21 A. The amount of air flow that's required to dilute gas
22 down to a given desired concentration, desired air flow,
23 is the gas rate of emission divided by the concentration
24 that you are looking for. .9 per cent. As a fraction it
25 would be .009. $.9/100$. So on the basis of their rate of

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1 gas emission, on the basis of .9 per cent here, they come
2 up with a value of 4.8 cubic meters per second in each
3 heading.

4 Q. So that is the volume of air that must be brought
5 into proximity with that gas in order to allow that gas
6 to be diluted within that volume?

7 A. Yes, sir.

8 Q. Your comments on the .9 per cent?

9 A. I've indicated that it is preferable to base the air
10 flow, as I said earlier, on a dilution of down to one-
11 half of the electrical cutoff region. In Nova Scotia
12 that cutoff point is 1.25 per cent. So if I take my
13 guideline of one-half of that, that is .625 per cent,
14 carry out the same calculation, then the air flow rate I
15 would have suggested, purely for dilution, not yet having
16 considered methane layering, but purely for dilution,
17 would have been 6.9 cubic meters per second.

18 Q. Okay. That's using all the other -- accepting the
19 other criteria accepted by Norwest?

20 A. Yes.

21 Q. Now Norwest though realized that this wasn't all
22 that you had to do; you had to actually mix that gas.
23 And they gave a velocity as well. How did they do that?

24 A. This was their use of my second and less-precise
25 method of looking at the methane layering problem.

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1 They simply made the assessment that in order to
2 prevent layering, top of page five, that there should be
3 a minimum air velocity of .4 meters per second. A little
4 higher than that mandated in the U.S. regulations.

5 Q. And do I take it that based on your knowledge, as
6 well as the fact that .3 is the mandated minimum in the
7 States, that there is no minimum mandated in Nova Scotia,
8 that their choice of .4 meters per second was a
9 reasonable one?

10 A. That is correct. I consider that to be reasonable.

11 Q. All right. And what did that give you?

12 A. Well, the Norwest Study, with respect to air
13 requirements, seemed to finish at that stage.

14 The next obvious stage would be to say that if we're
15 going to have an air velocity in the headings of not less
16 than .4 meters per second, using their own value which I
17 agree with, and taking the nominal cross section of those
18 entries, those headings, to be 6. -- six meters by 3.5
19 meters, then the air flow required would be, a formula
20 I've lost off the board, it's cross-sectional area times
21 velocity. "U" x "A". And that's what we've got here,
22 cross-sectional area, in my calculation, second
23 paragraph. 6 x 3.5, that's the width times the height,
24 multiplied by the velocity, required velocity, .4. That
25 gives 8.4 cubic meters per second.

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1 Q. So that in the roadways as -- with the dimensions
2 that you have taken, the actual velocity of air that you
3 would need to prevent layering, using the assumptions
4 made, would have been 8.4 cubic meters a second or 17,800
5 cubic feet per minute?

6 A. That is the air flow required.

7 Q. Significantly higher than that required for
8 dilution?

9 A. Yes, sir.

10 Q. And because the velocity requirement was higher than
11 dilution, the design should be based on that requirement,
12 not the dilution requirement?

13 A. Yes.

14 Q. On that point, Mr. Commissioner, you may wish to
15 break.

16 COMMISSIONER When do you come into conflict then with
17 sufficient velocity to stir up the coal dust? You know,
18 does that factor in there at any time?

19 A. Yes, but the velocities required to give -- to
20 exacerbate the dust problems, there are always dust
21 problems in mines, but the velocities required to
22 exacerbate that are very much higher than this. 10 times
23 as much.

24 COMMISSIONER Oh okay. Thank you. Recess until 2:00.

25 INQUIRY RECESSED (TIME: 12:33 p.m.)

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1 INQUIRED RESUMED (TIME: 2:01 p.m.)

2 COMMISSIONER Good Afternoon.

3 ALL Good Afternoon.

4 COMMISSIONER Now, Mr. Merrick, you were saying?

5 MR. MERRICK Thank you.

6 Q. We were just taking a look, Dr. MacPherson, at the
7 Norwest Study which was the most detailed preliminary
8 ventilation analysis, I guess, that was made of the
9 various reports that are available to us. And you had
10 told us before the lunch break that they had determined
11 that they wanted to dilute the methane down to a level of
12 .9 and that to do so they therefore needed an air flow of
13 4.8 cubic meters per second in the headings. And you had
14 given as your comments to the effect that perhaps a more
15 appropriate dilution ratio would be down to .5. You also
16 went on to point out that they did not take into account
17 the volume of air or air flow required to create the
18 necessary velocity to handle the layering phenomenon, and
19 that taking into account, using their perimeters and
20 their information, you arrived at a required air flow of
21 8.4 cubic meters per second or 17,800 cubic feet per
22 minute. That being the higher of the two design
23 requirements, that's the one that you should go with in
24 your system.

25 Let me take you now to the second report that we are

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1 aware of. This is the AMCL one that you looked at as
2 well, and I'm looking at page six of your report at this
3 point.

4 COMMISSIONER Mr. Merrick, would you give me that
5 figure, that Dr. McPherson had arrived -- was it 8.4, you
6 said?

7 MR. MERRICK 8.4, Dr. MacPherson?

8 A. 8.4 cubic meters per second, yes.

9 COMMISSIONER Okay, thank you.

10 MR. MERRICK That was the required air flow that,
11 according to their design perimeters, would be necessary
12 to give you the correct layering number -- or to make
13 sure your layering number was where it should be. Have I
14 got that right?

15 A. To inhibit the --

16 Q. Layering.

17 A. The formation of a layer, yes.

18 Q. Okay, perhaps just before we leave the Norwest
19 Report, it would be useful for you to pick out as well a
20 couple of other design criteria that they chose. What
21 was the total system air flow that they determined the
22 mine would need? These were the calculations that we
23 were doing for the purpose of air flow at a heading, for
24 example, as I understand it.

25 A. Yes.

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1 Q. What did they say would be the total air flow that
2 would have to be pushed through the mine system itself?

3 A. This is given of page five of my report. The
4 Norwest Study indicated that in the fourth year of the
5 life of the mine, the air flow through the main fan
6 should be at 155 cubic meters per second.

7 Q. That's in the fifth paragraph down?

8 A. Yes, sir.

9 Q. And how do they arrive at 155 cubic meters per
10 second?

11 A. They carried out calculations and/or estimations in
12 the way I indicated earlier with respect to dilution of
13 gas in the various then projected areas of the mine,
14 summed those together to obtain the total face air flow
15 requirements, then increased that by a factor to account
16 for leakage through stopping seals, et cetera, and hence
17 arrived at a main fan air flow.

18 Q. So they took the individual calculations, basically
19 totalled them up, built in a factor for leakage, and
20 arrived at 155 cubic meters a second.

21 A. Yes.

22 Q. What fan pressure did they estimate would be
23 required?

24 A. At that same time, a pressure of 2145 pascals.

25 Q. All right. Now let's look at what others also

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1 looked at.

2 I'm going to take you first to the one that you
3 refer to on the bottom of page six which is the Placer --
4 It comes under various headings, but the Pictou County
5 Feasibility Study, Volume 2, Mining, July '87. How
6 extensively did they look at the ventilation planning for
7 this mine?

8 A. The reference to ventilation was limited to one
9 single paragraph in that report and the diagram referred
10 to is a general ventilation flow. That was all.

11 Q. Very preliminary?

12 A. Less than preliminary, I would suggest, Mr. Merrick.
13 It was completely inadequate.

14 Q. All right. In any event, did they come up with any
15 design parameters at all?

16 A. Yes, they did.

17 Q. What did they come up with?

18 A. They came up with main fan duty of 175 cubic meters
19 per second and a corresponding fan pressure of 2080
20 pascals.

21 Q. I assume that what they did is that by looking at
22 the plan that they were considering at that point, they
23 figured out the required air flow movement through each
24 of their sections and they just added them up.

25 A. That again allowed for leakage in an empirical

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1 manner.

2 Q. That's that efficiency factor of 51 percent?

3 A. Yes.

4 Q. Okay. You make a comment on the bottom of your page
5 there that you thought was significant in reflecting on,
6 I suppose, the values that they arrived at.

7 A. You're referring to the comment with respect to
8 methane?

9 Q. Yes.

10 A. At the bottom of this page?

11 Q. Yes.

12 A. Yes, they do make what seems to be quite astonishing
13 statements. Their prediction was the methane will not be
14 a limiting factor in the mine ventilation requirements.
15 They go on to say the limiting factor will be the
16 extensive use of diesel powered equipment.

17 Q. Do you understand how they can make a statement that
18 methane will not be a limiting factor in the mine
19 ventilation requirement?

20 A. You're asking me to speculate into the minds of the
21 authors of this particular report, and I'm happy to do
22 that if you so wish.

23 Q. Well, is it a comment that you would make knowing
24 what you know about Westray?

25 A. No, sir.

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1 Q. All right, that's adequate for my purposes.

2 Let me take you to the third study that you looked
3 at and this is one we should take a few moments with
4 because it's the one that was used as the basis for
5 apparently the mine plan, the mine approval, and that's
6 the Kilborn Engineering Study. How did they arrive at
7 their ventilation design criteria?

8 A. Again, this treatment of mine ventilation was
9 limited in this case to one single page in the Kilborn
10 Report. Again, the treatment is very simplistic. They
11 assumed the coal production of 450 tonnes in each section
12 during each eight-hour shift producing gas at a rate of
13 6.2 cubic meters per tonne.

14 Q. And that is the number that was what the various
15 studies tried to determine that we looked at this
16 morning.

17 A. That is one of the several numbers, yes. And using
18 that emission rate gives an air flow of 20 cubic meters
19 per second to dilute it down to .5 percent. So they used
20 a dilution concentration of .5 percent.

21 Q. Again, they were looking at only the amount of air
22 flow required to dilute just as was Norwest.

23 A. Yes, sir.

24 Q. That is not intended to be the air flow required to
25 mix or prevent layering?

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1 A. No.

2 Q. All right.

3 A. So they arrive at a value of air flow of 20 cubic
4 meters per second for each section. They employ five of
5 these sections.

6 Q. They assume that there'd be five sections working at
7 any one time?

8 A. Yes, sir. Let me backtrack on that. They assume
9 five sections will require ventilation at any one time.

10 Q. Yes.

11 A. That's not quite the same thing. So five times 20
12 gives 100 cubic meters per second air flow requirement in
13 the working areas. And they used a volumetric efficiency
14 of 55 percent. If one divides 100 cubic meters per
15 second by .55, we arrive at the main fan air flow of 180
16 cubic meters per second. So the required air flow
17 through the main fan was 180 cubic meters per second.

18 Q. That would give them what they thought they needed
19 at the five sections plus the leakage and other
20 accommodation for efficiency.

21 A. Yes.

22 Q. Okay. So they come up with 180. Norwest came up
23 with 155. Did Kilborn do any calculation for air flow
24 for mixing purposes to prevent laying?

25 A. No, sir, not that I could ascertain.

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1 Q. Okay. I take it that they did their calculation --
2 sorry, did they use computer-assisted programming to do
3 their calculation, as far as you could tell?

4 A. Not that I saw.

5 Q. And what was the amount of fan pressure that they
6 expected would be needed?

7 A. 2,100 pascals.

8 Q. Okay, so that those three are fairly consistent one
9 to -- not consistent, but they fall in a general pattern
10 of the design perimeters, each of them, however, leaving
11 out the air flow required for prevention of layering.

12 A. Yes.

13 Q. You say in your report that the most detailed of
14 them was the Norwest one, and we looked at that in more
15 detail. Based on the documentation that's been made
16 available to you by the Commission, have you see any
17 evidence of any further ventilation planning done prior
18 to the start of this mine?

19 A. Prior to the start of the mine, no, sir.

20 Q. Have you seen evidence that following the start of
21 construction of the mine they attempted a more detailed
22 ventilation planning?

23 A. Yes, the modern approach that I had referred to this
24 morning using computer simulation, they did attempt to
25 employ such methods, I believe, late in 1991.

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1 Q. So we have some indication from the documents that
2 they were doing that kind of schematic and networking
3 analysis by late 1991?

4 A. Yes.

5 Q. At that point they had pretty well committed to
6 their main entries and their main fan system.

7 A. They were in place at that time, yes.

8 Q. What's the significance of that, in your opinion?
9 This apparent lack of any detailed ventilation planning
10 between these feasibility studies that we see or whatever
11 they are and the actual construction of the mine?

12 A. My opinion on this is that they constructed the
13 slopes. They designed the layout, which was subject to a
14 number of changes as they progressed, with an old-
15 fashioned method of ventilation planning used by Norwest,
16 completely inadequate attention paid to ventilation by
17 the other two studies that we've looked at, and did not
18 at all employ modern methodologies before the mine was
19 sunk, before the slopes were put in. That would have
20 made it very difficult, if not impossible, for them to
21 project the ventilation, schematics ventilation design,
22 for longer than the first two, three, four years of the
23 mine's life. There was no long-term planning done.

24 Q. Okay. Let me take you to that if I can. Did you
25 take a look at the efficiency or the manner in which

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1 their main mine ventilation system was operating and the
2 extent to which it may have been close to capacity at the
3 time of the disaster?

4 A. I refer to this, Mr. Merrick, starting on page nine
5 of my report.

6 Q. Yes.

7 A. My first comment on this is that for the short life
8 of this mine, the ventilation infrastructure; that is,
9 the main through-flow paths, the slopes and the main
10 intakes and the main returns were adequate for that short
11 life of the mine. So the ventilation infrastructure was
12 adequate, in my opinion, up to and including the May
13 period when the explosion occurred.

14 The second part of your question was how adequate
15 would it have been in the future, and this is where we
16 have some difficulty. If referring to the table on page
17 nine of my report, we look at the middle column, this
18 represents air flows in thousands cubic feet per minute
19 in the area of crosscut 9 of the slopes. You'll notice
20 that in that last month through April into early May,
21 these air flows were hovering around the 200,000; that
22 is, 200 kilo cubic feet per minute.

23 Q. These numbers are taken off actual measurements that
24 were done that we're going to look at in a few minutes.

25 A. These are taken off actual measurements, yes.

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1 Q. All right.

2 A. Turning over to the top of page 10, what I have done
3 there is to take the nominal sizes of the two drifts,
4 cross-sectional areas, of 266.5 and 252 square feet
5 respectively. If one divides the 200,000 CFM, air flow,
6 by the cross-sectional areas, you obtain velocities.

7 $Q=U \times A$.

8 You can look at either slope, but let me refer, let
9 me pick one. Let me pick the conveyor slope. If you
10 divide 200,000 by the cross-sectional area of that slope,
11 252 square feet, then that gives a velocity of 794 feet
12 per minute. That was the velocity of the air at that
13 stage. This is approximately four meters per second,
14 4.03 meters per second. Now bear that figure in mind.

15 Earlier this morning, we referred to design
16 limitations on velocity, I believe to a question from the
17 Commissioner, and in addition to minimum velocities for
18 methane layering problems, there are also maximum
19 recommended velocities because of the dust problem and
20 because of the economics, ventilation economics effects.
21 Those maximum recommended air velocities are given in the
22 middle of page 10.

23 Q. These are sort of industry maximum recommended air
24 velocities?

25 A. These are not mandated in any legislation. They are

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1 simply again engineering guidelines. Now if we take the
2 maximum recommended air velocity for the conveyor drifts,
3 five meters per second, we have already by April '92
4 reached four meters per second; that is, 80 percent of
5 that recommended maximum at this early stage in the life
6 of the mine. That is indicative that as the mine
7 continued to be developed and extended further with more
8 workings and more leakage, the air flow requirement would
9 clearly increase further. There would be required air
10 flows that would give velocities in excess of these
11 recommended maximums. That would mean that one of two
12 things. It would mean either they would have to exceed
13 these recommended maximums and, therefore, have dust
14 problems and also have very high operating costs for
15 power, electrical costs. Or they would need additional
16 surface connections, more slopes, or a new shaft.

17 Q. All right. So that at the stage of the life of the
18 mine that it reached on May the 9th, 1992, the air that
19 was pushing down around through the main system to
20 ventilate the extent of the mine that existed at that
21 point was close to the recommended maximum velocity that
22 you could push through that kind of a passage.

23 A. Yes, it had already reached 80 percent in the case
24 of the conveyor slope and without repeating the
25 calculation for the No. 1 intake slope, that was at 63

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1 percent of the recommended maximum.

2 Q. Now this is all based on your calculation as to the
3 cross section. I'll come back to that in a minute.

4 Let me talk about the air flow measurements on which
5 this calculation was based. In your report, or the
6 exhibit book that goes with your report volume, Exhibit
7 37-A, can you turn to page 33, and we see there the first
8 of what is really a series of pages that runs between
9 there and -- Let me get the last page of it. I guess
10 page 96. What are those documents?

11 A. They carry the titles of ventilation surveys for the
12 dates that are specified on each of the series of
13 readings. I'll come back to the question of that title,
14 ventilation surveys, in a moment, but the numerical data
15 that is included on these sheets indicates the
16 measurements of air volume flow that were made at a
17 number of ventilation measuring stations, "V" followed by
18 an integer, was the nomenclature that you used to
19 identify these stations.

20 Q. Would this measurement have been the type of
21 measurement you described to us earlier where you take an
22 anemometer and do a transit of the cross section?

23 A. Yes, exactly.

24 Q. Okay.

25 A. And they also contain, those same sheets contain

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1 other information with respect to the conditions of
2 stoppings, where stoppings needed repairing, for example.
3 This is noted in conditions of fans, fan tubing and from
4 early April onwards, I believe, indications of methane
5 concentrations which were also measured at those
6 stations.

7 Q. So that if we start on page 33, that's the most
8 rudimentary of them all, I guess.

9 A. Yes.

10 Q. And that would have been earlier in the life of the
11 mine, 17th of May, each of those stations in that first
12 column would be a specific location in the mine, and they
13 would consistently take readings at each of those
14 particular locations?

15 A. Yes.

16 Q. So that you could have some sort of comparison or
17 bench mark between the various measurements?

18 A. Yes.

19 Q. The average reading that would be taken of that
20 station and the cross-sectional square feet would then
21 give you the volume of air passing that location?

22 A. Yes.

23 Q. All right, and as we flip through the pages, we see
24 that as they went, the readings taken on those dates,
25 they began to make notes of various things. They became

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1 perhaps even a little more extensive in the number of
2 stations. We see even some textual notes made as to
3 areas that needed work, observations made, et cetera.

4 A. Yes.

5 Q. And we come right up to the last page which was a
6 survey done --

7 COMMISSIONER 97?

8 MR. MERRICK 95. And that was a series of measurements
9 apparently made on May the 8th, 1992?

10 A. Yes.

11 Q. Now what was your concern with the designation of
12 them as being ventilation surveys?

13 A. It was the use of the word "survey," Mr. Merrick,
14 that grated a little bit on my mind as a professional
15 mine ventilation engineer. A ventilation survey, in the
16 proper use of the term, is a very well organized and
17 managed series of observations which include air flow
18 measurements, pressure differentials, pressure drops
19 along entries, as we indicated on my picture earlier this
20 morning, pressure differentials across doors, stoppings,
21 air crossings, as well as the main fans and any booster
22 fans. There were no booster fans in Westray. But any
23 air flow, through flow producing fans -- all of that
24 information being the required information to measure the
25 real actual resistances of those entries.

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1 When we spoke about the evaluation of resistances
2 for the initial network analysis before the mine was
3 started, then we had nothing more to go on than
4 geometrical data, than sizes of the entries. When you
5 have a mine in existence and you're projecting forward
6 from that existing mine, then the manner in which you
7 obtain those resistances is to go down the mine and
8 measure them. And you need "P" and you need "Q"
9 measurements, pressure drop and air flow measurements in
10 each entry in order to do that.

11 As far as I've been able to ascertain from the
12 information I've seen, no such survey was carried out in
13 Westray. So the use of the word "survey" in this context
14 of what we see before us is a misuse of the name. What
15 we have, in fact, before us are a series of air flow
16 measurements, nothing more than that, made approximately
17 one week intervals. These are necessary and required
18 measurements to maintain, to maintain assurance that the
19 ventilation of the mine is sufficient and efficient. So
20 these are air flow measurements that should have been and
21 were taken and seem to be taken in a proper manner, but
22 they would not, in my mind, constitute the title of
23 "survey."

24 Q. In a prudently run mine, do I take it from your
25 evidence then that it would be customary to do this kind

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1 of air flow measurements about this -- with about this
2 frequency? Approximately weekly?

3 A. For, and purely for control and confirmation
4 purposes: control of the ventilation, to ensure you were
5 not losing an inadvertent amount of air through a hole
6 stopping, for example; to ensure that the air flows were
7 sufficient throughout the infrastructure to maintain your
8 gas concentrations at safe levels. Yes, these
9 observations were necessary; they were carried out, and I
10 have no problem at all with the way in which they were
11 carried out. But they should not be confused with the
12 term "a ventilation survey" which is carried out for
13 quite different purposes, and that is to assist on the
14 acquisition of accurate data for the future planning of
15 the ventilation of the mine.

16 Q. How often should ventilation surveys be done in a
17 prudently-run mine?

18 A. The answer to that one is the same answer I gave you
19 with respect to so-called "time periods of planning." It
20 will depend upon the rate at which the mine is developed.
21 So when new sections, for example, become opened up
22 and/or old ones are closed down, those are good times to
23 go down and to take proper ventilation survey
24 measurements, including pressure drops as well as air
25 flows.

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1 Q. In the case of the Westray Mine, I take it from your
2 evidence then that when they decided to go into the
3 Southwest District initially, somewhere around, I guess,
4 July of 1991, a survey should have been done at that
5 time?

6 A. I would have suggested it even before that, Mr.
7 Merrick. At the period of time when the main slopes were
8 completed and they had reached the coal seam, those main
9 slopes were the most -- the -- at that time, the most
10 important airways entries in the whole mine. All the air
11 flow went through those slopes. It was particularly
12 important that they achieve accurate real resistances of
13 those entries. That would have required a full pressure
14 drop quantity survey. And I've not seen any evidence --
15 I have not seen any evidence of that survey being carried
16 out.

17 Q. And I assume that when they decided to come out of
18 the Southwest 1 District in the end of March 1992, that
19 that might have been an occasion to trigger another
20 ventilation survey?

21 A. Yes, sir. Yes.

22 Q. And you've seen no evidence of such ventilation
23 surveys being done at any of these times?

24 A. No. The only measurement of pressure differential
25 that I've seen was an attempt to measure the pressure

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1 across the main fan. But I've seen no evidence at all of
2 pressure drops having been measured in the mine itself.

3 Q. What about when they came to try to the more modern
4 technique of the circuit network analysis in late '91?

5 A. Yes. It's interesting to look at that data input
6 that they used. And even though the mine was by that
7 time in existence and the slopes were there, even though
8 they were there to take measurements on, they still used
9 the old empirical values of friction factors, measure of
10 the roughness of the linings, and geometric data. They
11 used the second-best method, whilst at the same time the
12 airways were there to go and take measurements in.

13 Q. All right. I asked you a few minutes ago about the
14 capacity of the main ventilation system, at least up to
15 the date of the mine explosion. And while we're talking
16 about the main mine ventilation system for a minute, let
17 me ask you about the recirculation tunnel that we've
18 heard apparently did exist physically. I'm going to show
19 you two photographs that, again, because of difficulties,
20 we haven't been able to photocopy yet, but counsel have
21 had a chance to look at them. Eventually, we'll all have
22 our own copies. They are Exhibit --

23 MS. MACDONALD 73, 2.

24 MR. MERRICK -- 73, tab two. And can you just take a
25 look at these and tell me if they do in fact show the

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1 existence of a recirculation tunnel.

2 A. Yes, they do.

3 Q. All right. Perhaps I'll show those to the
4 Commissioner while I get you to describe. Now can you
5 describe what they're showing and what its purpose and
6 function is supposed to be?

7 A. Better show it in diagrammatic form so we don't get
8 confused in details. [Drawing a diagram on board] Here
9 is the main intake slope. Here is the return conveyor
10 slope.

11 COMMISSIONER Could you give us a name for that, please,
12 Doctor? I mean for the drawing.

13 A. Sure. Recirculation duct.

14 COMMISSIONER Okay. Thank you.

15 MR. MERRICK Perhaps what we should doing is numbering
16 these things, it may be simpler to --

17 A. Yeah.

18 Q. -- track. Okay.

19 A. The fan was located above, close to the surface, but
20 above the return airway. Let us show it diagrammatically
21 in that form. In order to prevent that fan from pulling
22 the air directly from the surface, ventilation doors were
23 in existence here to prevent directional circuit. Okay.

24 So the air was being drawn down the intake, around
25 the workings, back up the return. The recirculation duct

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1 was running across the surface of the mine, a metal duct
2 system that went from the high pressure side of the fan,
3 the outlet side of the fan, back into the intake airway,
4 so that a proportion of the return air was returned back
5 into intake circuit. In diagrammatic form, this is what
6 the recirculation duct was. This one.

7 Q. And why did they do that?

8 A. In a number of Canadian mines there are difficulties
9 with very low temperatures in the winter that can give
10 rise and does give rise to problems of freezing in the
11 intake airways. It's clearly uncomfortable for mining
12 personnel in those intakes and it can also give rise to
13 difficulties with equipment, some pieces of equipment.
14 For that reason it is not unusual for the intake air in
15 mines in cold climates to be heated, artificially heated.
16 The most dominant method of doing this is by using
17 propane burners.

18 In order to reduce the amount of expenditure on fuel
19 for such heating, recirculation of the warmer return air,
20 part of it, part of it, recirculation of a fraction of
21 that warmer return air back into the intake will reduce
22 the amount of heating required of that intake air.

23 Q. Let me just ask you for a moment about the heating
24 method used because we may run across documentation and
25 evidence as to propane heaters being used at this mine.

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1 A. Yes.

2 Q. That would not be unusual, I take it, in this kind
3 of a heating system? I'm not talking about a
4 recirculation tunnel now; I'm talking about heaters in
5 the intake main entry itself. Just graphically describe
6 it for me so I can understand what these heaters might
7 look like.

8 A. Okay. The intake air would be drawn through, let us
9 call it a room, a pre-fabricated room. Typically, the
10 air will come in from the top or from the side, move down
11 through a grill, sometimes with special fan assistance;
12 divorced from the main fan system, and then progress into
13 the main take airways, slope in this case, of the mine.

14

15 In that room, in that prefabricated room, there will
16 be a circuit of tubes which spray jets of fuel, liquid or
17 gaseous fuel. Propane is the common one. That fuel will
18 be burning, so we'll have jets of flame through which the
19 intake air is passing, so heating the intake air up.

20 That is one of the methods; there are others.

21 Q. Basically like passing the air -- intake air through
22 a propane burner?

23 A. Exactly.

24 Q. All right. Now -- but to avoid the costs incurred
25 with that, or minimize the costs incurred with that, if

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1 you recirculate, then you don't have to do that? Or
2 don't have to do it as much?

3 A. That is correct.

4 Q. What's the difficulty with a recirculating tunnel?

5 A. Recirculation is a concept that has been under an
6 investigation and with increasing usage for the past 30
7 years or so. It still remains a matter of controversy in
8 the coal mining world. A number of mining industries use
9 it conventionally. It is quite common in metal mines,
10 for example. It is less common in coal mines. And,
11 indeed, in most countries it remains illegal to
12 recirculate in coal mines.

13 The reason for that doubt in the case of coal mines
14 is the intuitive expectation that when one recirculates,
15 even to a partial extent, that there will be a buildup, a
16 continuous buildup of pollutants in the recirculating
17 system. That is the intuitive danger.

18 Q. So if you've got a certain methane content in your
19 general body of air that's coming back out of your mine
20 and you recirculate part of it back down, that will build
21 up and just continually build up the more you
22 recirculate? Theoretically.

23 A. No, Mr. Merrick. I chose my words carefully.

24 The --

25 Q. All right.

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1 A. -- intuitive expectation would be that the
2 pollutants would build up continuously. The reality is
3 that the pollutants reach a certain level and do not
4 proceed beyond that level. But nevertheless, it is that
5 intuitive expectation that still causes this to be a
6 controversial topic in coal mining circles.

7 Q. Now we may have some con -- we may have some
8 evidence on this as to whether or not Westray actually
9 ever used the recirculation tunnel that we see in the
10 photographs. Were you able, from your review of the
11 records, to find any evidence one way or the other as to
12 whether that tunnel had been put into use?

13 A. I find one such indication on the air flow
14 measurements that were made on December 31st, 1991.

15 Q. And that's that bundle of the documents we were
16 looking at in Exhibit 35-A. And what was the page
17 reference to that? What was the date?

18 A. December 31st, '91.

19 Q. Page 43?

20 A. You're quicker than I am. Yes. Yes, there is a
21 reference on page 43 to an air flow of measurement of
22 54,000 cfm passing through the recirculation duct.

23 Q. Just a minute now. I'm missing it. I led you to
24 the page but I can't see it. Where is it?

25 A. Page 43.

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1 Q. Yes.

2 A. Station VA.

3 Q. Oh yes. Yes. So Station VA, according to the note
4 that says the location of end station says "in
5 recirculation duct"?

6 A. Yes.

7 Q. And Station 50-A was passing 54,000 cubic feet per
8 minute on December the 31st, 1991?

9 A. You'll notice also that the main slopes are passing
10 approximately 200,000. 204,000, 212,900. So this would
11 be a recirculation of some 25 per cent. Roughly.

12 Q. Okay.

13 A. Of the total air flow.

14 Q. All right. That's the only evidence that you have
15 been able to locate to date as to whether it was actually
16 in use?

17 A. Yes.

18 Q. All right. We will have later evidence that deals
19 with this in more detail from other witnesses.

20 Let me bring you to -- we talked about the main
21 circulation system and whether it was adequate. Let's
22 now talk about the auxiliary ventilation system in this
23 mine. To begin with, a general question, and for my own
24 edification perhaps as much as anything. We know in the
25 Nova Scotia legislation there is the prohibition that not

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1 more than 40 per cent of the main body of air is to be
2 taken for the purpose of ventilating a heading. Why is
3 that? We see that kind of restriction in many
4 jurisdictions. What's the rationale behind that kind of
5 a restriction?

6 A. The rationale is the one that I referred to just a
7 few moments ago. The intuitive expectation or fear that
8 if recirculation occurs that there will be a buildup of
9 gases. Putting a fraction, a limit, 40 per cent in this
10 case, on the amount of the air taken from a crosscut into
11 a heading, maintaining it well below one, we take it all
12 up the heading, is an insurance that recirculation will
13 not happen. Did I make that clear? I -- or shall I draw
14 the diagram?

15 Q. You'd better draw a diagram for me because this is
16 one I have a little trouble with.

17 A. All right.

18 Q. I'm the lowest common denominator in this room; if
19 you can get it by me, you've got it by everybody.

20 COMMISSIONER Speaking for myself, I wouldn't take bets
21 on that, Mr. Merrick.

22 A. Let's draw a forcing system of auxiliary
23 ventilation. "Forcing system" means we're taking air
24 from the intake side, the fresh air side, put a fan down
25 here.

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1 MR. MERRICK Now just step to the side as much as
2 possible when you're drawing that so the Commissioner can
3 see what you're doing.

4 A. I'm sorry. Okay. So we have an air flow moving
5 from right to left. We're taking a fraction of that air.
6 Let's put some numbers on it. Let's say we have 10 cubic
7 meters per second here and therefore 10 cubic meters per
8 second leaving the area; there being no other inlets or
9 outlets between.

10 Nova Scotia law states that we are not allowed to
11 take more than 40 per cent of that; that is, four cubic
12 meters per second, into the heading. Now explaining
13 again the reason the rationale behind this kind of law:
14 if there were no such law, if mine operators were allowed
15 to take any amount of air they liked up here, then
16 supposing with the same 10, they put 15 cubic meters per
17 second coming up here, let's see what the situation would
18 be.

19 Q. And they might do that if they needed velocity up
20 there?

21 A. That is one of the advantages of controlled
22 recirculation. But let's deal with the --

23 Q. All right.

24 A. -- your first question. Supposing they took 15
25 cubic meters per second up here and goes around the face

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1 of the heading, comes back 15 cubic meters per second.
2 They only have 10 here. That means that five of this
3 would have to recirculate and the other 10 would go out.
4 That is a system of recirculation. The intention of the
5 40 per cent limit in Nova Scotian law is to make sure
6 that this situation does not arise. 40 per cent and not
7 100 per cent gives a safety factor.

8 Q. And as long as you've got less than 100 per cent
9 going up into that heading, you're not likely to get
10 recirculation. But as you say, they've set it at 40 for
11 a safety factor. Now --

12 A. Yes.

13 Q. -- here's a question: In modern mining ventilation
14 knowledge, are there times when indeed it may be useful
15 and perhaps even arguably safer to allow that to happen?

16 A. Yes, indeed.

17 Q. Tell me about that.

18 A. It is.

19 Q. Because that will go to the relevancy of our
20 continuing our 40 per cent restriction in our existing
21 legislation.

22 A. Let's draw a diagram again. And we'll call this
23 "controlled partial recirculation." One can repeat this
24 with the exhausting types of auxiliary ventilation, but
25 let's stick to our forcing system.

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1 Q. It would be the same thing with exhausting, I take
2 it, as forcing?

3 A. The calculations come out in a different way, but
4 the principles remain the same.

5 Q. All right.

6 A. Okay. And let us stick to the same air flows: 10
7 cubic meters per second. Supposing we had a gas emission
8 into this heading of 0.1 cubic meters per second. This
9 is gas emission in red; air flow is in black.

10 Q. Yeah.

11 A. Sticking to the law, and we've got a maximum of four
12 cubic meters per second air flow going up the duct.
13 Mixing, let's assume it mixes sufficiently, with the gas
14 emission, then we have a concentration of -- do the
15 calculation, concentration of gas flow over air flow, .1
16 over 4 is multiplied by 100 to get it into a percentage,
17 is 2.5 percent. Is this clear?

18 Q. I think so.

19 A. "Concentration" is the gas flow divided by the --
20 that's what "concentration" means: how much gas there is
21 per unit --

22 Q. Are you saying that with that amount of air flow in
23 that heading with that amount of gas make, we will get
24 2.5 per cent?

25 A. Yes.

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1 Q. In the general body of air?

2 A. Yes.

3 Q. All right. I think I follow.

4 A. Okay. Now let us disobey the current law.

5 Supposing we took all of this 10 cubic meters per second;
6 we're not recirculating, but we're just on the point.
7 We're taking all of the air flow. We have the same gas
8 emission. Use black. Concentration in the about-to-
9 recirculate system now becomes same gas flow, .1, over
10 10. 10 now going up here, which is one per cent. A
11 lower concentration yield than you would have if you
12 constrained yourself to the legal limit.

13 COMMISSIONER By putting an arbitrary limit on the
14 amount of air for recirculation, what you are doing then
15 is building up the methane content to an explosive level?
16 Or you're -- to a higher level.

17 A. You -- to a higher level.

18 COMMISSIONER To a higher level, yes.

19 A. Yes. Hopefully, it will not get to explosive
20 levels.

21 COMMISSIONER Yeah. Okay. That's five, yeah, okay.

22 A. Two further points I'd like to make on this, Mr.
23 Merrick.

24 MR. MERRICK Yes.

25 A. One is that as we increase the air flow in the duct,

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1 then clearly you are increasing the velocities of the
2 air. Okay? Velocity is two and a half times what it
3 would have been with the four. You can go beyond that.
4 Supposing we went to our previous picture of taking 15 or
5 20 up here, recirculating. Recirculating. Velocity is
6 getting higher and higher and higher as you recirculate
7 more and more. So you're going to get better mixing of
8 the methane. That zone through which you're progressing
9 through the explosive range is getting smaller and
10 shorter-lived. That's one point.

11 So a system which allows more than the current
12 mandatory limit will inhibit this problem of methane
13 layering. That's one of the two points I wanted to make.

14 The second one is a limitation and a very prudent
15 limitation on these thoughts. And that is that these
16 calculations and this example I've given assume that this
17 main air flow remains at 10. It does not go below 10.

18 The danger I want to point out is that mine
19 personnel working in any place in a mine are conscious of
20 the air movement over them, over their own bodies at that
21 particular location. They are not cognizant of where
22 that air has come from or where it's going to. So if you
23 allow recirculation, then the workers in the heading here
24 will feel much happier when they've got a real flow of
25 air. It could give them a false sense of security. If

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1 this recirculating, giving them plenty of velocity, but
2 if this falls away -- and the danger is if that falls
3 away and you continue to recirculate, then you've got
4 uncontrolled, uncontrolled recirculation. And that is a
5 danger that whenever recirculation or the approach to
6 recirculation is allowed, and it's allowed in many places
7 now, by exemption from the law, that precautions are
8 taken against this condition of a reducing through-flow.

9 Q. What kind of precautions can be taken?

10 A. Two precautions. Two sets of precautions. One is
11 air flow monitors to ensure that this value does not fall
12 below a pre-determined and pre-set value. Number one.
13 And number two, environmental gas concentration monitors
14 actually in the zone of recirculation. So that if those
15 goes beyond, again, pre-set levels, then the
16 recirculation system will automatically revert back to a
17 conventional non-recirculating system.

18 COMMISSIONER What would cause that to drop below 10?
19 Resistance or --

20 A. A number of things --

21 COMMISSIONER This is your main flow of air, isn't it?

22 A. There are two things, Mr. Commissioner, that could
23 result in that falling below the pre-set level. One is
24 the transit defects that occur in mines. People walk
25 through doors somewhere outbye; the air flow drops inbye;

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1 there's a fall of roof; a blockage caused by equipment;
2 supplies being left in an inappropriate place in a main
3 intake. Those are all immediate and rapid-acting causes
4 of this falling away.

5 There's a second one, and this is perhaps more
6 serious with respect to changes that may be considered in
7 the law. And that is that unless, unless this routine,
8 forward-looking ventilation planning is carried out in
9 the way that I have suggested and should be done, then
10 over a longer term and looking at this complex network of
11 airways, not just a simple heading, that somewhere within
12 that complex system of headings this may begin to drop
13 away because of these longer term effects and not be
14 rectified. There's a short term and a long term danger.

15 COMMISSIONER Yeah, okay.

16 MR. MERRICK In the area -- in the jurisdictions that
17 no longer have a legislated man -- minimum diversion of
18 air for auxiliary ventilation, I take it that it is often
19 done by way of special permission?

20 A. Yes, sir.

21 Q. So that mine management, for example, if they had a
22 heading that they wanted to have the benefits of
23 increased velocity or increased air flow generally --

24 A. Yes.

25 Q. -- they could apply for and if the circumstances

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1 warranted it, get an exemption from the mandated minimum
2 diversion?

3 A. Yes.

4 Q. And that in -- if the circumstances are right, that
5 gives a greater flexibility to mine management to ensure
6 that safe ventilation is in fact occurring?

7 A. Yes, indeed. There is an added advantage that we
8 have not spoken of yet. We have concerned ourselves with
9 the advantages of safety and health, reducing methane
10 concentrations, reducing probability of methane layering.

11 There is an economic advantage as well, particularly
12 for mines which have workings well away from the surface
13 connecting shafts or slopes. As you get further and
14 further away from those surface connections, the costs of
15 ventilation, the power costs of driving the fans,
16 increases because the resistance of those airways are
17 increasing. You still need the same amount of air out
18 there to ventilate the working areas. One way of
19 handling this is by the use of booster fans further out
20 into the workings, a method that is used in Nova Scotia,
21 in Cape Breton.

22 A second way of doing it is by using controlled
23 partial recirculation, not on a single heading basis, but
24 on a complete section of the mine basis. This is being
25 done in the United Kingdom, for example, at the present

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1 time. So in addition to the safety and health
2 advantages, there is an economic advantage as well.

3 I might add, Mr. Merrick, that the initial research
4 in the concept of recirculation was carried out for the
5 purposes of dust control initially in the 1960s and
6 1970s. Again, this was in the United Kingdom. And it
7 was found that dust concentrations were brought down
8 considerably, factors of two, three, four, in headings
9 like this. It was also found that methane concentrations
10 were being reduced because of the types of calculations
11 that are done here. The method was then used in a more
12 widespread manner. South Africans use it. Not for gas,
13 not for dust, but for cooling. Their major environmental
14 expenses are refrigeration in those very deep and hot
15 mines, and they found that by recirculating air that had
16 already been cooled, they could reduce their total
17 refrigeration costs.

18 It also expanded to Canada for the exact opposite
19 circumstance and we referred to that earlier. That is
20 the saving of heating costs in colder climates. So this
21 concept of recirculation has become very widespread and
22 is utilized in a number of places in the world, but let
23 me repeat, as I started, that it does still remain a
24 matter of controversy within coal mining circumstances.
25 As far as I know, this still remains illegal in most if

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1 not all coal mining industries around the world. But it
2 is used by special exemption, by special permission, case
3 by case.

4 COMMISSIONER While we're into that point, let me pose a
5 question to you that I'm confused about and that is a
6 subject you mentioned a moment ago and that is booster
7 fans. Now a double-barrelled question. If your
8 ventilation planning is done correctly as you described
9 it to cover off the ultimate use or the maximum use
10 during the life of that mine, what is the requirement for
11 a booster fan? And the second part of the question is:
12 Why under CFR-30 in the U.S. are booster fans frowned
13 upon?

14 A. Let's take those two questions in turn. First of
15 all with respect to the ventilation planning, the longer
16 term planning of the mine, where booster fans are allowed
17 in the underground mines, and they are in the vast
18 majority of coal mining industries and metal mining
19 industries around the world, then those booster fans are
20 incorporated as a part of that planned system.

21 Now if one goes back several decades, booster fans
22 were used, let us say pre-50s, as a means of increasing
23 the air flow where that air flow had been inadequately
24 planned for before, prior. Remember this was well before
25 the days of computerized network analysis and it was all

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1 very much literally suck and see, hope for the best.

2 As booster fans became more and more widespread in
3 metal mining and also in coal mining industries in most
4 countries, it was realized that booster fans had very
5 distinct advantages, not only in terms of improving the
6 air flow in specific sections of the mine but also again
7 in terms of economics as well as health and safety. Once
8 we've gone out a long way from the surface connections,
9 as I mentioned, then it becomes more economic to use
10 booster fans. So these booster fans are now in most
11 mining industries planned into a system. If you're going
12 to need them, they're going to be economically beneficial
13 as well as beneficial in terms of dilution of pollutants,
14 then they are planned as an integral part of the system,
15 not as an add-on tail pipe emergency, as they used to be
16 some decades ago.

17 COMMISSIONER We're not including in that the auxiliary
18 fan.

19 A. No.

20 COMMISSIONER That's just booster, okay.

21 A. Booster fans refer to the through flow of air.

22 COMMISSIONER Yeah, okay.

23 A. Now your second question is why are they not allowed
24 in the CFR-30? I did mention that the use of
25 recirculation was controversial in the world of coal

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1 mining. Booster fans are, in fact, allowed in CFR-30,
2 Chapter 57, for metal mines. It's only in Section 75
3 coal mines that they are illegal. The background to that
4 is this intuitive fear of recirculation causing build-up
5 of pollutants. This is a matter that I have argued on
6 many occasions with mine safety and health administration
7 personnel. The use of booster fans has been recommended
8 by the vast majority of ventilation personnel in the
9 United States. The reason it has been turned down
10 consistently time after time is because of two things.

11 One we already mentioned, the fear of uncontrolled
12 recirculation, fans being used in a section by section
13 context when there's not enough through flow to keep them
14 safe, number one.

15 And, two, the argument is that in the United States,
16 there are a large number of small mines, very small
17 mines, and inspecting these from the point of view of
18 proper booster fan installations would be rather
19 difficult. It would be difficult to enforce the
20 conditions under which booster fans are allowed to be
21 used. And we can go into those conditions.

22 Q. No, no.

23 A. They are quite specific. Those are the reasons.

24 COMMISSIONER Okay, thank you very much. Do you want to
25 take 10 minutes?

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1 HEARING RECESSES (TIME: 3:08 p.m.)

2 HEARING RESUMES (TIME: 3:23 p.m.)

3 COMMISSIONER Thank you.

4 MR. MERRICK Just to pick up on a point before the
5 break that you mentioned, and I have to ask it, you said
6 that this recirculation that might be permitted under
7 certain circumstances helps in bringing down gas content
8 and increases velocity, but it also helps in dust
9 control? Could you just explain that to me for a moment?

10 A. Yes. Where this was used initially in the United
11 Kingdom, early trials, the duct systems then, as now, for
12 dust control purposes were either exhaust systems or
13 forcing overlap. You can ask me the definitions of these
14 terms in a moment if you wish. But the point is that the
15 air flow that was withdrawn from the working faces of
16 those headings was passed through in-line filters in the
17 duct and the reason that the total amount of air-borne
18 dust, respirable dust, the dangerous dust, was brought
19 down was simply that more air under a recirculation
20 system was being filtered, the same total mass of air
21 passing several times through the filters. So the dust
22 counts came down. That was the initial reason for using
23 recirculation. The reductions in methane concentration
24 came as a bonus afterwards.

25 Q. I see. So they did that initially for dust control.

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1 A. Yes, sir.

2 Q. All right, let me move on. I want to talk -- I want
3 to ask you questions about the auxiliary ventilation
4 system that was actually used in the Westray Mine. We've
5 heard briefly the sort of pros and cons of exhausting
6 versus forcing. Briefly, your opinion on exhausting
7 versus forcing auxiliary ventilation?

8 A. Forcing ventilation in auxiliary systems is implied
9 within the regulations in Nova Scotia. That's the first
10 point. It is a legal requirement to use the forcing
11 system. Now the pros and cons of forcing and exhausting
12 systems, again if I might use the board on this.

13 Okay, let's draw our picture again, the one we're
14 getting used to. Let's draw a forcing system first
15 again. And as we saw before, this is with the fan on the
16 intake or fresh air side, forcing air through the ducts
17 into the heading.

18 The alternative system is with the duct on the other
19 side; that is, on the return side of the heading. In
20 this case, the air flow is being withdrawn back down
21 through the duct. Okay, but set up the system, forcing
22 and exhausting.

23 The primary advantages of the forcing system are in
24 headings where gas is, indeed, a problem. I assume this
25 is the reason for it being mandated in the law in Nova

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1 Scotia for coal mines. And the reason it is advantageous
2 in gassy headings is that the peak emissions of gas are
3 most likely to occur at the time of mineral winning,
4 fragmentation up here at the face. So this is where
5 you're going to get most or a large part of the methane
6 emission.

7 The forcing system, because the air is concentrated
8 into a relatively small duct, small compared with the
9 total cross section of a heading, is coming out of here
10 as a jet, just like water comes out of a hose pipe, and
11 is therefore directed through the kinetic energy, the
12 inertial energy, forward, projected forward, scours
13 around the face of the heading before returning back
14 through the body of the heading. So the potential for
15 this then is to give a good mixing effect, a dilution
16 effect of the methane at the place where it is most
17 needed; that is, the face of the heading.

18 If we look at the exhausting system, then air is
19 moving up the body of the heading much more slowly than
20 it was moving up the forcing duct. There's no jet effect
21 here. So the tendency is for this air to be drawn
22 preferentially right into the end of the duct leaving an
23 area up here which is stagnant, or near stagnant.

24 So from the point of gas dilution, this is not very
25 good. This is the preferred method. The advantages of

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1 the forcing system in gassy headings.

2 Now if dust as distinct from gas is the major
3 problem, then what's happening here? All the dust that's
4 being produced, and again that will be predominantly at
5 the working face of the heading, is being maintained all
6 the way back through this sluggish flow in the body of
7 the heading. So personnel working in here are going to
8 be exposed to those dust concentrations. So from the
9 point of view of dust, it is preferable for that dusty
10 air to be drawn rapidly into the exhaust duct. So, for
11 that reason, exhaust systems are preferred where dust is
12 the major problem; forcing systems where gas is the
13 predominant problem.

14 Q. All right.

15 A. There are combinations of those two, so-called
16 "overlap systems" that combine the advantages of both.

17 Q. Now it's customary in a coal mine for there to be an
18 established set of procedures enacted that can be
19 referred to by various designations. But I take it that
20 the terminology of "managers' safe work rules" or
21 something of that nature is generally the terminology.

22 And I take it that in this particular case we did
23 have a set of procedures or guidelines established for
24 the operation of Westray, including the establishment of
25 auxiliary ventilation.

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1 Can you turn to Exhibit 37A at page 118. Actually,
2 these start at page 108 and are titled "Managers' Safe
3 Working Procedures." These are the working rules that
4 should govern the operation of the coal mine, is that
5 correct?

6 A. These were the rules chosen by Westray management as
7 their recommended procedure.

8 Q. At page 118 of those rules, is that where management
9 had set out the method of auxiliary ventilation?

10 A. Yes, sir, the coal drivages.

11 Q. Can you point us there to what in the text refers
12 to, however ambiguously, to whether this was to be a
13 forcing or exhausting system? For example, I note in
14 Section 1, just under the title "fan location," the
15 statement: "Auxiliary fans will be located at least 6.5
16 meters outbye the return to the section or development
17 heading which it is feeding." That implies to me that
18 that might be an exhausting system.

19 A. That is what the wording suggests, Mr. Merrick. We
20 are referred to Diagram 5 at the end of that sentence.

21 Q. And that's at page 130?

22 A. Page 130, yes. If we refer to page 130.

23 Q. Looking at those two, what is your interpretation as
24 to what kind of a system was being called for by the
25 rules?

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1 A. Diagram 5 indicates a forcing system, clearly. The
2 fans are on the fresh air side. That is a forcing
3 system. So the wording and the diagram don't appear to
4 be entirely consistent. If I might add my interpretation
5 on this?

6 Q. Yes.

7 A. I believe that the author of these words intended to
8 say that the auxiliary fan, I'm looking at the left-hand
9 side of Diagram 5, you'll notice the distance of 6.5
10 meters minimum.

11 Q. Yes.

12 A. Which is indicating the distance between the forcing
13 fan and the junction, which might then be referred to as
14 return air. Some of it is returning from the heading. I
15 believe that is what the author intended to say, that the
16 6.5 meters should be the distance back from the return
17 where the forcing fan should be placed. But I agree with
18 you, the wording is ambiguous.

19 Q. Okay. So that looking at the two together though, I
20 take it the predominant interpretation would appear to be
21 that the mine rules called for forcing and auxiliary
22 system.

23 A. Yes, sir.

24 Q. And that clearly the diagram relates to a forcing
25 system.

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1 A. Yes.

2 Q. All right. So we know that the legislation, Coal
3 Mines Regulation Act, prohibits an exhausting system
4 except on the written permission of an inspector and the
5 rules seem to be calling for a forcing system.

6 A. Yes.

7 Q. From your review of the documents, do you know if
8 Westray applied for permission to use an exhausting
9 system? And I'll give you a page reference assistance,
10 if you can stay in the same exhibit book and turn to page
11 136.

12 A. Page 136 is a letter written by Mr. Atherton of
13 Westray to Mr. MacLean of the Department of Labour
14 requesting permission to use auxiliary fans to ventilate
15 headings.

16 Q. All right.

17 A. Followed by five bullets there indicating the
18 conditions under which those fans were intended to be
19 used. And Bullets 4 and 5 indicate that they will be
20 used either as forcing fans or exhausting fans.

21 Q. So that the legislation reads: "An auxiliary fan
22 may be installed or operated in a mine only on the
23 written permission of an inspector and after such fan has
24 been installed..." Then it goes on to say, "Shall be
25 situated on the intake side," which implies a forcing

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1 system.

2 A. Yes.

3 Q. An interpretation of that would be that the
4 legislation mandates that you can't use auxiliary fans
5 unless approved and when approved they must be a forcing
6 system. Now I know that here are other provisions in the
7 Act, though, that provide that where necessary some other
8 method approved by an inspector shall be used, which, I
9 suppose, might be broad enough to authorize exhausting
10 systems. In any event, Westray on October the 15th,
11 1991, applied for permission to use both exhausting or
12 forcing auxiliary fans.

13 A. Yes.

14 Q. And if you can look at pages, in that same exhibit,
15 pages 99 and following, I take it that those are the
16 formal approvals that according to your document review
17 were ultimately granted by the Department. Is that
18 correct?

19 A. These appear to be approvals for the particular
20 types and models of fans that Westray wished to use.
21 COMMISSIONER Would the type or model indicate whether
22 they were exhaust or forcing?

23 A. That was exactly the point I was about to make, Mr.
24 Commissioner. They do not, I believe, refer to the mode
25 in which they were used. They were approvals

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1 specifically for the model and type number of the fans --
2 the hardware, not how the hardware was going to be used.

3 COMMISSIONER I suppose whether a fan is exhausting or
4 forcing would depend on where it was located in the air
5 flow.

6 A. Exactly.

7 COMMISSIONER Yeah.

8 A. Which way the ducting was configured and which the
9 fan was turned around, exactly that. So any or all of
10 these fans could have used in either mode.

11 COMMISSIONER Okay.

12 A. The point I'm making here is the permission, is that
13 if we look at the permissions that we're looking at, are
14 permissions to use these specific fans without reference
15 to how they were being used. That's a different issue.

16 MR. MERRICK And these are the only permissions that
17 you have found so far on the document review.

18 A. Yes, sir.

19 Q. We know that there were a number of communications
20 and conversations that took place with department
21 officials, and we'll have that evidence from other
22 witnesses. You weren't privy to those, so you can't
23 speak to them. All right, so that your evidence on this
24 point we'll leave at that, that the legislation has those
25 provisions in it. The manager's rules appear to require

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1 forcing ventilation, and we saw the request for
2 permission for both forcing and exhausting.

3 Let me bring you to the adequacy of the auxiliary
4 ventilation that was actually used by Westray. Still
5 looking at the manager's rules and looking this time at
6 page 118 of that exhibit, same page we looked at
7 previously, what requirements did management have for the
8 amount of air flow to be directed at the face?

9 COMMISSIONER At what page again?

10 MR. MERRICK 118.

11 A. Two air flow numbers are mentioned, Mr. Merrick.
12 One is where LHDs; that is, diesel equipment, is being
13 used in the headings and at those times the minimum air
14 flow specified by these rules was 7.5 cubic meters per
15 second.

16 Q. That is in the second paragraph under the vent
17 tubing title?

18 A. Yes, it is.

19 Q. Yes?

20 A. "When diesel equipment is not within the heading..."
21 that is, using the words here, "not inbye the last
22 crosscut, the tubing will be sufficiently close to allow
23 for not less than two cubic meters per second within 8.5
24 meters of the face."

25 Q. 2.5 cubic meters per second?

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1 A. Yes.

2 Q. All right, so that's the air flow quantity that the
3 rules appear to require in the area of the face when
4 there are no diesel pieces of equipment operating there?

5 A. Yes.

6 Q. Take me back for a minute to what you calculated
7 would be required to prevent layering. No, just before
8 we deal with that. That amount of air flow that the
9 manager's rules called for, what do you say as to the
10 amount of air flow that that would result in?

11 A. The air flow is specified. You're requesting
12 information with respect to velocity. Air flow is
13 specified, 2.5.

14 Q. All right.

15 A. Cubic meters per second. If you can bear with me
16 just for a moment.

17 Q. All right. What about page 14 of your report?

18 A. Well, if we take that air flow, and thank you for
19 the reference, Mr. Merrick. You know my report better
20 than I do.

21 Q. Only that one. That was sheer luck.

22 A. If we take that manager's rule of 2.5 cubic meters
23 per second, and we take the cross section of the heading
24 to be the nominal value, 6 by 3.5 meters, those values
25 give an air velocity of .119 meters per second, or 24

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1 feet per minute.

2 Two comments about that velocity. One is that an
3 air velocity as low as that would be imperceptible to the
4 human body. One could not sense that with human senses.
5 So workers in an environment with that velocity would
6 effectively be conscious of stagnant conditions, number
7 one.

8 Number two, that velocity of 24 feet per minute is
9 clearly and significantly less than that that would be
10 required to prevent methane layering.

11 You recall the value of 60 feet per minute that I
12 quoted as mandatory as the minimum air velocity under
13 U.S. law? This is less than half of that. So this was
14 completely inadequate to prevent methane layering.

15 Q. Do you have any idea where management would have
16 gotten that number for their specified amount of air flow
17 for auxiliary venting of their headings?

18 A. I have no idea where they got it from.

19 Q. And I take it your comment that with that velocity
20 of air, it would, in effect, appear to be stagnant. That
21 would then be consistent with the actual anecdotal
22 recollections of any of the miners that the air would
23 feel dead and stale?

24 A. Yes.

25 Q. Let me take you to the actual measurements. We now

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1 know what the mine rules called for for air flow through
2 a heading and how insignificant it would be or how
3 significantly it was less than what was required to
4 prevent layering, and let's take you to where they did
5 actual measurements prior to the explosion of the amount
6 of air flow to see what they were actually getting in
7 fact. Can I take you to those air flow measurements that
8 we were looking at earlier and page 95 of Exhibit 37-A?
9 This is the measurement taken May the 8th, a day before
10 the explosion. And can you tell me from that what
11 measurements they were getting as to air flow through the
12 headings?

13 A. These are shown on that page you've referenced, 95.
14 They're also shown on the map of the May 8th. It may be
15 appropriate at this stage to have that map up on the
16 screen.

17 Q. All right, let's do that. That's Exhibit 45, tab
18 11.

19 A. The headings we're looking at specifically and given
20 on the sheet you've just referenced, Mr. Merrick, are
21 these two. One of those had an air flow of, and we have
22 a real mixture of units here, 5,200 cubic feet per
23 minute. And the other one, approximately the same, 5,300
24 cubic feet per minute.

25 Q. You're taking those numbers off the air flow

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1 measurements on page 95.

2 A. Yes, sir.

3 Q. And I take it that the locations that you're reading
4 those at are Southwest 2, one fan; Southwest 2, C fan.

5 A. Yes.

6 Q. Can you give me exactly where those locations would
7 be, where those readings would have been made?

8 A. Now the precise locations are not indicated, as far
9 as I'm able to find, on the ventilation sheets. One
10 would assume that they have been taken at the one or
11 other end of the ducting.

12 Q. The designation of fan, would that indicate that
13 they were taken at where the fans would be?

14 A. That would be the implication. It is not made
15 completely explicit, but the interpretation of it would
16 be that those measurements were taken at the positions of
17 the fans here.

18 Q. Okay. And using that volume and calculating it with
19 the cross section, what do you say as to the adequacy of
20 that volume of air to prevent layering in those headings
21 the day before the explosion?

22 A. Let's take the 5,200 cubic feet per minute that was
23 measured in one of those headings. That actually
24 converts to a metric unit of 2.45 cubic meters per
25 second.

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1 COMMISSIONER 2.45?

2 A. 2.45, sir, yes. So this was close to the 2.5
3 indicated in the manager's safe working procedures.

4 MR. MERRICK Yes.

5 A. So it was close to those manager's requirements,
6 which indicates, of course, that it was grossly
7 inadequate to prevent methane layering.

8 Q. In fact, doing the two calculations, I think you've
9 said in your report that between the two of them, one was
10 only 26 percent of what was needed to prevent layering
11 and the other one was only 44 percent of what was needed
12 to prevent layering.

13 A. That's right.

14 Q. If that is the case, and leaving aside for a moment
15 any other mechanisms by which mixing could occur, as far
16 as the auxiliary ventilation was concerned, it would not
17 prevent gas from layering. Therefore, any gas coming out
18 of the headings that were being cut or out of the walls
19 itself would tend to stream up to the roof and layer
20 along the roof?

21 A. Yes, if you refer again to my pictures of exhausting
22 and forcing, an exhausting system was being used in these
23 headings. So the velocity that we're referring to, the
24 air flow of 2.45 and the corresponding velocity of .119
25 or 24 feet per minute, pertained here. Where you really

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1 need it is up here, and, of course, the velocities up
2 there caused by the ventilation system in the heading
3 would be even less. So the answer to your question, and
4 sorry for the long explanation, is, yes, the gas would be
5 likely to be streaming up the sides, the rib sides, in
6 that end of the heading and, in that case, would produce
7 formation of methane layers.

8 COMMISSIONER So the air at the working face was, for
9 all intents and purposes, stagnant.

10 A. We should perhaps, Mr. Commissioner, get on in a
11 moment to the other reasons why there would be air motion
12 at this end.

13 COMMISSIONER Okay.

14 A. What we're saying is from the point of view of the
15 duct system, there was effectively no ventilation at
16 the --

17 COMMISSIONER Okay, thank you.

18 MR. MERRICK Let's look at what other mechanisms there
19 might have been to avoid it being completely stagnant.
20 To begin with, the cutting heads on the miner itself
21 rotate.

22 A. Yes, sir.

23 Q. To what extent and how adequately would they cause
24 circulation in order to mix the methane?

25 A. Taking that by itself for the moment, the motion of

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1 the cutting head of the drum, the cutting drum of the
2 continuous miner would create air movement around that
3 cutting head, and this would be a mechanism that would
4 help to dilute the methane that's produced at the peak
5 point. That by itself might also, in the absence of any
6 other mechanism, cause uncontrolled recirculation in the
7 immediate vicinity of the drum itself. So this would be
8 a means of mixing, but this would be a good example of
9 uncontrolled recirculation which could and would result
10 in a build-up of gases.

11 Q. So that you may be mixing methane to bring it into
12 the content of the general body of air, but the general
13 body of air in the vicinity of the rotating head may be
14 going up to an explosive level of methane.

15 A. Right, unless, unless there is a through flow of air
16 to continuously maintain further dilution of the methane.

17 Q. And how effective, assuming for the moment that the
18 cutting heads are, in fact, mixing the methane and
19 diluting it, how effective is that for the whole of the
20 area of the face that's being cut itself? For example, I
21 understand that when they cut, they will sump in the
22 cutting heads some distance.

23 A. Yes. The actual situation, of course, is that they
24 will sump in and cut coal on one side of the heading. So
25 now shading in the solid coal, we have a situation like

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1 this. So the machine, the continuous miner, would sump
2 in one side, raise its cutting jet to the roof upwards or
3 downwards, and leave sides here of very recently exposed
4 fresh coal surface. And although mixing could well be
5 and would be taking place in this sump area, there would
6 be little mixing caused by the drum on these freshly
7 exposed rib sides. And, of course, this whole block here
8 is still emitting methane also.

9 Q. All right.

10 A. Methane is being emitted from all of the rib sides
11 all the way back, but the older these surfaces; that is,
12 the longer they have been exposed, then the less will be
13 the amount of methane coming through them unless they are
14 being subjected to squeeze and are further crushing as we
15 discussed this morning.

16 Q. Okay. I understand that there are other systems on
17 the continuous miner that might also cause mixing. For
18 example, a dust extraction system, which we know that
19 these continuous miners had. To what extent, if it were
20 running, would that provide some degree of mixing of
21 methane to overcome the deficiencies in the auxiliary
22 ventilation?

23 A. This would assist significantly. The purpose of the
24 dust suppression extraction system is to draw dust-laden
25 air from the vicinity of the cutting heads, pass it

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1 through, pass that dust-laden air through a filter and
2 eject it out of the back of the continuous miner. That,
3 of course, implies a ventilation system across the
4 continuous miner and through the continuous miner itself.
5 So that would be another means of diluting the methane
6 actually at the cutting head.

7 If the exhaust from that dust suppression system is
8 encaptured by the flow of air going into the end of the
9 exhaust duct, then that would assist in the overall
10 dilution of the end of the face. You recall in the
11 manager's rules that the end of the duct should have not
12 been more than 8.5 meters back from the working face.
13 This is the purpose of that kind of restriction, to
14 ensure that the ducting, the end of the ducting in either
15 case is kept sufficiently close to the face that that
16 through flow ventilation is maintained close to the face;
17 that is, up to the back of the continuous miner. It
18 would clearly be impracticable to take the ducting right
19 up into the face itself. The continuous miner is in the
20 way.

21 Q. Yes. I would assume as well that if the dust
22 suppression system on the continuous miner were
23 operating, there would be the risk of an uncontrolled
24 recirculation occurring there as well.

25 A. If the ducting is not sufficiently far advanced to

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1 take the exhaust coming out of the back of the continuous
2 miner into the duct, yes.

3 Q. All right. In your review of the documentation and
4 statements that have been provided, have you located any
5 evidence indicating whether on the night in question the
6 dust extraction system on the continuous miner up in that
7 heading was, in fact, operating?

8 A. Yes, sir.

9 Q. And perhaps I'll refer you to Exhibit 37-B at page
10 113.

11 COMMISSIONER 37-B?

12 MR. MERRICK B, page 113. This is a statement given by
13 Mr. Don Dooley, I take it on the evening of September the
14 27th, 1992, in a debriefing following an incursion into
15 the mine by a draeger crew with the RCMP doing an
16 investigation. This would have been after the explosion,
17 of course, and they would have been looking at the
18 equipment and, in particular, the continuous miner up in
19 the roadway. Now let me just find it for you.

20 A. If you look at approximately two-thirds down the
21 page, there's a sentence starting "Check the dust
22 collection system..."

23 q. Yes.

24 A. "On the miner," continuing, "In the off position.
25 Was not running at the time."

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1 Q. So that if, in fact, at the time of the explosion
2 that system was turned off, then for some period of time
3 at least prior to that, it would not have been assisting
4 in any way in the mixing of the methane up in that
5 heading?

6 A. That is correct.

7 Q. Even if it had been running and taking in account
8 the mixing abilities of the dust suppression system and
9 the mixing abilities of the cutting heads as they would
10 work, in your opinion, would they be sufficient to
11 overcome the inadequacies of the auxiliary ventilation as
12 we know it existed in there prior to the explosion?

13 A. No, sir, I believe not because the inadequacies of
14 that ventilation in the headings were inadequacies with
15 respect to methane layering. The layering would occur,
16 in my opinion, because of streaming of gas from surfaces
17 other than those immediately being worked. The
18 references you've made to dust suppression and the
19 movement of the cutting heads would help, certainly, to
20 mix gas in the immediate vicinity of the fragmentation
21 process, but they would do nothing all around these
22 surfaces that I referred to which were standing rib
23 sites. Methane produced from those rib sites, from those
24 freshly exposed surfaces, would stream to the roof in the
25 absence of adequate velocity and form methane layers.

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1 May I add one further comment on this? And that is
2 that the air velocity in any mine airway is not uniform
3 across the full cross section. This is why one takes an
4 integrated traverse when measuring the volume flow. The
5 air velocity around the perimeter, roof, floor and sides,
6 drops down essentially to zero. So, at these positions
7 on the rib sides where methane is streaming upwards,
8 there is very little velocity even in an adequately
9 ventilated heading.

10 Q. Would it be fair to say then that on all the
11 evidence that we've just reviewed, there is a pretty good
12 indication that immediately prior to the explosion, there
13 was inadequate mixing of the methane gas occurring in
14 that heading and, indeed, it was likely that methane was
15 layering?

16 A. That is my opinion.

17 Q. All right, thank you. Now we'll come back to a
18 couple of the other components of this in a minute. Just
19 before I do, I want to cover off the ducting size that
20 was being used in there as we talk about the adequacies
21 of the auxiliary ventilation system. Your opinion is
22 that they were using inadequately sized ducting.

23 Let me start or perhaps the best way to start with
24 how you arrive at your -- You tell me how you arrive at
25 your opinion. You begin with the Norwest numbers again,

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1 and as I understand your report, they arrived at the
2 figure of 4.8 -- Is this cubic meters or meters per
3 second?

4 A. Cubic meters per second.

5 Q. Cubic meters per second to dilute the gas. They
6 then decided that they should have at least 6.6 cubic
7 meters coming through the duct in order to accommodate
8 leakage.

9 A. Yes.

10 Q. Is that right?

11 A. Yes.

12 Q. And they then stated the duct diameter, without
13 doing a calculation, at 36 inches.

14 A. Yes.

15 Q. In fact, if we look at volume 8, just so we can
16 track it step by step, and we look at page or section 13
17 decimal one -- or dash one. Actually, it should be 13
18 dash 11. My eyes have gone on me.

19 A. I seem to have lost my copy of Exhibit 8, Mr.
20 Merrick, but please proceed.

21 Q. No, just a second, we have a very efficient system
22 here.

23 A. Page number again?

24 Q. 13 dash 11.

25 A. Yes, thank you. Yes, I've got it.

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1 Q. They show a ducting diameter there of 915
2 millimeters which is what in inches so I can compare
3 apples to apples?

4 A. 36 inches.

5 Q. All right, do they give any explanation as to how
6 they arrive at that?

7 A. No, they seem not to have given any explanation.
8 It's simply stated as a factor they've used.

9 Q. Okay, but according to your calculations, if you
10 were, in effect, to have sufficient air flow to dilute,
11 you told us earlier in your evidence you would need 6.9
12 cubic meters per second to bring it down to a .5 dilution
13 ratio. And that to avoid layering, and we went over this
14 before the break, you would need 8.4 cubic meters per
15 second of air flow. Now assuming that to be correct that
16 we need 8.4 cubic meters per second, what duct size would
17 you require?

18 A. I calculated it to be 40.7 inches. In practice, one
19 would round up to the nearest standard size above that in
20 which case this would be 42 inches duct diameter.

21 Q. And if you were to attempt to put an air flow
22 through a 36-inch duct tubing that would, in fact, be
23 adequate enough to prevent layering in the heading, for
24 example, if you were getting readings near the roof or
25 reading of methane, and you had to therefore put that

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1 volume of air through that ducting, what impact does it
2 have on the ducting?

3 A. The calculations that Norwest engaged in and implied
4 a velocity of -- velocity, not volume flow, of 10 meters
5 per second, an air speed of 10 meters per second through
6 the ducting. That is again a guideline number that I
7 also use for initial estimates of duct size. So I'm in
8 agreement with their duct size for their air flow. The
9 reason I finished up with a larger duct size was because
10 of my increased air flow requirement.

11 Now having said that: What happens if you use a
12 smaller diameter? Let us take an air flow, a fixed air
13 flow. Let us agree on some air flow that's going to go
14 through a duct. That is fixed. If we then make that
15 duct smaller with the same air flow, then obviously the
16 velocity has to increase.

17 As the velocity increases, that means two things.
18 First of all, it means you have to put a fan on there
19 developing a larger pressure. And secondly, the power
20 taken by that fan will increase. It will be more
21 expensive to run.

22 Now I would be quite happy to see duct diameters
23 going down, air velocities increasing, and fan powers
24 going up to a certain limit. I have, in fact -- mining
25 engineers will have seen air velocities of up to twice

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1 the 10 meters per second, 20 meters per second going
2 through ducts. But this does mean that you're going to
3 have to have larger pressure fans, one. And two, you're
4 going to have to have fans with greater power, greater
5 pressure, and let me add a third: because of that greater
6 pressure, you're going to have to have ducting that is
7 mechanically, physically, strong enough to withstand
8 those higher pressures.

9 So the point of this dissertation, Mr. Merrick, is
10 to say that my 10 meters per second used by myself and
11 Norwest is not cast in concrete; it can be increased, but
12 at the expense of larger fans, greater power requirements
13 and higher pressures in the ducting.

14 Now being specific about the situation at Westray:
15 They employed ducts that gave them inadequate air flows
16 in the headings. Now instead of increasing the duct
17 sizes, they attempted to compensate for that by adding
18 higher-powered fans in an exhausting system. In
19 exhausting systems. That meant that they had greater
20 pressures, suction pressures, being developed by those
21 fans, and the spiral ducting that they were using was
22 inadequately strong, on a number of occasions, to
23 withstand that higher suction pressure, and the tubing
24 collapsed on those occasions.

25 Q. That would thenfore [sic] explain any incidents that

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1 we've seen recorded in the shift reports of collapsed
2 tubing?

3 A. Yes.

4 Q. Or problems where they had to replace tubing because
5 it collapsing. Or anecdotal evidence from miners who
6 were there --

7 A. Yes.

8 Q. -- who say they saw tubing collapse?

9 A. Yes.

10 Q. In your opinion that is because they were putting a
11 fan power on that tubing that was too much for the
12 tubing --

13 A. Yes.

14 Q. -- and trying to compen -- as you say, trying to
15 compensate for the lack of a sufficient auxiliary
16 ventilation and certainly the ventilation coming through
17 that sized ducting?

18 A. To compensate for the inadequately-sized ducting,
19 yes.

20 Q. All right. In your report you have in the middle of
21 it, a table in which you have gone through the shift
22 reports, and I'm looking at page 22 and following, and
23 pulled out and noted incidents relating to various
24 components of the mining process. And in particular, if
25 you can turn to page 28, we see there on the date of May

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1 the 7th, 1992, "Southwest 2 vent tubes collapse on new
2 fan. Night shift." That would corroborate what you're
3 saying?

4 A. Yes, sir.

5 Q. Okay. Let me take you to one other preliminary top
6 -- not preliminary, but component to this whole picture.
7 Series ventilation. Now you've told us that series
8 ventilation -- or we've heard that series ventilation can
9 be safe provided that there's adequate flow-through to
10 dilute the methane that's coming out of the one heading
11 and going into the next. Can you identify for us whether
12 they were using series ventilation in both the Southwest
13 District and the North? And I would appreciate your
14 comments on the significance of it.

15 A. Yes, again, we should refer to the maps on the
16 board. The headings being fed by Southwest 2B Road, we
17 have one, two, three headings, effectively. Four
18 headings including the stump here where the roof bolter
19 is. Those are being ventilated by two ducts, in both
20 cases, bifurcated, each duct serving two headings. And
21 those are coming out exhausting into the crosscut.
22 Southwest 2 -- 2 Crosscut here. That air then having
23 been partially utilized within those headings is also
24 moving onwards; the air direction is downwards, as we
25 look at the board. And that air which has already been

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1 used, partially used, in these headings, is again
2 utilized by the exhaust ventilation duct in this heading.
3 So there we have this set of headings and the A-Road
4 heading being ventilated in a series. That is an example
5 of series ventilation.

6 Q. Yes.

7 A. Now, as you've indicated, this is an acceptable
8 practice provided that there is sufficient air moving
9 around the infrastructure, moving around here in this
10 case, to provide adequate dilution of the gases that are
11 coming out of the ducting into that ventilation
12 infrastructure.

13 Q. And what do you say as to whether, with the
14 ventilation flows that we know about, that that was the
15 case here?

16 A. I am quite happy with the infrastructure, the
17 through-flow system, in the Southwest area. So the total
18 flow-through here, the numbers are given. There's an air
19 flow measured there, of 59,800 cubic feet per minute
20 which would certainly be adequate to dilute the polluted
21 air that's coming out of two sets of headings in series.
22 So I have no problems with this. This is quite
23 different, of course, to what's happening inside the
24 headings themselves.

25 Q. Yes.

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1 A. Okay?

2 Q. Yes. Now I'm going to take you to the North Mains
3 though where perhaps a different scenario unfolds. Tell
4 us what we've got there for series ventilation and your
5 opinions on that.

6 A. Well, in this case, and we're looking at the
7 situation as it pertained on May the 8th, the day before
8 the explosion. We have the main infrastructure again, a
9 measurement of 63,800 coming up the intake here, going
10 back, eventually, along the returns. "Blue" is intake;
11 "red" is return on these diagrams.

12 The crosscuts, I'd like to refer to -- between the
13 intake and the return, refer to as 4 Crosscut moving
14 back, 2 Crosscut moving back, 1 Crosscut. In normal
15 circumstances one would expect for a leakage to take
16 place from the intake to the return side through those
17 crosscuts. Leakage that should be controlled by
18 adequately constructed stoppings in those crosscuts. At
19 the time of the explosion, this crosscut --

20 Q. This is --

21 A. -- had a stopping that was not finalized. It was
22 not completed.

23 Q. What's the identification of that crosscut?

24 A. Crosscut 4. No, I'm -- No. It's Crosscut --

25 Q. It's the one above --

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1 A. -- is the one --

2 Q. -- or inbye 4?

3 A. It is not labelled here; presumably, it would be
4 Crosscut 5. But it appears not to be labelled.

5 Q. Okay. But there's a notation to the side that
6 notes, "Chocks covered with plywood bracket (being
7 constructed at time of accident)" end of bracket.

8 A. Right. The point being that was not a completed
9 stopping at the time of the explosion. So one would
10 expect that there would be a short circuit, a direct
11 short circuit, between the intake and the return because
12 of a stopping which was not completed. There appears to
13 be nothing to prevent that air from short circuiting
14 across there under normal circumstances.

15 But let's take a look at what was actually the
16 situation. Going -- following the blue arrows around
17 here in this little loop from intake to return. This
18 flashing light is annoying me.

19 Q. It's a rocker switch. It's hard to get that front
20 position.

21 A. I'll use it in this way. The air moving around
22 here. Let's examine this circuit. This air is moving
23 around and let's count them. Headings in these donated
24 roads, A Road, B Road, et cetera, all in series, one
25 after the other. One heading, two, three, a double one

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1 here, four and five. Five headings being ventilated in a
2 series in a loop which probably, there's no measurements
3 given in here, probably contain inadequate air flows to
4 dilute that methane down to safe concentrations.

5 Q. So for that number of series ventilation, it's
6 doubtful whether the air flow would have been adequate?

7 A. Yes, sir.

8 Q. Yeah.

9 A. If I may carry on? We now have five headings in
10 series following that same return route coming down here.
11 We now have the headings in the Southeast area also
12 effectively in series.

13 Q. Yes.

14 A. There's another two headings down there, so we now
15 have finished up with seven headings in series.

16 Q. For that same general body of air?

17 A. For that same general body of air.

18 Q. Yeah.

19 A. There were further problems associated with this
20 area of the mine; do you want me to speak to those now or
21 -- while I have the map in front of us?

22 Q. No, might as well.

23 A. Okay. It was clear to the mine personnel in this
24 area of the mine that gas concentrations were not
25 satisfactory. And one can look at this map and see the

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1 steps they try to take. Here, for example, we have a
2 duct in a -- a forcing duct. A short stub of forcing
3 duct in a most unusual location.

4 It is taking its air from this path and blowing it
5 just a short distance into this heading. Now one can
6 only assume that that was placed there because of the
7 inadequacy of the exhausting system to pull air up the
8 heading and then return it back through the exhausting
9 duct. So one assumes that this was an attempt to
10 persuade air to move into the heading. By physical
11 principles, it could not have been very successful.

12 Also, when we come back around the return route --
13 Q. Just before you leave that, because this particular
14 combination was also drawn to our attention by Mr.
15 Smales, who had no explanation as to what they were doing
16 or why they were doing it. Does it make sense to you,
17 what they've done?

18 A. It is very poor ventilation practice, number one.
19 Number two, I can only assume it was an attempt, and I'm
20 repeating myself here, I can only assume it was an
21 attempt to persuade air to progress up this heading and
22 back along the exhaust ducts. By the laws of physics, it
23 could not have been very successful, if successful, in
24 any sense at all.

25 Q. All right.

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1 A. Okay. Another feature of this repeated system of
2 fans in series was one which, again, by physical
3 principles was inevitable, although it may not have been
4 obvious due to the people on the spot, and that is that
5 each time, each time, we have a jet of air coming out of
6 the end of the fan, exhausting back through the duct --
7 remember we talked about jets of air in the forcing
8 system? The same thing is happening. But, of course,
9 now the jet is into the return side of the main body of
10 air. This is happening all the way around here. A jet
11 of air will induce motion of the general air body. It's
12 used quite commonly in civil engineering tunnels for
13 vehicular transportation and so on. Free-standing fans
14 just producing a jet of air. They're called "jet fans."
15 So these would induce a through-flow ventilating effect.
16 This would also be the situation here, perhaps
17 exacerbated by this short length of forcing duct.

18 It was analogous to little fans producing an air
19 flow and therefore a ventilating pressure around this
20 circuit. And one can refer to, and when I go back in a
21 moment you may help me to find these -- refer to
22 situations where instead of the air moving from intake to
23 return, as it normally would through leakage, it was
24 actually going the other way.

25 Q. Because those little fans were increasing the

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1 pressure in that return roadway --

2 A. Right. They were --

3 Q. -- over and above what the pressure was in the
4 intake?

5 A. Exactly. They were pressurizing the return above
6 that of the intake causing uncontrolled recirculation.
7 This is what gives recirculation a bad name. This kind
8 of situation. This is uncontrolled recirculation.

9 So this would result in increasing methane
10 concentrations around that loop in the same location
11 where we have seven headings in a series. This was a
12 complete nonsense from the point of view of ventilation
13 design.

14 Q. Let me just take a look for a moment with you at
15 those ventilation air flow measurements so we can close
16 off this point, just to establish that that's in effect
17 what was happening. In Exhibit 37-A, let's start at page
18 80, I guess. And this is reflected in a number of the
19 documents but -- actually, 80 is -- well, I'm looking at
20 the wrong one. Do you see it there? Maybe not.

21 A. Yes. If you turn to -- yes. In the middle of page
22 80. "Crosscuts N-4."

23 Q. Yes.

24 A. "Block by 4 approximately 11,000 cfm recirculation."
25 Let's take a look at Crosscut 4. There are other

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1 examples of this. But Crosscut 4 was the one I got
2 confused about earlier. It's this one.

3 Where one would expect the airf low to go from
4 intake to return, in fact, 11,000 cfm were going that
5 way.

6 Q. So they were actually measuring this --

7 A. Yes.

8 Q. -- coming back in the wrong way?

9 A. That was measured.

10 Q. Okay.

11 A. And there are other examples of that in these --

12 COMMISSIONER That's that "N-4 Crosscut blocked by fall,
13 approximately 11,000 cfm recirculation"?

14 A. Yes, sir.

15 COMMISSIONER Is that what you're referring to?

16 A. Yes.

17 COMMISSIONER Okay. Thank you.

18 MR. MERRICK I assume that the N-2 Crosscut would be
19 the one a little further outbye --

20 A. The one below, yes.

21 Q. -- and they were measuring recirculation there as
22 well?

23 A. Yes.

24 Q. And if we were to go through those air --

25 COMMISSIONER The B Road outbye, did you say? The B

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1 Road outbye.

2 MR. MERRICK No, the -- I was looking at the 2 Crosscut
3 which I was saying would be outbye the 4 Crosscut that we
4 just looked at on the map.

5 COMMISSIONER I can't find the 2 -- oh, up in the -- in
6 the fan section?

7 MR. MERRICK No, right there in the stoppings. We
8 looked at the No. 4 Crosscut --

9 COMMISSIONER Okay. Yeah.

10 MR. MERRICK -- and No. 2 Crosscut.

11 COMMISSIONER Okay. Fair enough.

12 MR. MERRICK And if I can just, for example purposes,
13 flip you to page 83, that's a measurement taken on April
14 the 15th, a week later. Do we see evidence of the same
15 thing again?

16 A. Towards the bottom of page 83. "Crosscut 4 again
17 approximately 10,000 cfm recirculation."

18 Q. So they're still recirculating that amount of air?
19 Approximately.

20 A. Yes, sir.

21 Q. And we can go on.

22 COMMISSIONER What was the time frame there, Mr.
23 Merrick?

24 MR. MERRICK This is the -- the date on that
25 ventilation survey was April the 15th. Page 82.

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1 COMMISSIONER Yeah.

2 MR. MERRICK And the one previous to that was April the
3 8th.

4 COMMISSIONER So in -- that recirculation was carrying
5 on undisturbed during that whole period?

6 MR. MERRICK To that extent, yeah. That's right. I
7 would assume, Dr. McPherson, that you would understand
8 that it was happening during the whole of that time
9 between those two measurements?

10 A. Yes, indeed. And would you also, Mr. Merrick, turn
11 to page 85? This is the April 23rd survey.

12 Q. Yeah.

13 A. Two pages further on, 87, subparagraph --

14 COMMISSIONER You're calling that a survey subject to
15 your previous reservations about the use of that term?

16 A. I am indeed, sir. Yes.

17 COMMISSIONER Okay.

18 A. Thank you. The comment there is that there is
19 13,260 cfm recirculation from 2 East into 1 East.

20 MR. MERRICK Which is?

21 A. 2 East, 1 East. This is recirculation presumably
22 back through this stopping here. So in addition to the,
23 let us call it the large loop of uncontrolled
24 recirculation, within that, we have another smaller loop
25 of uncontrolled recirculation, but this time to a larger

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1 extent: 13,000 cfm plus.

2 Q. Leading up to May the 9th?

3 A. [Witness nods head "yes"]

4 Q. What --

5 COMMISSIONER Is it fair to say then as a result of
6 those recirculation -- as the air was going through this
7 uncontrolled recirculation, it was picking up whatever
8 methane was around and increasing the volume in the
9 recirculated air?

10 A. To a certain limiting level, sir, that is true.

11 COMMISSIONER Okay.

12 A. The limiting level will be determined by the amount
13 of through-flow air, not readily apparent from these
14 maps, that was going around those loops.

15 COMMISSIONER Okay. Thank you.

16 MR. MERRICK So what you've described to us is a series
17 of loops? Not just one recirculation loop in the North
18 Mains but a series of them.

19 A. Two loops. To be specific in the answer.

20 Q. And --

21 A. Well, yes, there are loops through every crosscut
22 that's recirculating. Yes, that's true.

23 Q. About four -- three or four of them? Maybe even
24 four or five of them?

25 A. Yes.

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1 Q. There's some impression I get as a lay person to
2 your evidence is, is that that's a dog's breakfast of a
3 ventilation circuit.

4 COMMISSIONER That's new mining term, Mr. Merrick.

5 A. I find it interesting to look at the response to
6 this situation that's given on these so-called surveys.
7 The one that's already in front of us, the three -- the
8 13,260. See what their response to this situation is.

9 MR. MERRICK What page are you looking at?

10 A. Sorry, page 87. I thought we were still looking at
11 this.

12 Q. Yes.

13 A. On page 87 their response was to construct a
14 stopping in 3 North to prevent that recirculation. And
15 one can look back at the pages we've already looked at
16 and see similar responses. The response was let's
17 improve or put stoppings in these recirculation zones.
18 Their response should have been why is that recirculation
19 happening and how can we stop it?

20 Q. And you've seen no indication of them being able --
21 of doing or being able to do that inquiry?

22 A. I've seen no such indication.

23 Q. And I guess more to the point than my layman's
24 comment of a few minutes ago, would it be fair to say
25 that what you see in the North Mains then was a serious

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1 ventilation problem that was probably tending to
2 increasing gas concentrations and had the mine not ended
3 on May the 9th may have been leading to a problem in the
4 North Mains?

5 A. Yes, it -- the whole system up there, Mr. Merrick,
6 was a complete abortion. It was ridiculous.

7 Q. So we've seen a mine that narrowly averted a
8 disaster in the old Southwest District 1 purely by luck;
9 hit a disaster on May 9th and yet was heading for another
10 one in the North Mains?

11 A. Apparently so.

12 Q. A series of disasters waiting to happen?

13 A. It may be described that way, yes.

14 Q. Perhaps, Mr. Commissioner, that would be an
15 appropriate break point.

16 COMMISSIONER Thank you, Mr. Merrick. We'll adjourn
17 until 9:30. Thank you, Doctor.

18 INQUIRY ADJOURNED (TIME: 4:35 p.m.)

REPORTER'S CERTIFICATE

I, Margaret E. Graham, Court Reporter, certify that the foregoing is a true and accurate transcript of the evidence taken by way of recording and reduced to typewritten copy.

Margaret E. Graham

DATED this 20th day of November, 1995, at Stellarton,
Nova Scotia.