6 The Explosion

To inquire into . . .

(c) whether any neglect caused or contributed to the occurrence;

(d) whether there was any defect in or about the Mine or the modes of working the Mine

The first of the terms of reference set out in the Order in Council that established this Inquiry deals with the direct cause of death of the 26 miners on 9 May 1992.[1] This Inquiry must address two main questions: How did those 26 miners die? And why did those 26 miners die? The "how" is relatively straightforward and will be answered, as best it can be, in this chapter. The "why" is decidedly more difficult and involves multifaceted considerations – of planning, development, supervision, management, and regulations – that take the balance of this Report to address and, as possible, to resolve. In my capacity both as a special examiner under the *Coal Mines Regulation Act* and as a Commissioner under the *Public Inquiries Act*, I feel it is incumbent on me to "inquire into and report" on the proximate and probable cause of the explosion.

I have relied to a considerable extent on the report and testimony of coal mine explosion expert Reg Brookes in compiling this chapter on the explosion. He has extensive and special expertise in underground coal mine fires and explosions. From 1960 until his retirement in 1987 he was involved in the investigation of all but one mine explosion in the United Kingdom, and he has written, alone or jointly, nine reports on the examination of mine explosions. He has done far-ranging research and has written extensively on the subject.[2] He came to the Westray mine in early June 1992, participated in the interviews of several mine officials, and went into the mine in the company of a team of draegermen (mine rescue personnel). I was most impressed with Brookes as a witness. He was generally understated in his commentary and gave freely of his expertise in answer to questions by counsel, without embellishment but with keen perception. His opinions and conclusions seemed to flow logically and dispassionately from an incisive grasp of the subject.

Brookes's testimony is not the only evidence on record to bear on the actual explosion. In reaching a conclusion about the probable source of ignition, we carefully examined all the related expert opinions and anecdotal evidence.[3] In addition, a wealth of material – such as research findings, other explosion reports, and commentary dealing with mine explosions – formed part of the inquiry into the immediate cause of the Westray explosion. It was important to examine the interrelationship of all the forces and factors at work, not only at the time of the ignition but also

[1] NS Order in Council 92-504, 15 May 1992.

[2] Exhibit 53.1, Curriculum vitae for Reg Brookes.

[3] My comments about Reg Brookes are in no way intended to denigrate the expertise of other expert witnesses. Although Brookes's expertise in explosion investigation is more closely focused on the subject of this chapter, I have relied extensively on the evidence of the other experts in matters germane to their areas of expertise. Of course, the facts on which the experts' opinions were based were drawn from the transcripts of miners' interviews, documentary evidence, and in some cases on the evidence of witnesses during the hearings.

leading up to that time. This is a useful exercise in that it illustrates how these seemingly unrelated components came together to create the fatal result. It further illustrates the importance of ventilation, methane detection and control, dust control, housekeeping, ground control, and equipment maintenance – and how each of these separate categories has an impact on mine safety in general. This is consistent with the closing comments of Dr Malcolm McPherson in his report of 28 February 1996:

> It was indicated earlier in the public hearings of the Inquiry that one of the purposes of these proceedings is to establish, as far as is possible, the sequence of events that took place in the Westray Mine on 9 May 1992. It is toward that end that rigorous examination of alternative hypotheses of the cause and behaviour of the explosion is directed. Nevertheless, I am in agreement with [Andrew] Liney and others who have commented that whatever the precise sequence of events, the conditions that were allowed to develop at Westray were such as to generate a very high probability that a major hazardous incident would occur early in the life of the mine.[4]

Brookes approached this question in a somewhat different manner when he replied to counsel for the Inquiry:

> Q. [W]hat do you say as to how significant it is that we may never be able to pinpoint the exact location?
>
> A. [I]t's nice to be able to answer the question and . . . from the investigator's point of view . . . being able to say that this was the point where it started and to explain it fully . . . but . . . in this case it's not a great deal of significance to actually know what the igniting source was. I think the point is that the igniting sources were there available and the fuel was there, was available. And those two produced a deadly mixture. You've got to have the two of them to produce the explosion.[5]

Basically, I interpret Brookes as saying that the conditions that were allowed to develop at Westray have greater significance than the actual source of ignition, since without those conditions any spark or other ignition source could not have propagated anything.

Sources of Ignition

A few cautionary comments may be helpful before continuing with the review of the evidence. Many of the facts and findings in this chapter are the subject of more detailed comment in other portions of this Report. For instance, a finding of excessive accumulations of methane will be more thoroughly reviewed in Chapter 7, Ventilation, so there is no need here to set out the background or the premises and scientific data on which those concepts and conclusions are based. By the same token, commentary on the matter of roof cavities and their propensity to trap methane will be discussed in both Chapter 8, Methane, and Chapter 10, Ground Control. Although this narrative is of considerable length and detail, we must bear in mind that the total occurrence, from the first ignition of the methane to

4 Malcolm J. McPherson, A Review of the Testimony of Andrew D. Liney, 28 February 1996, p. 7.

5 Hearing transcript, vol. 11, p. 2031.

the surface blast through the main portal, probably lasted fewer than 20 seconds.[6]

A word of caution about the evidence of the draegermen and the miners who later accompanied the RCMP into the mine to assist in their investigation. When they went into the mine during the rescue operation, they were primarily interested in locating the missing miners. Their observations of the conditions would be peripheral to their main task – rescue. Their only source of light at these times would be their cap lamps, which are very directed. Areas of the mine not directly illuminated by the lamps would be in pitch darkness, and, for this reason, the witness's perspective as to distance and location would be somewhat limited. These comments are not meant as criticism of the work of the draegermen or other rescue workers, or to denigrate their evidence. I make these observations only to underline the extremely stressful conditions that draegermen had to contend with, and how that may affect the accuracy of their recollections. For these reasons, we may be faced with seemingly contradictory interpretations of the conditions existing in the post-explosion underground.

The Equipment

The various pieces of equipment referred to throughout this Report may be unfamiliar to the average reader. Some of the equipment is illustrated in Reference, and the following brief comments on their respective places in an underground mine may assist readers in understanding the narrative.[7]

Continuous miner Photo 1 in Reference shows a new continuous miner on the surface at Westray. This machine literally carves the coal from the working face of the mine. It is the producer and the key to room-and-pillar mining. A horizontally rotating drum is studded with picks, which chew the coal from the face (see photo 2). This cutting head is hydraulically raised and lowered to mine the coal. The resulting chunks of coal fall onto a chain conveyor that carries the coal to the rear of the machine. The continuous miner is powered by electricity and is self-propelled, moving on bulldozer-like tracks. Normally, two people operate and tend to the machine.

Shuttle car This box-shaped vehicle receives coal from the continuous miner and transports it to the feeder-breaker. The rubber-tired shuttle car is electrically powered and driven by one operator. A new shuttle car (without wheels) is illustrated in photo 3 in Reference.

Stamler feeder-breaker This machine, located at the tail end of a belt conveyor, takes coal from the shuttle car, breaks up the larger pieces, and

6 Brookes estimated the flame speed as it travelled out of the mine to be 150 m/s or 340 miles per hour. He agreed with the Commissioner's suggestion that, after developing into a coal dust explosion, "the entire event would have been over in less than 10 seconds . . ." (Hearing transcript, vol. 11, pp. 2027–28). Liney came to a similar conclusion about flame propagation speeds (vol. 18, p. 3318).

7 These and other pieces of mining equipment are also defined in the glossary in Reference.

feeds the coal evenly onto the belt conveyor. See photo 4 in Reference. The feeder-breaker is not mobile and can operate unattended.

Roof bolter After the continuous miner finishes a "cut," this machine is brought into the heading. The roof bolter drills holes in the roof (and sometimes the ribs) and sets steel bolts in the holes with resin. The bolts hold the roof strata together to keep the roof from "caving," or falling apart. Screens and straps are then secured to the bolts with steel plates and nuts to keep small material from falling to the roadway. The roof bolter incorporates an automatic temporary roof support (ATRS) system to enable the bolting crew to work under otherwise unsupported roof. Like the continuous miner, the roof bolter moves on tracks and is electrically powered. A crew of three operated the double roof bolter used at Westray. Photo 6 in Reference shows a typical bolting operation underground at Westray.

Boom truck This rubber-tired diesel-powered utility vehicle transports materials to working areas of the mine. It is equipped with a hydraulic arm for lifting and moving heavy materials.

The Mining Cycle

It may be helpful to the reader to describe briefly the sequence – the "mining cycle" – in which this equipment is used. Graham Clow and John Smith gave succinct descriptions of the cycle – cut, support, clean up, and do it again.[8] The cycle commences with the continuous miner, which moves to the working face and cuts coal from floor to roof for about 6 m.[9] As the coal is cut, it is transported by a chain conveyor on the miner to a shuttle car parked at the rear of the miner. When loaded, the shuttle car takes the coal to a feeder-breaker, which breaks up any large pieces and feeds the coal onto a conveyor belt for transport to the surface. At Westray, the continuous miner normally operated with two shuttle cars taking turns, thus keeping the miner as productive as possible. Because of the width of the roadways at Westray, the continuous miner made two cuts into the working face for each mining cycle.

After completing a cut, the continuous miner is moved out of the heading and the roof is secured with roof bolts. When the entire cut has been adequately bolted, the roof bolter is removed. The newly mined and bolted heading is cleaned by gathering any loose coal and garbage with a Scooptram or other permissible equipment. The loose coal is moved to the face, where it will be picked up by the continuous miner on the next cut. When clean, the area is stonedusted to render any remaining coal dust non-explosive. The mining cycle is complete and will start again.

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8 Clow (Hearing transcript, vol. 74, p. 16201); Smith (vol. 58, p. 12772).

9 In underground coal mines, people are not permitted to work under unsupported roof. At Westray, the continuous miner operator sat at the controls on the machine, thus limiting the depth of cut to the distance from the cutting heads to the operator's position. Continuous miners at some mines (Jim Walter Resources in Brookwood, Alabama, for example) are operated by remote control; the operator stands to the rear of the machine, thereby allowing more advance per cut without exposing the operator to unsupported roof.

Westray commonly developed two headings together so that the continuous miner and the roof bolter could alternate positions. This practice increased productivity by minimizing downtime for the machines.

At the time of the explosion, there were three operating areas in the Westray mine (see map 1 in Reference):

- the Southwest 2 section, comprising SW2-1 Road, the Lefthander (a formal designation seems not to have been assigned to this roadway), and SW2-B Road;
- the North mains section, comprising A, B, and D Roads to the north of the North 4 Cross-cut;
- the newly developed Southeast section, comprising 1 East, 2 East and 1 Southeast.

The inquiry experts generally agree that the fire and the explosion started in the Southwest 2 section of the mine. As equipment and materials expert John Bossert explained: "All of the experts appear to agree that the explosion originated in the Southwest 2 region of the mine. This means that all of the equipment in this region should be considered as possible sources of ignition."[10] For the purposes of this discussion, the Southwest 2 area is illustrated in Figure 6.1.

The Southwest 2 area was developed in early 1992 after a very quick and opportune withdrawal[11] from the section inbye SW1-3 Cross-cut.[12] At the time of the explosion there were three working faces in the section: SW2-B Road, the Lefthander, and SW2-1 Road. Figure 6.1 shows a continuous miner and a shuttle car[13] at the face of SW2-1 Road, roof bolters at the working face of the Lefthander and SW2-B Road, and a boom truck located at the intersection of SW2-B and SW2-1 Roads – at SW2-2 Cross-cut. The positioning of this equipment has been established from the evidence of the draegermen who entered this area immediately following the explosion:

Continuous miner and shuttle car Don Dooley noted that the shuttle car showed very little evidence of burning. The driver's seat was not burnt, nor were the tires.[14] David Sample said the shuttle car was "parked behind the continuous miner in the position it would be to be loaded and was at least seven-eighths loaded with coal."[15] Wyman Gosbee confirmed the

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10 Exhibit 55.3, p. 4, undated addendum to Bossert Report, 4 November 1992. See Malcolm McPherson's evidence: "It is my opinion that the most probable location of the initial ignition was in the Southwest 2 area" (Hearing transcript, vol. 9, p. 1670). Bossert also points in his report (p. 3) to Don Mitchell's letter of 21 September 1992, which refers to the continuous miner as the ignition source.

11 **Comment** In fact, the company was literally "chased out" of the Southwest 1 section by the extremely unstable and hazardous roof conditions.

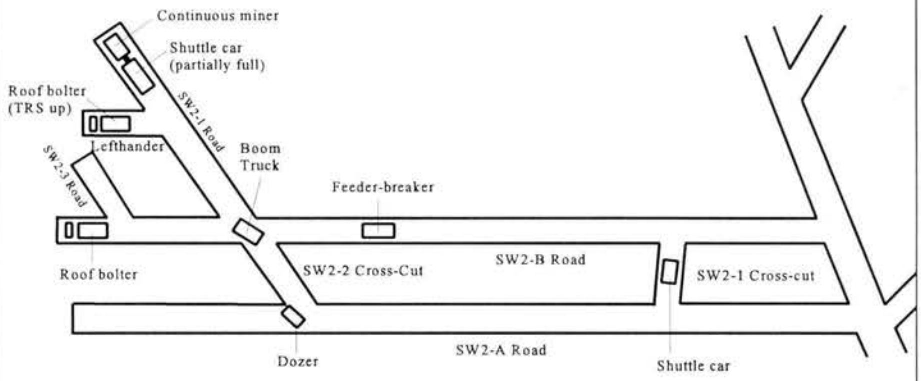
12 "Inbye" describes the location of things beyond a certain point in a mine. "Outbye" has the opposite meaning of a location closer to the portal or entrance. See the glossary in Reference.

13 There are varying estimates about the amount of coal in the shuttle car, ranging from 30 to 90 per cent full. They are relevant only to establish that the car was being loaded at the time of the explosion.

14 Hearing transcript, vol. 37, p. 8153; see also evidence of Jay Dooley (vol. 41, p. 9127).

15 Hearing transcript, vol. 30, p. 6517.

Figure 6.1 The Southwest 2 Section of the Mine, Showing Locations of Equipment at the Time of the Explosion



Source: From Exhibit 45.06.

location of the shuttle car, with the continuous miner at the heading, by reference to Exhibit 59, photo 25.[16] Jay Dooley said that the last sump was made by the continuous miner in SW2-1 Road and that the cutter had stopped after having "only made it down three or four feet."[17]

Roof bolter in the Lefthander We can infer from the evidence that one of the roof bolters was in the Lefthander.[18] Randy Facette confirmed this position: "There was another bolter further down in SW2-1 Road and in the cross-cut there off to the left, the Lefthander."[19] Clive Bardauskas examined the bolter located on the Lefthander of SW2-1 Road.[20] Lenny Bonner indicated that the continuous miner and the roof bolter switched places, and the bolter went into the Lefthander on 8 May 1992.[21]

Roof bolter in SW2-B Road This bolter was located at the face of SW2-B some 50 m from the intersection of SW2-2 Cross-cut and SW2-B Road. Jay Dooley described a piece of screening found at the top of SW2-B Road as being "at the bolter."[22] According to Facette, it was the bolter at the face of SW2-B Road on which he was working on 8 May along with Nelson LeDrew.[23]

16 Hearing transcript, vol. 25, pp. 5044–45.

17 Hearing transcript, vol. 39, p. 8703.

18 Hearing transcript, vol. 39, p. 8704.

19 Hearing transcript, vol. 33, p. 7239.

20 Hearing transcript, vol. 23, p. 4665.

21 Hearing transcript, vol. 24, p. 4791.

22 Hearing transcript, vol. 41, p. 9128; again, Dooley confirmed the location of the bolter (vol. 39, pp. 8705–06).

23 Hearing transcript, vol. 33, p. 7239.

Boom truck The boom truck was located at the intersection of SW2-B Road and SW2-2 Cross-cut, which runs directly into SW2-1 Road. It shows clearly in Exhibit 59, photo 27 (see photo 21 in Reference). Don Dooley also described it as being in that location.[24]

Inquiry experts Miklos Salamon, Malcolm McPherson, Reg Brookes, and John Bossert each suggested that one of these four pieces of mining equipment was the most probable source of ignition. Andrew Liney, a ventilation expert retained by the RCMP for the criminal prosecution,[25] postulated that the boom truck was the prime candidate as the source of ignition. His evidence will be dealt with later in this chapter.

The opinion of the experts varied. Brookes said, "I would put the continuous miner first . . . the boom truck second and the bolter third."[26] McPherson said, "I would not want to choose between the continuous miner and the boom truck. I think that both of them, Commissioner, were equally likely to have been the source of this particular ignition."[27] It is noteworthy that McPherson made this comment early in the hearings and before the evidence of the miners had been taken. In subsequent discussions, he seemed to favour the continuous miner as the most probable source.

Finding

The source of ignition that caused the methane accumulation to catch fire, most probably, was the cutting mechanism or picks of the continuous miner, which, when they struck either pyrites or sandstone, caused sparks of sufficient intensity to light the gas. The gas would be ignited in much the same way that the spark from the flint of a cigarette lighter will ignite the gas emitted from the lighter reservoir.

I shall now set out my reasons for finding the continuous miner as the strongest probable source of ignition: the continuous miner was likely operating at the time of the explosion, since the shuttle car was partially filled, the switches on the miner were in the "run" position, the conveyor on the miner had coal on it, the position of the cutting heads indicate that the miner was operating, and the evidence suggests sparking at the miner.

There is sufficient evidence on which to base the finding that the continuous miner was operating at the time of ignition, or very close to that time. This is contrary to the conclusions suggested in the final submission to the Inquiry of the United Steelworkers of America Local

24 Hearing transcript, vol. 37, p. 8156. This piece of equipment also figured prominently in the investigation of the possible sources of ignition. It was the subject of some discussion among the experts, as will be seen later in this chapter.

25 *R. v. Curragh Resources Inc., Gerald J. Phillips and Roger J. Parry.*

26 Hearing transcript, vol. 11, p. 2029. In that evidence, Brookes corrected himself where he inadvertently placed the bolter second.

27 Hearing transcript, vol. 9, pp. 1676–77.

9332,[28] but it is consistent with other persuasive evidence. The presence of a partly filled shuttle car immediately behind the continuous miner is just one indicator of the state of the continuous miner at the time of the explosion. It would not be normal for the continuous miner to stop operating before the shuttle car was full. As mining expert Don Mitchell said, "[Y]ou have to have a darn good reason not to completely fill the shuttle car and let it get down and dump." He concluded that the shuttle car was about two-thirds full.[29] As noted earlier, Sample thought it was "at least seven-eights loaded with coal."[30] Don Dooley said that the operator of the continuous miner "wouldn't have backed out until he filled his shuttle car."[31] I have observed that a shuttle car can be fully loaded in less than a minute if the continuous miner is operating effectively.[32]

Clive Bardauskas was employed as a mechanic at Westray. He had some 20 years' experience in coal mining, including 19 years with the British Coal Board. He accompanied the RCMP into the Westray mine in September 1992 and he "walked right up to the continuous miner." All three switches on the continuous miner were in the "run" position, and he concluded that the continuous miner was cutting coal at the time of the explosion. The conveyor on the continuous miner had coal on it, and the cutting heads were "at the face." I asked Bardauskas how close the continuous miner was to the face, and he responded, "As close as you could get."[33] Don Dooley was a member of the mine rescue team that went into the mine on the day following the explosion, and he later went into the mine to assist the RCMP with the investigation. He told the Inquiry that, when he came upon the continuous miner during the rescue attempt, "the miner head was only two feet from the roof."[34] He was convinced that the operator backed away from the face and stopped mining because his equipment gassed out.[35] He didn't know of any other reason why the operator would back off from the face with the shuttle car not full. Jay Dooley said, "I believe he had come down on the sump about three, four feet from the back."[36] Don Dooley suggested hydraulic leakage over the intervening several months as the cause of the miner head being in a lower

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28 "The continuous miner was on but it was pulled back two or three feet from the face. Most of the coal on its conveyor had run through, suggesting the operator was not cutting coal at the time he decided to leave the machine." David Roberts, "Ingredients for Disaster" (Halifax: Local 9332 USWA, 1996), 37.

29 Hearing transcript, vol. 16, p. 2927.

30 Hearing transcript, vol. 30, p. 6517.

31 Hearing transcript, vol. 37, p. 8194.

32 Jim Walter Resources, Inc., Brookwood, Alabama, uses a ramcar, which is about the same size and serves the same purpose as the shuttle car, except that it loads and unloads from the same end.

33 Hearing transcript, vol. 23, pp. 4663–66. Of the bolter located in the Lefthander, the witness said: "[T]here was no drill steel, they weren't drilling." As to the boom truck, he said, "At the time of the explosion, the boom truck was running."

34 Hearing transcript, vol. 37, p. 8186.

35 Hearing transcript, vol. 37, p. 8189.

36 Hearing transcript, vol. 39, p. 8703.

position in Exhibit 59, photo 24. This photo, reproduced in Reference as photo 17, was taken on 27 September 1992, some four and a half months after the explosion.

There is also sufficient evidence on which to base the finding that the continuous miner was the probable source of ignition. In his evidence, McPherson described the phenomenon of a "streak of incandescent material"[37] appearing like a ribbon of red hot or white hot material flowing from the back side of the cutting head picks. This incandescent streak would not be inhibited by the continuous miner's water sprays, which, under normal circumstances, are directed at the cutting head, not to the back of it.[38] The primary purpose of this water spray is to suppress the coal dust at the working face, not to prevent sparking.[39] To reach the degree of heat necessary to create the incandescent streak, the cutting head picks must find a non-coal material of sufficient hardness and abrasiveness to create sparks.[40] Individual sparks would seldom be of sufficient intensity to ignite a methane-air mixture, but the incandescent streak – a continuous cascade of individual sparks – may provide sufficiently prolonged heat to allow ignition. Dull cutting picks will also encourage sparking as the bits cut into or strike non-coal material. Rick Mitchell witnessed sparking of this nature when he operated the continuous miner in SW2-B Road. The sparking occurred even when the water sprays on the continuous miner were activated. At one time when the continuous miner was cutting into pyrite, Mitchell was burned on his neck from sparking.[41] Kevin Gillis, a geologist with the Department of Natural Resources who visited the Westray mine 12 times between May 1989 and September 1991, supports the evidence of sparking at the working face as the continuous miner operated: "And as it came near the roof, it would . . . put out a shower of sparks."[42]

The roof bolters located in the Lefthander and in SW2-B Road have been given low priority as a possible source of ignition. According to an RCMP report, "no steel drills were fitted and it appeared that those bolters

[37] Hearing transcript, vol. 9, p. 1672.

[38] Hearing transcript, vol. 9, p. 1674. It is perhaps this phenomenon that prompted I. Hartman to comment in US Bureau of Mines Information circular No. 7727 (1955) that water "should be injected on both sides of the cutting bars, or better still compressed air-water sprays." This opinion is referred to by F. Powell, "Ignitions by Machine Picks: A Review," *Colliery Guardian* 239 (November 1991): 245.

[39] Bossert (Hearing transcript, vol. 12, pp. 2163–64); McPherson (vol. 10, pp. 1715–16).

[40] Photograph 16 in Reference clearly shows non-coal material at the face where the continuous miner was working.

[41] Hearing transcript, vol. 31, pp. 6762–65: "Well I was cutting into the face and, naturally, we were cutting into that pyrite. . . . you could see the sparks rolling right with the head . . . when one came right back into the cab and burnt me in the neck." Continuous miner operator Buddy Robinson agreed that there "would probably be a lot [of sparking]" if the continuous miner was cutting into the rock pictured in Exhibit 59, photo 23, and if the operator wasn't using his water sprays (vol. 30, p. 6418).

[42] Hearing transcript, vol. 46, p. 10110.

were not working."[43] McPherson suggested that the roof bolter in the Lefthander was "running" at the time – not necessarily operating.[44] That would allow for the possibility that the roof bolter could have been the source of an electrical spark, which is consistent with Brookes's comment that "it doesn't rule out a possible electrical source of ignition."[45] Again, with respect to the bolter at the working face of SW2-B Road, the evidence is fairly compelling that this machine was not operating at the time of the explosion, although it may very well have been running.[46] In such circumstance, the bolter motors may have been energized, but were neither drilling nor installing bolts.

In their evidence, some witnesses considered the boom truck a possible source of ignition. It was located at the intersection of SW2-B Road and SW2-2 Cross-cut (the continuation of SW2-1 Road), 100 m from the working face where the continuous miner was found. As shown in photo 21, the boom truck is a low-slung vehicle, lying quite close to the road. According to Bossert, this truck (No. 975-0414) was built in 1975 and originally conformed to U.S. standards as a flameproof machine. It was first used by Kaiser Resources at its hydraulic coal mine in British Columbia. Over the years, the boom truck underwent substantial modifications, which appear to have affected its flameproof condition:

> This machine was originally built as a flameproof diesel truck but . . . it has been modified extensively and is no longer flameproof. In addition, it was built in 1975 and has seen service in at least two coal mines so the engine was probably well worn. If one or more of the valves leaked, flames could have escaped into the intake or exhaust which were no longer equipped with flame arresters. This machine was correctly listed as a non-flameproof diesel machine and, as such, was not permitted beyond the last cross-cut or within 300 feet of the face. Therefore, it should not have been driven to the point where it was found.[47]

For these reasons, Bossert concluded that the exhaust from the boom truck was "the most likely source of the ignition." Brookes, referring to the boom truck, said, "I think it very unlikely that anything like that would be allowed in a British mine."[48] However, he still favoured the continuous miner as the most likely source of ignition. [49]

Andrew Liney, after examining some of the photographic evidence at the hearing,[50] advanced the theory that the boom truck was the most likely source of ignition. His hypotheses differ from those of other expert

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43 Brookes (Hearing transcript, vol. 11, p. 2014). This information comes from Jay Dooley's report for the RCMP in Exhibit 34.0139–40.

44 Hearing transcript, vol. 9, p. 1676. "Running" is used to describe equipment that is energized (powered up) but not necessarily actively operating. "Operating" is used to describe equipment that is being used at the time to perform the tasks for which it is intended.

45 Hearing transcript, vol. 11, pp. 2014–15.

46 Hearing transcript, vol. 11, p. 2015.

47 John Bossert, "Report of the Investigation of the Equipment and Materials used in the Westray Coal Mine prior to the Explosion of May 9, 1992" (1995) (Exhibit 55.3, p. 5).

48 Hearing transcript, vol. 11, pp. 2019–20.

49 Hearing transcript, vol. 11, p. 2029.

50 Exhibit 59, photo 27; Exhibit 122.09, photos 197–8; and Exhibit 73.10.66A.

witnesses and involve a piece of vent tubing that was found wrapped around the boom truck:

> I believe [that] the boom truck as it was travelling around the corner, under the duct, which it clearly had to do to arrive in the position that it was, the back end of the boom caught the duct which at that time was maybe hanging a bit low. If it pulled on it at all, it would have pulled it down for some length, and it would have laid it down on top of the boom truck . . .[51]

He then went on to say that he didn't believe it was duct that was laid on the floor near the boom truck because that was not the way one stored ducting. Normally, when ducting is stored in the mine, it is left in "concertina" fashion, rather than stretched out as this piece found on the floor appeared to be. He further explained that the operators of the boom truck would have been concerned about tearing down the piece of tubing that was supplying air to the bolting crew working inbye on SW2-B Road. He speculated that they would have left the boom truck running and started up the roadway to warn the bolters of the accident. Liney concluded that, as the men went into the heading towards the bolter,

> either the duct ignited, which is, in my opinion, entirely feasible, although I have no scientific evidence to suggest that the heat generated by the exhaust [of the boom truck engine] would ignite it. I do know that a relatively low temperature will ignite this type of duct. Or the gas that was entrained in the activity of pulling the duct down was ignited. And I favour the duct being ignited myself.[52]

He then described how the resulting methane fire would have dispersed throughout the Southwest 2 section and caused the death of the 11 miners working there at the time.

I find it difficult to accept Liney's theory as a plausible explanation for the source of ignition of this mine explosion. Too many factors that are not supported by the evidence would have to come into play.

The evidence of Don Dooley is, perhaps, the most damaging to Liney's theory. This evidence was not available when Liney appeared at the Inquiry. Dooley said there were fragments of used vent tubing lying around on the floor of the mine in this vicinity. He speculated that the shuttle car, in its many runs through this area, could have caught a piece of this discarded tubing and dragged it partly out into the roadway. He then suggested that the boom truck operator, Robbie Doyle, could have run over two or three feet "before he got stopped" to give the shuttle car enough room to get by. With respect to the vent tube wire wrapped around the boom truck, Dooley said, "Those are just a conglomeration of old vent tubes. That's not vent tubing that was hanging on the roof."[53] We must remember that Liney's theory was based, in part at least, on the assumption that any vent tubing lying on the roadway would be packed tubing in its compressed "concertinaed" configuration. Dooley also

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[51] Hearing transcript, vol. 18, pp. 3302–03.

[52] Hearing transcript, vol. 18, p. 3306.

[53] Hearing transcript, vol. 37, pp. 8166–67.

concluded that the boom truck was running at the time of the explosion, and said, "again, that leads me to believe the boom truck operator simply got off the boom truck to look for his supervisor to find out where to put his supplies."[54]

Don Mitchell would not speculate on whether the piece of vent tubing entwined around the boom truck was pulled down by the truck. He said there was no way of postulating that, since there was no evidence from the investigation that could lead to that sort of conclusion:

> [A]ll I can say from this [examination of boom truck photos][55] is there is little question that this vehicle indeed ran over some duct. Whether it was duct that was actually supplying air to the face at that time . . . or whether it was . . . just a piece of duct on the floor, I'm not capable of answering.[56]

Ted Deane was one of the boom truck operators. He said, "You always travelled with the arm [boom] back down onto the bed." When asked to comment on the possibility of the boom truck hitting and knocking out a vent, he replied: "Nobody would travel with it up that high to hit a vent. . . . There's no reason to travel with it up that high."[57] Steven Cyr, another of the boom truck operators, said that they ran over bolts, resin, and vent tubing "quite a bit."[58] He had never known the boom truck to snag a piece of vent tubing that was hung up, and the only such incident he could recall was one time when the continuous miner knocked out a piece.

For all the above reasons, I must reject the boom truck and return to the continuous miner as the most probable source of ignition.

Methane

The conclusion that the cutting head on the continuous miner is the most probable source of the sparking that caused the ignition of methane is defensible both historically and statistically.

The ignition of methane (or firedamp[59]) by the impact of hand tools and machines is a common cause of coal mine fires and has been known as such for several hundred years. In the 30-year period ending in 1989, there were more than 370 reported frictional ignitions of methane in mines in the United Kingdom. In 1979, there were 87 similar ignitions in coal mines in the United States.[60] One does not have to travel far afield to see evidence of these sorts of mine hazards. In the introduction to a study entitled "Frictional Ignition Control," the editor stated: "As the use of power loading equipment has become more widespread, frictional ignition

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54 Hearing transcript, vol. 37, p. 8161.

55 Exhibit 73.10.066A, photo 200; RCMP photo 199. The former is reproduced as photo 22 in Reference.

56 Hearing transcript, vol. 18, p. 3131.

57 Hearing transcript, vol. 26, pp. 5441–42.

58 Hearing transcript, vol. 25, p. 5156.

59 "Firedamp" is a common British term for a flammable methane-air mixture, descriptive of the gas's potential to ignite or explode. It is also used as a synonym for methane.

60 F. Powell, "Ignition by Machine Picks: A Review," *Colliery Guardian* 239 (November 1991): 241.

incidents have increased. There have been many fatalities and injuries from this cause."[61] The seriousness of these machine pick ignitions cannot be overestimated:

> While most of these machine pick ignitions produced no more than a localised flame, every ignition of firedamp [methane] is a potential disaster. Nine miners were killed in a 1963 Utah mine explosion in which frictional ignition was a likely cause. The seriousness of the problem cannot be overstated: in February 1979, in Nova Scotia, an ignition that led to a coal-dust explosion in which 12 miners died was attributed to frictional ignition caused by a shearer.[62]

Since it appears almost impossible to eliminate sparking at the mine face, especially when using machines such as a continuous miner, the first line of defence against a propagating methane fire – which could develop into a full coal-dust explosion – is ventilation.[63] Although this Report will study elsewhere, and in considerable detail, the mechanics of mine fires and explosions, the following excerpt from a South African journal is meaningful in the context of this chapter:

> One of the more usual disaster scenarios involves the following sequence: 1. The growth of a large, flammable methane-air zone near the face that is being mined. The flammable zone growth is the result of increasing methane emission. The mining process results in the rapid advance of the mine void into the fresh seam, which steepens the internal pressure gradient of the coal seam, which increased the flow of methane into the mine. If the ventilation [is] inadequate to dilute, render harmless, and to carry away that increased emission, significant flammable volumes are generated. 2. The ignition of that flammable volume by the frictional heating of cutting bits, by an electric or electrostatic spark, or by an explosives shot. 3. The development of a localized methane-air explosion, referred to as a "face ignition," and its outward acceleration from the closed-end or "face" of the mine entry. 4. The lifting of coal dust accumulations by the flows and pressures generated by the accelerating "ignition," and the mixing of that dust with air to create a flammable dust-air mixture. 5. The ignition of the dust-air mixture by the methane-air explosion. 6. The further turbulent acceleration of the flame front, which intensifies the aerodynamic disturbance, which lifts more coal dust mixing it with air throughout an increasingly lengthening zone in advance of the flame. 7. The propagation of a dust explosion throughout the mine.[64]

Of particular significance in this analysis is the work of the U.S. Bureau of Mines and its study of coal mine explosions.[65] The

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61 R.K. Singhal, D.B. Stewart, and J.P.L. Bacharach, "Frictional Ignition Control," *Colliery Guardian* 235 (May 1987): 176.

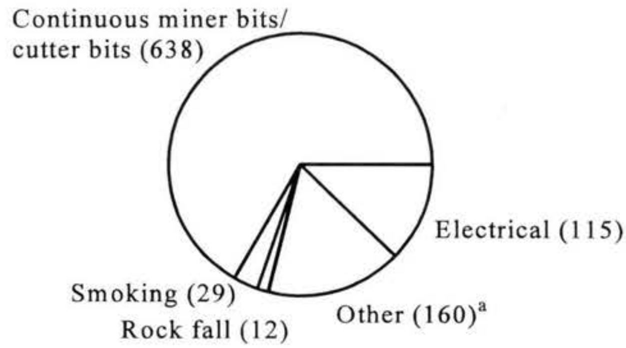
62 Powell, "Ignition," 241. The reference to the Nova Scotia mine is No. 26 colliery of the Cape Breton Development Corporation. See Commission of Inquiry into Explosion in No. 26 Colliery, Glace Bay, Nova Scotia, on February 24, 1979, *Report* (Canada: Department of Labour, 1980) (Chair Roy Elfstrom) [Elfstrom Report].

63 See Chapter 7, Ventilation.

64 Martin Hertzberg et al., "Methane and Coal Dust Explosion Inhibitors Tested," *Coal, Gold and Base Minerals of South Africa* 32 (September 1984): 21.

65 J.K. Richard et al., *Historical Summary of Coal Mine Explosions in the United States, 1959–81* (Washington, DC: Department of the Interior, Bureau of Mines, 1983).

Figure 6.2 Number of Ignitions and Explosions by Cause (U.S. Coal Mines, 1959–81)



Source: J.K. Richard et al., *Historical Summary of Coal Mine Explosions in the United States, 1959–81* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1983), tables A1, S2.

[a] Includes cutting and/or welding, frictional ignition by roof drill bits, explosives, defective flame safety lamp, longwall bits, other frictional, other non-frictional, and cause unknown or not yet specified.

overwhelming cause of U.S. coal mine explosions from 1959 to 1981 was continuous miner bits. Figure 6.2 illustrates that, of the 954 recorded "incidents," 638 were attributable to frictional ignition from continuous miner (and other cutter) bits. These findings were largely supported in a study by John Nagy for the U.S. Mine Safety and Health Administration (MSHA) in 1981. As a result of his analysis, Nagy concluded:

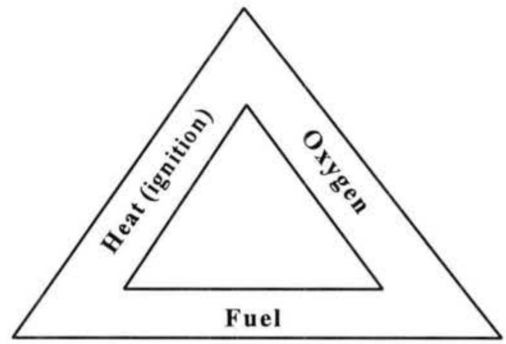
> Eighty-five percent of these ignitions were caused by frictional sparks generated by cutting machines or continuous mining machines when the bits struck hard materials at the working face. Each ignition has the potential to become an explosion if sufficient force develops to cause damage. . . . The trend in methane ignitions in British coal mines is approximately the same as in American coal mines.[66]

Propagation

Based on an analysis of the evidence and of the laboratory, statistical, and historical data, I have concluded, as noted above, that the ignition occurred at the working face as a result of sparking at the picks of the continuous miner. A spark cannot of itself, however, generate a lethal underground explosion. The classic "fire triangle" must be present. All three legs of the triangle must be present for a fire to sustain itself and, in this case, to

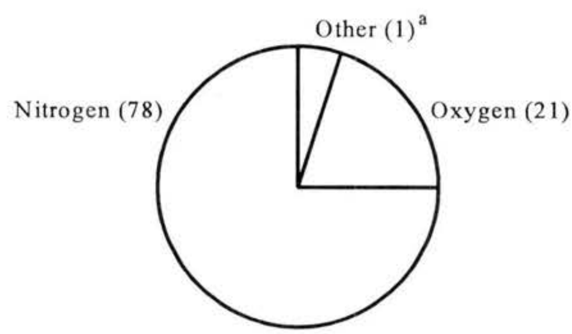
[66] John Nagy, *The Explosion Hazard in Mining*, IR 1119 (Washington, DC: U.S. Department of Labor, Mine Safety and Health Administration, 1981), 8. The author cites H.S. Eisner, J.K.W. Davies, and F.R. Brookes, "Mine Explosions: The Current Hazard," *Symposium on Health, Safety and Progress* (Harrogate, England, 1976).

Figure 6.3 The Fire Triangle



Source: Donald W. Mitchell, *Mine Fires*, 3rd ed. (Chicago: Intertec Publishing Inc., 1996), 5.

Figure 6.4 Composition of Clean Dry Air at Sea Level (approximate per cent by volume)



Source: United States, Department of Labor, Mine Safety and Health Administration, *Mine Gases*, Safety Manual No. 2 (Washington, DC: MSHA, 1991)

[a] Includes argon, carbon dioxide, neon, helium, krypton, xenon, hydrogen, methane, nitrous oxide, and ozone.

propagate into an explosion (see figure 6.3). The first leg, heat (or ignition source), has been established, on a strong balance of probability, as set out in the foregoing analysis. One can easily assume that the second leg, oxygen, was also present – men were working in the area, and the mine ventilation system was delivering air to them. Air normally contains approximately 21 per cent oxygen, as shown in figure 6.4. That leaves for determination only the presence of the third leg – the essential fuel on which the fire will feed.

It is almost a given that explosions in underground mines are caused by the ignition of methane – a colourless, odourless, non-toxic gas that is lighter than air. Its lower and upper explosive limits are approximately 5 per cent and 15 per cent, respectively, with 9.5 per cent being the optimum explosive mixture.[67] How much heat, or energy, is needed to ignite methane? Nagy and Mitchell continue:

> A gas-air mixture is readily ignited by a weak electrical spark, a frictional spark, a heated surface, or an open flame.[68] The minimum electrical energy of a spark causing ignition varies with gas concentration, humidity, oxygen content of the atmosphere, temperature, and turbulence. As little as . . . about one fiftieth of the static energy accumulated by an average-sized man walking on a carpeted floor on a dry day [is required].

Finding

The ignition caused a rolling methane flame to travel away from the working face of SW2-1 Road and also propagated into the Lefthander, consuming all the oxygen in the roadways and leaving deadly quantities of carbon monoxide in its place. The rolling flame moved to SW2-2 Cross-cut, where it followed SW2-B Road both inbye and outbye the cross-cut and continued as a rolling methane fire inbye SW2-2 Cross-cut towards the roof bolter at the face. The rolling flame did not develop into a methane explosion, although it did increase in intensity.

As the flame turned outbye SW2-2 Cross-cut, three factors combined to cause the flame to propagate into a methane explosion, which, in turn, generated a preceding shock wave: the boom truck located in the intersection, the auxiliary fan in the cross-cut, and the change of direction of the flame down SW2-B Road towards SW1-B Road. The resulting shock wave then created greater pressure and increased turbulence, which caused dust particles to become airborne – just in time for the extreme heat of the trailing methane explosion to generate a full-blown coal-dust explosion. It is probable that this coal-dust explosion started at or near the Stamler feeder-breaker located about 30 m down SW2-B Road outbye SW2-2 Cross-cut. The resulting coal-dust explosion then moved rapidly through the entire mine, causing death and devastation in a matter of a few seconds.

The description of the rolling methane flame is consistent with Don Mitchell's evidence. Mitchell said that the Stamler feeder-breaker was the most probable location for the start of the coal-dust explosion, since it could create sufficient turbulence to raise coal dust into suspension – to be ignited by the methane explosion.[69] Eleven bodies were recovered from Southwest 2 section, six in SW2-1 Road between the working face and the intersection with SW2-B Road, and five along SW2-B Road between the intersection and the face at which one of the roof bolters was located. The precise location of the bodies is a matter of some uncertainty, since the evidence of some of the rescue teams is not conclusive. From the general

67 John Nagy and Donald W. Mitchell, *Experimental Coal-Dust and Gas Explosions*, Investigation No. 6344 (Washington, DC: Department of the Interior, Bureau of Mines, 1963), 19.

68 Nagy and Mitchell, *Experimental Coal-Dust and Gas Explosions*, 19; the authors cite H.F. Coward and G.W. Jones, *Limits of Flammability of Gases and Vapors*, U.S. Bureau of Mines Bulletin (1952), 503.

69 Hearing transcript, vol. 17, p. 3000.

location of the bodies relative to the equipment on which the miners had been working, it is a fair assumption that most of the men were running and that they fell as they were overtaken by the flame. If so, the miners in the Southwest 2 section had at least some minimal warning (perhaps 10 seconds) of the methane fire. This would support the finding that the methane had burned briefly before propagating into an explosion and would, as Don Mitchell suggested, also give more weight to the assumption that the fire started in the Southwest 2 section.[70] Other than these suggestions, it would be imprudent to speculate anything more from the location of the bodies.

According to the report of the chief medical examiner, Dr R.A. Perry, 10 of these miners died of carbon monoxide poisoning in the range of 65–80 per cent saturation.[71] The 11th deceased, Robbie Doyle, died of combined carbon monoxide poisoning (22 per cent saturation) and flash burns. Doyle's body was located in SW2-B Road some 20 m inbye the boom truck.

In his evidence at the criminal trial, Dr Perry indicated that all the deceased in the Southwest section, except Doyle, had superficial burns to parts of the body, whereas Doyle's body showed evidence of "burns of varying severity."[72] The relatively lower level of carbon monoxide poisoning and the increased severity of the burns led the doctor to conclude that the lower carbon monoxide level was consistent with acute spasm of the larynx (vocal cord area) due to the flame and heat effect on the larynx.[73] We can only speculate why Doyle suffered a different death from the other 10 miners who were in the same area of the mine and, presumably, were exposed to the same conditions. It could be that Doyle was located beneath a roof cavity containing additional methane, and, as the rolling flame from the methane fire passed over him, a more intense flash occurred, causing more severe burns and the acute spasm that was the primary cause of death.

What is significant in this analysis is that there were no signs of trauma on the bodies of these 11 miners in the Southwest 2 section to the degree shown on the bodies of the four miners found outside the Southwest section. Two of the latter group died of multiple blunt injuries, and, while the remaining two died of carbon monoxide poisoning, there was evidence of more severe external injuries as well as broken ribs. We may logically conclude that these four miners were buffeted about by a force such as the shock wave that would precede the coal-dust explosion. The more severe burning of these bodies is further indication that they had been involved in the coal-dust explosion rather than a methane fire. As Brookes said, "There would be considerable after burning of the coal dust particles which would cause severe burning to the men as opposed to just

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70 Exhibit 48.2.

71 Exhibit 44.0074–82.

72 *R. v. Curragh et al.*, transcript, 14 February 1995, pp. 209–10.

73 *R. v. Curragh et al.*, transcript, 14 February 1995, pp. 213–14.

superficial burns of the men here [referring to the Southwest section on the map]."[74] In the absence of similar evidence of trauma on the bodies of the 11 miners in the Southwest 2 section, it seems reasonable to conclude that the methane fire had not propagated into a full-blown coal-dust explosion at the time of their deaths. This is just another factor that supports the finding that the methane fire originated in Southwest 2 and probably propagated into a full coal-dust explosion shortly thereafter – probably before getting to SW1-B Road.

Brookes followed approximately the same line of thinking in arriving at his conclusion that the continuous miner was the most likely source of ignition. He stated his impression thus:

> So my picture of these men trying to get away, they're getting part way down the roadway, but then the flame developed in this layer and the turbulence caused by the initial flame starts to mix the gas so that the mixture of gas comes lower in the roadway, starts to burn more quickly and, indeed, may have passed over them as they made their way down the road. The products of the combustion, the carbon monoxide then hit them. They breathe that in and fell on the spot. . . .[75] And then you would get a more violent explosion down these two roadways and that violence would continue, perhaps picking up any gas from other cavities or any gas that was in those roadways in the form of a layer mixing it and increasing in violence until it reached the C-1 or B Road there, particularly the B Road where the conveyor is situated.[76]

Coal Dust

The Stamler feeder-breaker was located in SW2-B Road some 30 m outbye SW2-2 Cross-cut. As earlier indicated, its function is to receive the coal from the shuttle car, break it into smaller segments, and feed it onto the conveyor belt for eventual transport to the surface. Owing to the very nature of its function, the feeder-breaker generated considerable coal dust and would also liberate methane as the coal was broken. The coal dust would settle on the roadway, the finer particles attaching to the ribs and even the roof of the roadway. The liberated methane would rise and be either swept away by the ventilation system or added to the methane layering at the roof, if the ventilation system was inadequate for the purpose. It is very probable that the feeder-breaker, with the coal-dust accumulation around it and the fact that its presence alone would cause some turbulence, was the point at which the methane explosion travelling

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[74] Hearing transcript, vol. 11, pp. 2013–14.

[75] **Comment** Carbon monoxide is extremely lethal. During a safety instruction at the Skyline mine in Helper, Utah, I was firmly directed to hold my breath while transferring from the mouthpiece of the self-contained self-rescuer to the oxygen tank. The absence of oxygen, having been replaced by methane, can be equally lethal. I was told of an incident at the Jim Walter Resources mine in Brookwood, Alabama, where an experienced mining engineer was investigating a roof fall in one of the mines. He climbed to the top of the fallen roof section, encountered methane, and died instantly. His co-worker was warned by the change in pitch of the engineer's voice and fell to the ground, thus avoiding a similar fate.

[76] Hearing transcript, vol. 11, pp. 2011–12.

down the SW2-B Road propagated into the coal-dust explosion. This strong probability was expressed by Brookes:

> In this scenario, the flame would develop moving faster as it came down to the open end of the entry. If there were cavities present, it may have produced turbulence which would bring gas out of those cavities because of the rising heat and combustion and convection and so that you start to get a rolling flame, and the progression of that flame would be faster, and by the time it got down to the intersection and into the SW1-A and SW2-B Roads where the conveyors [and the feeder-breaker] were situated, or perhaps at the intersection, there would be enough gas mix so that the whole roadway might be filled with a flammable mixture at this point. And then you would get a more violent explosion down these two roadways and that violence would continue, perhaps picking up any gas from other cavities or any gas that was in those roadways in the form of a layer mixing it and increasing in violence until it reached the C-1 or B Road there, particularly the B Road where the conveyor is situated.[77]

Dr Paul Amyotte is a mining engineer with considerable expertise and experience in experimental coal-dust and methane explosions. He is widely published in that and associated fields. He provided, both in his written report and in his testimony at the Inquiry, some interesting insights into the explosive characteristics of coal dust and methane. He bases some of his discussion on a graph, "Analysis of Post-Explosion Dust Samples from the Southwest Section," reproduced here as figure 6.5. The graph was prepared by Ken Richmond, formerly of the U.S. Bureau of Mines. Richmond was engaged, post-explosion, by the RCMP to analyse coal-dust samples taken from various areas of the Westray mine. The graph shows the results of tests performed for Richmond at the Ottawa laboratory of the Canada Centre for Mineral and Energy Technology (CANMET). The top line on the graph shows the average combustible content of the dust samples taken in the Southwest section. That line starts at the working face of SW2-1 Road, where the combustible content is shown as 70 per cent. At 60 m outbye the face, the line starts to dip and then levels off at about 100 m, where the combustible content is shown as 58 per cent. Commenting on this analysis, Amyotte said:

> I think that is one way, to me, in which the combustible content could decrease, that if that sample had previously been involved in a coal-dust explosion, you would expect the combustible components to be less . . . based upon my expertise in dust explosions, [it] is possible that the decrease in combustible content can be equated with the initiation of coal dust burning.[78]

It is obvious that Amyotte was somewhat tentative in the conclusions he drew from the Richmond charts. To further questioning on that point, Amyotte indicated that there was evidence of "coking" in the samples with the lower combustible readings. Coking is the term used to describe coal that has been subject to burning – generally when the more highly volatile

[77] Hearing transcript, vol. 11, pp. 2011–12.

[78] Hearing transcript, vol. 13, p. 2298.

elements in the coal are burned off. He presented this evidence merely as a postulation that the drop in combustibles in the samples taken along SW2-1 Road and the Lefthander and out to SW2-2 Cross-cut could be accounted for by their being consumed at that point in a coal-dust explosion. "It's a piece of evidence that I felt was important to my analysis and which lent credence to that analysis," Amyotte told the Inquiry. "It was a valuable piece of evidence, as far as I was concerned." He agreed with me that this may present "[j]ust another little piece in the puzzle."[79] To further confirm that this evidence could be of some significance, Amyotte's testimony and the accompanying graphs were forwarded to McPherson for his review and comment.

McPherson observed that there was considerable scatter of the points on the Richmond graph (figure 6.5). Because of such scatter, no "well-defined line" could be drawn through the points. He also suggested that, in moving away from the working face of a mine, one usually found a reduction in combustible content. He concluded: "This particular set of results shows that the combustible content was lower in the throughflow airways than in the headings. I would be hesitant to put any stronger interpretation than that upon them."[80]

McPherson also presented a graph (figure 6.6), showing the results of dust sample tests from the cross-cuts of the main roadways – No. 1 Main (intake) and No. 2 Main (return). He explained the straight, ascending line this way: "This plot indicates that the further we move down the mains into the mine, the greater is the amount of coal in the settled dust. This is hardly a surprising result and is a trend that we could find in the majority of drift (slope) coal mines." In his concluding remarks, McPherson made the following comment:

> The bottom line on all of this is that the dust samples provide an additional indication that the initial gas explosion generated a dust explosion somewhere within the Southwest 2 workings and probably before reaching the B or C1 roadways. It may be inadvisable to be more dogmatic than that.

The analysis of the Richmond tests, as illustrated by the graphs, does not support any firm conclusions about the origin of the ignition or the subsequent explosion. It does provide one more indication that the coal-dust explosion occurred somewhere in the Southwest 2 section of the mine.

I shall now advance to an analysis of further evidence respecting the source of the ignition and the propagation of the coal-dust explosion.

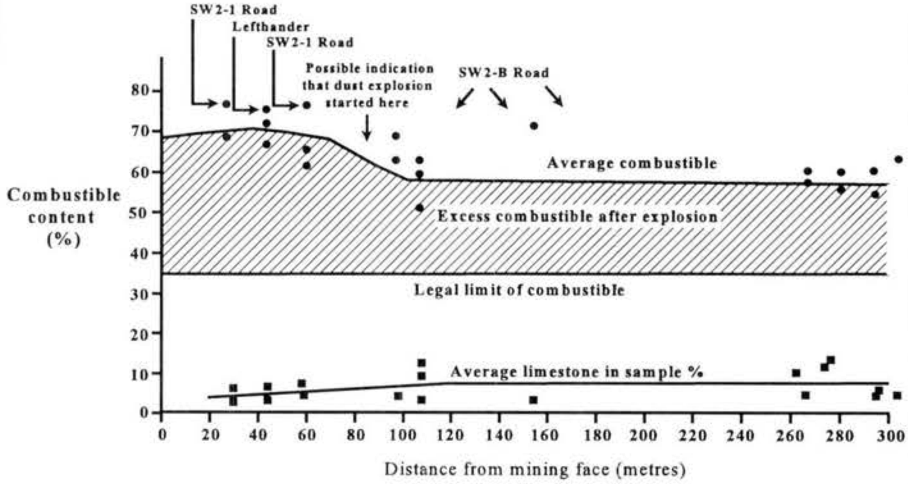
Ventilation

Early in this Inquiry, I reached the conclusion that ventilation in an underground coal mine is the most crucial aspect of mine safety in the

[79] Hearing transcript, vol. 13, pp. 2299–300.

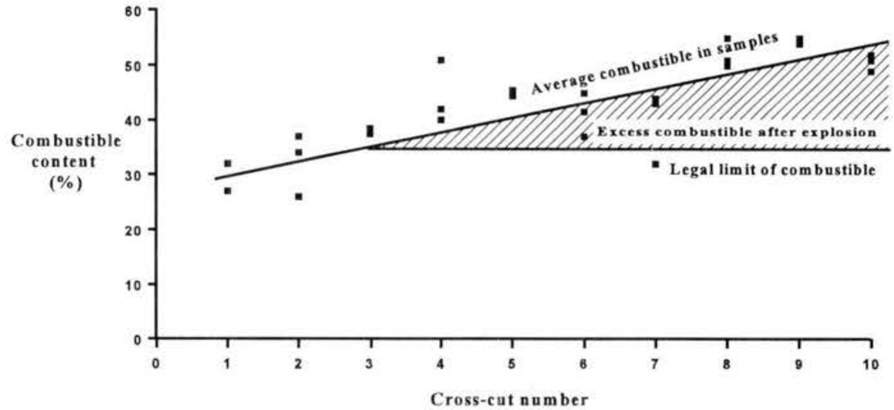
[80] Malcolm J. McPherson to Westray Mine Public Inquiry, 5 January 1996.

Figure 6.5 Analysis of Post-Explosion Dust Samples from the Southwest Section, Westray Mine



Source: From Exhibit 73.13 (second of two graphs).

Figure 6.6 Analysis of Post-Explosion Dust Samples from Cross-cuts between No. 1 and No. 2 Mains, Westray Mine



Source: From Exhibit 73.13 (first of two graphs).

context of mine fires and explosions.[81] This conclusion has been supported, and indeed strengthened, by later testimony and documentation.[82] A coal mine can be quite "forgiving" with respect to general housekeeping, stonedusting, and other aspects of safety, as long

[81] Based on a review of the experts' reports as well as other pre-hearing readings.

[82] Any repetition here of material covered in detail in the following chapters on ventilation and methane is for the reader's convenience.

as the ventilation system is properly planned, efficient for its purposes, and conscientiously maintained. Chapter 7, Ventilation, considering its length and detail, gives credence to this premise. This is not to say that the other aspects of safety are not important, but that coal mine ventilation is crucial in lessening or neutralizing many of the detrimental effects of the other factors.

We may conclude that there was a considerable degree of methane layering in the Southwest section of the Westray mine at the time leading up to the 9 May explosion.[83] Because methane, like the helium we use in balloons, is lighter than air,[84] it will tend to rise to the roof of mine openings once it has been liberated by the mining process or by fissures in the coal seams. With proper ventilation, the methane will be diluted by mixing with the main body of air; once mixed, it cannot segregate out again to form layering.[85] Without adequate ventilation, the methane will tend to accumulate on the roof in methane-air mixtures that may vary from almost pure methane (up to 100 per cent) to non-combustible quantities of less than 5 per cent. As the term implies, layering may also refer to the percentage of methane at any particular level near the roof of an opening. Methane content will likely be highest at the roof. Depending on ventilation conditions and the thickness of the methane layer, methane content may decrease with distance down from the roof. At some point, it will pass through its explosive zone (5–15 per cent). Then, as it gets closer to the airflow, the methane layer will be reduced to non-flammable levels of less than 5 per cent. Where the mine roof is uneven, particularly where overbreaks or cavities are created by roof falls, the methane may become trapped in the resulting cavities and remain undisturbed by the ventilating air passing through the mine roadway. This scenario is illustrated in figure 6.7.

How did methane accumulate in the roadways of the Southwest 2 section in quantities sufficient to create such a severe hazard? Much of the answer to this question is detailed in the following two chapters on ventilation and methane, but to complete our analysis of the explosion, some repetition is necessary here.

Methane is a natural component of coal, a by-product of the decomposition of the plant and animal matter from which coal is formed. In peat, an earlier stage of decomposition, the methane is popularly referred to as "swamp gas." Further into the earth, the decomposed material, which is now coal, has trapped within itself quantities of methane. When the coal is disturbed in its resting place of millions of years, this gas is emitted through the various seams and fractures. The coal acts as a sort of hard sponge that holds methane, which is released when

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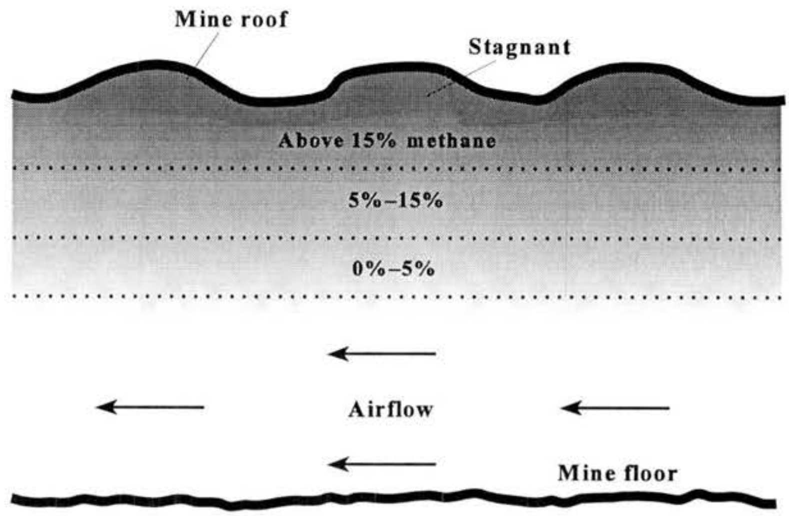
83 **Comment** Indeed, had there not been such methane layering in SW2-B Road, the explosion might not have occurred. The methane fire might never have passed out of SW2-B Road and propagated into a coal-dust explosion.

84 The specific gravity of methane is 0.554.

85 McPherson explains this phenomenon in his testimony (Hearing transcript, vol. 10, pp. 1796–97).

Figure 6.7 Methane Layering Near the Roof of a Coal Mine Opening



Source: Prepared by Malcolm J. McPherson for the Westray Mine Public Inquiry.

the coal is broken. Gas can escape from coal even after it has been cut from the mining face.

Methane can escape into the mining roadways in several ways:

- Gas is released in quantity as the cutting heads of the coal-cutting machines break the coal away from the face. This source probably produces the most methane.
- After the coal has been mined, the resulting disturbance will open fissures in the remaining coal through which methane will escape.[86] This seepage could go on for a considerable time, or until that coal is also mined.[87]
- Gas can seep into the active roadways of the mine from the abandoned or mined-out sections, depending on the effectiveness of the stoppings constructed at the entrances to those abandoned sections.

One of the principal functions of the ventilation system is to clear the methane at the working face of the mine (as the mining machines cut into the coal) and exhaust it out of the mine in non-explosive concentrations. It is clear that the Westray ventilation system was grossly inadequate for this task. It is also clear that the conditions in the mine were conducive to a coal-dust explosion. We will now discuss these two aspects of the explosion in greater detail.

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86 It is not uncommon to see methane bubbling up from the floor of the roadway or through the ribs.

87 At Jim Walter Resources, Inc. mines in Brookwood, Alabama, the methane is drained from the mined-out area (gob) for up to two years after mining has ceased.

The Exhaust System

There are two ways to move fresh air through a coal mine: the exhaust system and the forcing system. The names more or less describe their functions. With the exhaust system, a huge fan placed at the portal of the main return (exhaust) airway draws the air out of the mine, thus drawing fresh air in through the intake main. With the forcing system, the fan placed at the portal of the intake main blows or forces air into the intake main, through the mine, and out through the exhaust main to the surface. In both cases, depending on the efficiency and maintenance of the installation, fresh air enters the mine, travels through the working areas of the mine supplying breathable air to the miners, and carries off whatever impurities – such as methane, coal dust, diesel exhaust, and carbon dioxide – result from mining. The exhaust system was in use at the Westray mine. Apparently, Westray management chose to ignore the advice of the several consultants who had been engaged earlier to complete feasibility studies of the mine site. As noted by McPherson in his report to this Inquiry:

> All three feasibility studies[88] recommended a forcing system of main ventilation to be consistent with the locations of conveyors in return airways. It is unclear why Westray decided to ignore these recommendations and implemented an exhausting system.[89]

The exhaust system of mine ventilation, if properly planned, supervised, and maintained, can be effective.[90]

So far, we have discussed the main ventilation system. Wherever people are working beyond the main airflows, ventilating air must be brought to the working area by an auxiliary ventilation system. Here, section 71, paragraph 9(d) of the *Coal Mines Regulation Act* implies a mandated forcing system.[91] Westray, though, mainly used auxiliary fans in the exhaust mode. Therefore, the mine was technically in breach of the act from the outset – a fact that seemed to escape the attention of the various government agencies charged with regulating the mine, or one that they chose to ignore.[92]

As we shall see, the exhaust system of auxiliary ventilation has inherent difficulties, although it does have an advantage where a lot of dust is being created at the face. Indeed, for that reason, fire and explosions expert Don Mitchell said he would prefer the exhaust auxiliary

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88 Norwest Resource Consultants Ltd, "Pictou County Coal Project Feasibility Study," volume 2: Mining and Processing, report for Suncor Inc. (Calgary, 1986) (Exhibit 8, s. 13.3.1); Placer Development Limited, "Pictou Project Feasibility Study," volume 1: Geology, and volume 2: Mining (Vancouver, 1987) (Exhibit 10.2, p. 17); Kilborn Limited, "Technical and Cost Review of the Pictou County Coal Project," volume 1 of a feasibility study for Westray Coal Inc. (1989) (Exhibit 4, s. 3.5).

89 Exhibit 56.2, p. 8.

90 The four large underground coal mines at the Jim Walter Resources complex in Brookwood, Alabama, are all ventilated by the exhaust system.

91 "An auxiliary fan . . . shall be situated on the intake side and at least twenty feet out by the last open cross-cut or entrance to the place being ventilated."

92 Director of mine safety Claude White testified that his interpretation of the act "is that they [exhausting auxiliary fans] are permissible" (Hearing transcript, vol. 64, p. 14066).

system at the Westray mine.[93] One of the recognized problems associated with exhaust ventilation in room-and-pillar mining concerns the method of directing the air flow so that it clears the methane and the coal dust from the working face of the mine. To create sufficient turbulence at the face with the exhaust system, ventilation air must move as close to the face as possible. With exhaust ventilation, the fan draws the air into the ventilation duct rather than expelling the air as in the forcing system. Therefore, the intake end of the duct must be close to the face. With the system in use at Westray, it would be impossible, without some modification, to get the duct close enough to the face to create the required amount of turbulence to clear out the gas and dust. Photo 18 in Reference shows a remnant of the ducting in use. It illustrates the fact that such ducting would create an obstruction if it was hung too close to the working face of the mine.

One way of creating sufficient turbulence is to hang line brattice and direct the ventilating air to the face.[94] Trevor Eagles, the engineer in charge of ventilation at Westray, did not think that brattice was an effective response to the problems at Westray:

> [Y]ou would have needed probably three or four feet on either side of the miner as a minimum to keep him [the continuous miner operator] away from the brattice. . . . The other thing with the brattice is it has to be far enough from the face that allows you to get your [continuous] miner into the face to take the complete cut on the face, to advance your face. So your brattice would have stopped up to about 40 or 50 feet from the face to allow your miner to get in and line up properly to take his cut, which means you would have still needed something to generate some turbulence at the face.[95]

I do not wish to impugn Eagles's abilities in any way. He was a young, newly graduated engineer with no experience or training in the coal mining industry. Once hired, he was given no direction and left virtually on his own. It is more an indictment on the management at the Westray mine when I say that industry practice does not support Eagles's view. In fact, with exhaust ventilation in a room-and-pillar environment, it is essential to bring brattice curtains close to the working face without interfering with the operation of the continuous miner.[96]

Westray management ignored the advice of the experts in opting for the exhaust system of mine ventilation. It seemed to develop auxiliary ventilation on an ad hoc basis, without regard to the primary safety purpose of clearing methane from the working face. It is painfully clear from the testimony of miners, supervisors, mining engineers, and ventilation experts that the Westray ventilation system was deficient

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93 Hearing transcript, vol. 16, p. 2903.

94 Brattice cloth, heavy canvas-like material, usually flame resistant, is hung from the roof of the mine and temporarily deflects air currents to areas that are otherwise difficult to reach. The use of brattice is almost as old as coal mining itself – as various historical texts attest.

95 Hearing transcript, vol. 76, p. 16571.

96 See the section on methods of auxiliary ventilation in Chapter 7, Ventilation.

in several respects. First, there appears to have been no comprehensive ventilation plan for the mine, other than a one-page map.[97] Second, there is no indication that the Nova Scotia regulatory agencies – the Department of Natural Resources and the Department of Labour – had reviewed or approved any comprehensive ventilation plan, nor had the Westray engineer in charge of ventilation ever seen a detailed ventilation plan. Third, the maintenance of the ventilation system seemed to be ad hoc rather than consistent; for example, when the continuous miner was in danger of "gassing out"[98] from high methane concentrations, air was diverted from the roof bolter to the continuous miner as an emergency measure.[99] All of these general factors tended to create an environment in the Westray mine conducive to a less-than-efficient ventilation system. And this inefficient system, in turn, was ineffective in clearing the methane released during and after the mining process.

A comprehensive review of the mine ventilation at Westray is in Chapter 7, Ventilation. At this time, we will deal in summary fashion with those deficiencies in the ventilation system that may have directly contributed to that unsafe underground environment.

Methane Layering

Some additional factors aggravated the problem of methane layering in the Southwest 2 section. First, the exhaust ventilation system brought the air up SW1-C1 Road to SW1-3 Cross-cut, at which point the air was directed through the cross-cut to SW1-B Road. As will be seen in Chapter 7, Ventilation, this routing brought the intake air across the temporary stoppings that blocked access to the entire Southwest 1 section. Miners had recently been chased out of this Southwest 1 section by hazardous roof conditions, and the stoppings were not adequate to contain the methane being generated in the abandoned gob. This accumulation of methane was therefore released into the intake airflow being drawn past the two stoppings.[100] Second, the airflow was not sufficient to disperse the methane accumulations adequately into the air. This methane naturally found its way to the mine roof where it combined with the methane being liberated by mining in the Southwest 2 section. Third, the actual quantity of methane was increased by changes in barometric pressure, as described later in this chapter. This layering of the methane provided an even more robust fuel supply for the rolling methane fire and subsequent explosion.

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97 For example, the map in Exhibit 45.1.15 is entitled "Ventilation Survey, May 8, 1992."

98 "Gassing out" refers to the automatic shutdown of the continuous miner when the concentration of methane in the air reaches a preset limit. This is to prevent accidental ignition.

99 Testimony by Wyman Gosbee (Hearing transcript, vol. 25, pp. 5021–23) and Lenny Bonner (vol. 24, pp. 4785–86) refers to an incident in Southwest 2 on 7 and 8 May 1992. Don Dooley discusses the practice in general (vol. 36, pp. 7862–64).

100 Contrary to the provisions of the *Coal Mines Regulation Act*, RSNS 1989, s. 71(6).

Finding

Methane layering, the result of inadequate ventilation, was permitted to propagate, virtually undetected, throughout the Southwest 2 section. It provided a rich source of fuel for any ignition source to feed upon.

The Barometer

The barometer is an essential tool in the maintenance of a safe and effective ventilation system. According to the Devco training manual:

> A barometric pressure reading is made before entering the mine. The results of the reading are noted in the mine examiner's report and compared with the reading from the previous shift. Large or sudden changes in barometric pressure can have a profound effect on conditions underground.[101]

If the barometric pressure on the surface drops significantly, it will affect the underground mining environment. As the pressure on the roof, ribs, and roadway of the mine decreases, there is a likelihood that higher levels of methane will be liberated through whatever fractures, fissures, or crevices may exist. This increase may dictate change in ventilation, either by increasing air flow or by adjusting regulators, to ensure that the increased methane is dissipated safely. Of greater concern is the effect of the lowered barometric pressure on mine stoppings, especially temporary ones. In this circumstance, the accumulation of methane in the gob or other unworked or abandoned areas of the mine may bleed out through the stopping and add methane to the mine air. This is exactly what happened at the Westray mine during the early morning hours of 9 May 1992.

According to barometric pressure readings taken at the Environment Canada station at Caribou Point, Pictou County, the barometric pressure dropped 3.7 millibars during the 7 hours preceding the explosion.[102] McPherson calculated that this factor alone would add approximately 18 cubic feet per minute (cfm) of gas emission from the Southwest 1 section.[103] That section is the subject of considerable testimony because of the ineffectiveness of the plywood and plastic stopping erected inbye SW1-3 Cross-cut, which joined SW1-B Road and SW1-C1 Road. This additional quantity of methane would enter the main airflow, as described in Chapter 7, Ventilation, and be added to the methane layers in the roadways of the Southwest 2 section. Tom Smales, mining engineer and Inquiry consultant, said, "It's vital that the barometer should be examined

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[101] Cape Breton Development Corporation, *Mine Examiner/Shotfirer Training Programme*, Module C/MO 4/3 (Sydney, NS: CBDC, 1987), p. 23.

[102] Exhibit 37b.095, fax to Gerald Phillips dated 20 May 1992 from the Superintendent, Climate Services, Atlantic Region, Atmospheric Environment Services, Bedford, NS.

[103] McPherson's calculations are explained in full in his report of 7 October 1995 (Exhibit 56.3), pp. 33–34. To put this in perspective, 18 cfm would be sufficient to fill the entire Southwest 2 section of the mine with 100 per cent methane in about three weeks; 18 cfm of methane would keep about 25 backyard barbecues going at maximum heat.

continuously."[104] The miner's perspective with respect to the importance of the barometer was expressed by Don Dooley as follows:

> [With a] dropping barometer, the gas is going to exhaust from the gob, from the actual working face, much more readily than a high barometer. The high barometer, the atmospheric pressure pushes that gas back in. So the barometer is very important.[105]

Trevor Eagles admitted quite candidly that he never saw a barometer at Westray and never realized the importance of having one. The only evidence of the presence of a barometer at the Westray mine came from miner John Lanceleve, who said he noticed one outbye No. 1 Cross-cut about three weeks before the explosion. He described it as "just a Canadian Tire, more or less, barometer," the same type as people had in their homes. He said he could tell "it was just put there because there was no dust or dirt on it."[106]

I am satisfied that, for most of the life of the Westray mine, there was no barometer on the premises. Even if one was placed near No. 1 Cross-cut, as suggested by Lanceleve, it was never used in a manner that would be effective in operating the mine ventilation system.

Finding

Westray mine management did not monitor the barometric pressure in any acceptable manner and neglected this significant factor in the maintenance of a safe and effective ventilation system.

The Water Gauge

Another essential piece of equipment for the maintenance of effective ventilation in the mine is the water gauge. Usually located inbye the main fan, the water gauge measures changes in the ventilating pressure in the mine. Changes in the ventilating pressure result from such circumstances as changes in fan speed, restrictions or obstructions in the airways, improperly set doors, improperly adjusted regulators, or airflow through the gob.[107] Any of these conditions may indicate that the ventilation system is not functioning properly, a problem that could result in insufficient fresh air getting to the various working faces in the mine. As well as causing a decrease in the availability of respirable air in the mine, a decrease in the airflow could increase the probability of methane layering at the roof. At Devco, it is the responsibility of the manager or the underground manager (at Westray, Gerald Phillips and Roger Parry, respectively) to "ensure that barometric pressure, temperature, water

104 Hearing transcript, vol. 1, p. 75.

105 Hearing transcript, vol. 36, p. 7784.

106 Hearing transcript, vol. 27, pp. 5548–49.

107 Cape Breton Development Corporation, *Underground Manager Training Programme*, Module C/MO 2/23 (1986), p. 47.

gauge, and humidity readings are taken each day at the mine."[108] It seems Phillips and Parry were either unaware of the importance of the water gauge or unconcerned about its absence at Westray.

Don Dooley was concerned about the absence of a water gauge at the mine. He had previous coal mining experience and was aware of the function of the water gauge. After having a consistent reading (commonly measured in inches) of the water gauge for several months, a change can indicate problems. As he explained:

> All of a sudden you go in there one morning and it's three inches. Well, there's something wrong with my ventilation. I've got a blockage here somewhere because it's [the fan] working too hard. . . . If it goes too low, I've got a short circuit in my ventilation. I'm losing my ventilation somewhere. Extremely important.[109]

Dooley went on to relate an incident with Parry concerning the location of the water gauge and the barometer. This exchange is interesting in that it shows the apathy – or incompetence – of the man who was the Westray boss underground:

> I asked Roger about both of them . . . "Where is my barometer; where is my water gauge?" I thought . . . maybe they did have one somewhere and I just wasn't privy to it. "We don't need those," he said, his exact words. "We don't need them."[110]

There was no water gauge at the Westray mine. It is obvious that the water gauge, if properly monitored and maintained, is a crucial instrument in determining the efficiency of the mine ventilation system. Without the water gauge, it would be almost impossible to get a daily assessment of the condition of the ventilation system – before entering the mine. Changes in the water gauge readings would give the underground manager or supervisor some indication of defects or radical changes in the ventilation system, which could affect the safety of the miners entering the mine. Such readings could give warning of recently occurring obstructions, such as roof falls, or problems with the fan itself, or evidence that regulators might have been left open and were short-circuiting the ventilation system. It is an extremely significant safety instrument.

Finding

Westray mine management failed to provide a water gauge to monitor the ventilation conditions of the mine from the surface and, as a result of this omission, deprived the mine workforce of another significant safety-monitoring device.

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[108] Cape Breton Development Corporation, *Underground Manager Training Programme*, Module C/MO 2/23 (1986), p. 6.

[109] Hearing transcript, vol. 36, pp. 7784–85.

[110] Hearing transcript, vol. 36, p. 7785.

If one accepts the comments of Parry as related by Don Dooley, it is difficult to describe this attitude in terms other than "cavalier" or "foolhardy." Whatever adjective one chooses, this attitude falls far short of the kind of behaviour or demeanour that one would expect from an underground mine manager charged with the safety of the mine workforce. Although the absence of a water gauge may not have had a direct bearing on the mine explosion, it is symptomatic of the overall attitude of mine management towards mine safety at Westray.

Auxiliary Ventilation Ducting

It will become clear from the findings in the Ventilation chapter that the ducting used in the auxiliary ventilation system to provide air to the headings at Westray was inadequate. Taken alone, the ducting itself was too small.[111] The flexible ducting used at Westray had a higher resistance to airflow than rigid ducting and had a propensity to collapse and greatly reduce the airflow. I question the technical wisdom of using this sort of flexible ducting in an exhaust system of ventilation, for several reasons. First, during the mining process, it is impractical to locate the suction end of the duct close enough to the working face to clear the face of methane and dust; with the exhaust system, it is impossible to blow air onto the face. Second, even with properly sized ducting, the air surrounding the duct itself is largely undisturbed by the air moving into it. There might be quite acceptable duct systems in use; the one in place at Westray was not one of them.

The principal defect in Westray's auxiliary ventilation system that bore directly on the propagation of the explosion was its inability to produce air flows of sufficient velocity to disperse the layers of methane that accumulated along the roof in the Southwest 2 section. McPherson isolated three weaknesses in the auxiliary ventilation system that contributed to the lethal buildup of methane layering at the roof of the Southwest 2 section:

> In particular, the main weaknesses were ducting that was too small, air volume flows that were inadequate to produce the air velocities that would prevent methane layering, and the use of exhausting systems that would inhibit adequate mixing of methane with air at the face.[112]

Finding

The combination of poor ventilation pressure, small ducting, lack of bratticing, and deficient ventilation controls made it almost impossible to clear methane from the working faces of the mine. Together, they are a further indication of incompetence or negligence in the safety planning and administration of the Westray mine.

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111 Malcolm J. McPherson, Ventilation at the Westray Mine, report prepared for the Westray Mine Public Inquiry (1995), (Exhibit 56.3) p. 15.

112 McPherson, Ventilation, p. 15.

Management Response

It is obvious that a number of factors combined to create a hazardous environment underground – factors that bring up the entire issue of planning and management at the Westray mine. Interestingly, management dismissed these factors and preferred another explanation for the explosion, which is dealt with in the following section of this chapter, Methanometer Tampering.

The hearing transcripts are replete with references to the excessive coal dust in the mine. This subject will be covered more fully in other sections of this Report, and I will merely refer here to four incidents. First, on 29 April 1992, mine inspector Albert McLean, his supervisor Claude White, and mine inspector Fred Doucette went into the mine for an inspection. As a result, an order was issued by McLean and served on the company the following morning requiring that coal dust be cleaned up immediately. Although he returned to the mine on 6 May, McLean did not follow up on that order, indicating instead that he expected the order to be carried out according to the directives. Second, Eagles said that, during the period from 29 April to the explosion, "In the areas that I travelled, there were still significant amounts of coal dust in some of those areas."[113] Third, Dan MacIntosh, a reporter-cameraman with ATV (Atlantic Television network), went into the mine on 7 May 1992 to shoot some television pictures following the award of the John T. Ryan safety trophy to the company.[114] He entered the mine with a normal TV camera that had no special safety features.[115] He found walking difficult, because the dust was soft and up to his ankles. He noted that the dust was dark in colour.[116] Fourth, miner Lenny Bonner gave evidence that on 5 May he had a "run in" with Phillips following an earlier confrontation with Parry. He concluded not only that Phillips was aware of the excessive coal-dust situation but that management intended to deal with it by installing a sprinkler system.[117]

Finding

During the period leading up to 9 May 1992, there was excessive untreated coal dust in the mine. Little or no effort had been made either to clean up that dust or to render it inert by the addition of sufficient stonedust. Mine management was aware of this problem, but failed to respond to complaints by employees or to the orders of 29 April 1992 from the Department of Labour.

113 Hearing transcript, vol. 76, p. 16640.

114 See Chapter 5, Working Conditions at Westray, for discussion of the award.

115 During my visit to the Skyline mine in Helper, Utah, I was directed to leave my flash camera on the surface, since it was prohibited in the mine. The RCMP, during its post-explosion investigation at Westray, used a camera in a scuba-diving (waterproof) case to avoid the possibility of sparking.

116 *R. v. Curragh et al.*, transcript, 15 February 1995, p. 339.

117 Hearing transcript, vol. 24, p. 4776.

During the course of the investigative and research phase of the Inquiry, I and the Inquiry staff were cognizant of the possibility that any number of mechanical defects could have caused or contributed to this disaster.[118] No evidence came to light of any inherent equipment faults, either mechanical or electrical, that could be reasonably considered in this context, nor did any documentation disclose any such fault.

The following commentary was prepared in direct response to certain explanations advanced over the past several years by Gerald Phillips and Clifford Frame. Neither of these key players in the Westray saga would come forward and give evidence at the Inquiry hearings. They instead chose the media in their various forms as their sounding board. That seemed to suit their particular purpose since such commentary is not subject to rigorous questioning or cross-examination, nor is it given under oath.

Methanometer Tampering

In his various comments reported in the media, Gerald Phillips seems consistently to blame the miners for the 9 May 1992 explosion.[119] In light of all of the evidence respecting the mis-management, neglect, and incompetence that seemed to plague Westray, this simplistic explanation proffered by Phillips can only be regarded as a defensive ploy to deflect attention away from the real causative factors. Unfortunately, this explanation was picked up by former premier Donald Cameron, as indicated in his statement: "The bottom line is that that mine blew up on that morning because of what was going on in there *at that time*. That's the bottom line."[120] I can only assume that Clifford Frame was referring to the same sort of conclusion when he said that the explosion was a "simple accident."[121] After hearing all the evidence and having that evidence analysed and studied by several mining experts, we are now able to label these explanations for what they really are – self-serving, cynical, and simplistic.

It is abundantly clear – from Chapters 7, 8, and 9, Ventilation, Methane, and Dust – that ventilation in the Westray mine was woefully deficient in almost every respect. The airflow was inadequate for the purpose of clearing methane from the working face during mining and

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118 During the hearings, it came to our attention that certain manufacturer's modifications had been made to the Fletcher roof bolter in order to reduce the incidence of sparking as the nut was tightened onto the steel roof plate. I thought it prudent to follow up on this information, even though it was merely a suggestion that came to our attention. We determined that the modification consisted of a vinyl washer placed on the roof bolt as the nut was tightened against the plate. In consultation with Tom Kessler, superintendent of the National Mine Health and Safety Academy, Beckley, West Virginia, and one of his consulting staff, I was informed that such a modification had indeed been made, but for a different purpose. The addition of the vinyl washer in the bolting process was prompted by a need to increase the torque on the bolt, and not by any sparking problem at the mine roof during the bolting process.

119 See, for example, the story in the Halifax *Chronicle-Herald*, 19 April 1996.

120 Hearing transcript, vol. 66, p. 14432. Emphasis added.

121 *Globe and Mail*, 17 February 1997.

preventing the layering of methane on the roof. As the coal was cut from the face by the continuous miner, the methane being released simply eddied about the face and rose to the roof to join with the existing methane layer.[122]

I don't dispute the many dangerous and foolhardy practices of the miners in the days immediately preceding 9 May 1992. There is a question, though, raised by the statements of Phillips, Cameron, and Frame: Had it not been for these practices, would the explosion of 9 May have occurred? The answer, based on the evidence and the careful analysis of the several experts, must be Yes, it would have. The consensus of the experts suggests strongly that Westray was an accident waiting to happen. Only the extent and the seriousness of that accident could not be predicted with accuracy.

Cameron was particularly adamant in his testimony that an incident of tampering with the methanometer on the continuous miner in the SW2-1 heading was a "pretty important [item] of why that explosion took place on that night."[123] Let us look briefly at the evidence concerning the activities in the Southwest 2 section, particularly with respect to the operations of the continuous miner during the last days of Westray.

According to underground mechanic Wayne Cheverie, the methanometer on the continuous miner in the Southwest 2 section had been not functioning for the entire night shift of 7 May.[124] He was told this by Mick Franks, the electrician who also said that he had not been permitted to take the machine out of production to repair it at the time that the methanometer had stopped working during the 7 May day shift. According to Cheverie, Franks "seemed quite upset that the continuous miner working in our section was cutting coal with no methanometer working on it." Franks had been told that the methanometer would be repaired on the night shift, but it had not been. As a result, this continuous miner in the Southwest 2 section operated for the entire night shift of 7 May without the methanometer. According to continuous miner operator Buddy Robinson, the "sniffer" on the methanometer was disconnected on the instructions of foreman Arnie Smith after it malfunctioned, and Robinson operated the machine for the shift using a hand-held methanometer. Robinson would check as close to the face as he could get with the methanometer after loading each shuttle car, which took about 10 seconds. He would get out of the cab of the continuous miner and check for gas. "But every time . . . the readings weren't what I would cut coal in," Robinson testified, "so I would have to wait until the gas dissipated." Robinson said that this was something that he had done in other mines: "[I]t wasn't something you would do every day. It wasn't

122 This is simplified here, but the subject is carefully detailed in the chapters referred to.

123 Hearing transcript, vol. 66, pp. 14428–29.

124 Hearing transcript, vol. 21, p. 4014.

common practice, but it wasn't something that you wouldn't do until parts were forthcoming and it was fixed."[125]

Apparently, the methanometer on the continuous miner was repaired by Franks on 8 May. The notation on Cheverie's tradesmen report for 8 May says "C/M 2002, helped electrician install new cable for sniffer. At the same time we had side & top covers off so I cleaned out and tightened loose hydraulic fittings."[126] According to Mick Franks, Myles Gillis, the night shift electrician, had brought the repair materials into the mine on the previous night intending to fix the methanometer and had left them by the switchgear in SW2-A Road near SW2-2 Cross-cut. After looking at Gillis's report and noting that "he wasn't that busy," Franks speculated that "they just wouldn't have allowed Myles to fix it the night before."[127] Franks said he repaired the methanometer by installing a new hose and cable to the sniffer. Franks did not have the gear to calibrate the methanometer properly, so he got Arnie Smith to check it against his hand-held methanometer: "[H]e checked . . . what was at the head, and it was 0.4 and it matched up . . . with the methanometer right there." Franks also said that Smith pushed the readout button and it flashed a warning light at 1 per cent and shut down at 1.2 per cent. At that point, Smith suggested that Franks adjust the methanometer to shut down at 1.5 rather than at 1.2 per cent:

> And Arnie said words to the effect of "I thought we were supposed to be turning these things up to 1.5," which is what I'd heard had been taking place. So I said, "Well I never really heard about that, Arnie," I said, "but, you know, I don't really want to do it, and besides it would take time. I don't want to be screwing around with it." . . . I don't think it was a real good idea to start turning up the set point on them. So he said, well, if I just turned the reading down a bit, it would be the same thing. I said, "It wouldn't be the same thing, Arnie." I said, "Whatever you figure, buddy, but just leave me out of it." And he took my screwdriver out of my top pocket – a little screwdriver, and he went to the back and turned down the set point. To my knowledge, he turned down the set point. So Wayne and I were putting the plates on the machine at this time.[128]

When Franks left the mine at the end of his shift on 8 May, "it [the methanometer] was still at 1.2 per cent. It was set to trip at 1.2 per cent, but the readings could have been anywhere after it had been tampered with. . . . I would say maybe 1.7 . . . I don't know. I'm no expert."[129]

John Bossert, the Inquiry's equipment and materials expert, gave evidence as to the effect of tampering with a machine-mounted methanometer in the manner described. Bossert said that the methane monitor from the continuous miner had been sent to the CANMET

125 Hearing transcript, vol. 30, pp. 6392–94.

126 Exhibit 75.3.3.

127 Hearing transcript, vol. 21, pp. 4182–83.

128 Hearing transcript, vol. 21, pp. 4184–86.

129 Hearing transcript, vol. 21, p. 4192.

Canadian Explosive Atmospheres Laboratory in Ottawa, which confirmed that the setting was 1.5 per cent. Bossert went on to say:

> There was another test done by Lobay and Dainty [CANMET laboratory personnel] to see whether the calibration of the instrument could be altered by adjusting the span adjustment. This is another adjustment accessible by removing this cover and they found that, yes, indeed, it could be. In fact, they were able to adjust it so that it wouldn't alarm until something like three and a half percent instead of one and a half. So not only was the higher level cutoff set, but it was possible if someone had the ingenuity to fiddle with the controls and make it read much lower that it should have
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> . . .
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> [T]hey were unable to determine whether the sensitivity had been adjusted because they did not have the original sensing heads from the machine. The RCMP removed the instrument but not the sensing heads. When they hooked up another sensing head, they did find, indeed, it was set. It was desensitized. There are variations between sensing heads, so that's not proof that it was set that way.[130]

None of this is in any way conclusive as to the effect of the tampering by Arnie Smith, or even if the methanometer was returned to its proper setting during the fateful night shift that ended early in the morning of 9 May. We do know that Myles Gillis was the electrician for that shift and we do know that Gillis had been ordered to adjust the methanometer (by raising the trip point) to 1.5 per cent on 5 May.[131] We also know that Gillis was anxious to repair the methanometer on 8 May, since he had brought the repair materials in with him that night, but, according to Mick Franks, he was not allowed to shut the continuous miner down for repairs: "I knew he intended to fix it, you know, and given the way Myles was, I knew he would have fixed it if he got the chance."[132] We also know that Gillis complained vehemently to safety officer Randy Facette when he heard rumours that they were going to turn up the set point to 2 per cent. Given all this, it is probable that Gillis would not have returned the methanometer to the 1.5 per cent setting unless he had been ordered to do so. We will never know that.

The fact remains that, after the methanometer was repaired by Franks on 8 May, it was not properly calibrated but only matched up to the 0.4 per cent reading on the hand-held methanometer. The only definitive conclusion is that the methanometer on continuous miner 2002 was not accurate, and it could not be set accurately without the proper gas sample for testing. Bossert has said that the worst case scenario, based on the evidence, is that the tolerance level of the methanometer on the continuous miner could increase to about 2.5 per cent. This would result from resetting the gauge from 1.2 per cent to 1.5 per cent, to which would be added the maximum of 1 per cent from the span adjustment. He

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130 Hearing transcript, vol. 12, pp. 2209–10.

131 Mick Franks, Hearing transcript, vol. 21, pp. 4189–90.

132 Hearing transcript, vol. 21, p. 4183.

also suggested that, since the lower level of flammability of methane is 5 per cent, there would remain a safety margin of 100 per cent (2.5 percentage points).[133] Even if that safety factor had been further eroded by a higher setting on the methanometer, if such was possible, it could not have had such a devastating result without the dismally inadequate ventilation system and the accumulation of untreated coal dust.

What does this mean in our examination of the cause of the explosion that took the lives of 26 men? Did the methanometer tampering by Arnie Smith, as foolhardy and as dangerous as that was, cause the explosion? Let us review the salient facts.

It is clear that the continuous miner in the SW2-1 headings had been gassing out on a regular basis, but in spite of this there was a reluctance to take the machine out of service for repairs. There is clear and unequivocal testimony from the experts that the ventilation system in the mine was inadequate, especially for clearing away the methane at the working face. It was this defect, combined with the apparent obstinate reluctance of management to do anything about it, that was causing the gassing out. To reduce the incidence of gassing out and losing production time, an underground supervisor, probably out of frustration, unwisely and foolishly tampered with the methanometer.

Had the ventilation system been in any way adequate, he would have had no reason to resort to such perilous tactics:

- With an adequate ventilation system, the methane at the working face would have been mixed into the air to a safe level and exhausted in the normal course.
- With an adequate ventilation system, there could not have been a build up or layering of methane along the roof of the mine, since that methane would also be mixed into the air and exhausted.
- With an adequate ventilation system, any methane fire caused by sparking during the coal cutting process would have been localized, and even if a large gush of methane were involved, its effect would probably remain confined to the working face.[134]
- Even if a methane fire did occur in the Southwest 2 section, with proper housekeeping procedures such as the removal of coal dust and stone dusting as required by the *Coal Mines Regulation Act*, the fire could not have propagated into a methane explosion followed by a coal-dust explosion sweeping through the entire mine.

For these reasons it is deceptive, simplistic, and disingenuous to suggest that tampering with the methanometer on the continuous miner, as foolhardy as it may have been, could be the sole cause of the explosion

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133 Conversation on 26 February 1997, followed by a confirmatory letter of the same date.

134 Many studies and reports give examples of such methane fires, which burn themselves out with little or no damage or injury.

on 9 May 1992.[135] This, in my view, is a complete answer to the cynical comments of Phillips as reported in the media and picked up by Messrs Cameron and Frame.

Finding

The evidence indicates that there was tampering with the methanometer on the continuous miner in the Southwest section. The evidence does not support a finding that this tampering in any way caused the explosion.

Conclusion

It is unfortunate that we are unable to state with complete certainty what caused the death of those 26 miners in the early morning hours of 9 May 1992. Failing that, we must analyse the known facts, and the opinions based on those facts, and arrive at the most probable cause of death. To support these findings, we relied on the anecdotal evidence of the miners and the mine rescuers, the photographic evidence gained as a result of the RCMP investigations, and the opinions, based on this evidence, of the several experts. The opinion evidence of Andrew Liney, Don Mitchell, and Malcolm McPherson, although not always in agreement on every issue, leads to the conclusion that the miners in the Southwest 2 section were overcome by carbon monoxide and died almost immediately. This conclusion is consistent with an intense methane fire that consumed all the oxygen, producing carbon monoxide among other products of combustion. It is also consistent with the findings of the chief medical examiner as set out above. The miners in the North mains and the Southwest sections most probably died of a combination of carbon monoxide poisoning and severe bodily injuries. They would have died instantaneously. This is consistent with a coal-dust explosion and the severe physical force exerted by the shock wave preceding the actual coal-dust conflagration.

In other chapters of this Report, we examine in considerable detail the workings of the mine and the planning of those workings; the geological structures and the impact those structures had on mine planning and safety; the operation, planning, financing, and management of the mine; daily working conditions in the Westray mine during its short lifespan; and the conduct and attitudes of the several government departments, and their officials, that had statutory responsibilities for various aspects of the Westray mine. As I suggested at the beginning of this chapter, these examinations have been made to answer the question of why 26 men died

135 **Comment** Donald Cameron, having no expertise in coal mining equipment, cannot be faulted for accepting the opinion of the mine general manager. What he can be faulted for is obstinately maintaining and defending that opinion in the face of overwhelming evidence to the contrary.

on 9 May 1992. It will become further evident during the ensuing examination why the Westray story was a predictable path to disaster.

Finally, the Report contains recommendations for avoiding similar tragedies in the future. Since workplace safety transcends the underground coal mining environment, many of the recommendations and suggestions will have general application in the workplace. Sadly, I have come to the conclusion that many workplace safety programs are disaster driven. Perhaps it is an opportune time for the three interested parties – owner, worker, and regulator – to move beyond a "reactive" mentality towards an anticipatory approach and to forestall such predictable events. This will be addressed at greater length elsewhere in this Report.