DEPARTMENT OF MINERAL RESOURCES AND DEVELOPMENT
NEW SOUTH WALES

CHEMICAL LABORATORY BRANCH

EXPLOSION AT APPIN COLLIERY ON 24TH JULY 1979: REPORT ON CERTAIN SCIENTIFIC ASPECTS

C. ELLIS
SENIOR SCIENTIFIC OFFICER
SAFETY-IN-MINES SECTION

18th October, 1979

P.O. Box 76 Lidcombe, N.S.W. 2141

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STATEMENT

My name is Clive Gordon Ellis. My home address is 34 Lithgow Avenue, Yagoona. I am employed in the Chemical Laboratory of the New South Wales Department of Mineral Resources and Development where I am the Senior Scientific Officer in the Safety-in-Mines section. I have the degree of Bachelor of Science from the University of Sydney. I have been employed by this Department in a full-time capacity for twelve years, most of that time being involved with explosives, flammable liquids, gas analysis and mine safety work.

This report contains the results of investigations into the explosion which occurred at Appin Colliery on 24th July 1979.

I arrived at the mine at 2.30 am on 25th July to assist in the analysis of gases, and was present until about 10.00 am on 26th July. I have since been underground at the mine on 1st, 3rd, 6th, 8th, 9th and 22nd of August. During these visits I examined equipment and structures in K, J, white and red panels, and collected samples of various items which had been involved in the explosion or affected by it.

At the Chemical Laboratory we have received 111 items (a few of which have been forwarded to the Londonderry Testing Centre), together with 45 roadway dust samples. Reports on the roadway dusts and on most of the other items form appendices to this report. Work on these items has been carried out by myself or, at my request, by colleagues in the Laboratory.

C. Ellis
Senior Scientific Officer
Safety-in-Mines Section

The report discusses the following topics:

1. Some Characteristics of a Propagating Explosion

There are two basic types of explosion:

(i) deflagration, and (ii) detonation

The characteristics of detonations need not concern us in this investigation, since it is uncertain whether a detonation of coal dust has ever occurred in an operating mine (ref. 2, p. 88. The exceptional experiment performed by Cybulski - page 283 - is not relevant here).

For deflagrations, theoretical considerations of a flame travelling at constant speed reveal the following characteristics:

(a) a shock wave travelling faster than the flame front, and faster than the speed of sound, which raises dust from mine surfaces as it travels, forming a dust cloud;

(b) a flame front consuming some of the fuel and oxygen in the dust cloud;

(c) a region between shock wave and flame front, in which the dust cloud has a constant forward velocity equal to about 85% of the flame speed, and in which the pressure is higher than atmospheric pressure.

(d) a region behind the flame in which velocity is zero, and pressure is lower than in (c), but still above atmospheric pressure.

The table below (from Cybulski, ref. 2 page 80, and Artingstall, ref. 1 page 16) shows the relationship between flame speed, shock wave speed, and velocity and pressure between the shock wave and flame front.

Flame velocity (m/sec)	Shock wave velocity (m/sec)	Velocity of air between shock wave and flame (m/sec)	Absolute pressure between shock wave and flame (atmospheres)
50	375	40	1.2
260	500	220	2.3
400	600	340	3.5
650	800	550	6.5
1000	1100	850	12.3

The table shows examples of the range of intensities of a coal dust explosion. An explosion travelling more slowly than 50 m/sec is unlikely to propagate. The maximum velocity attainable (excluding detonations) is about 1100 m/sec.

An object in the path of the shock wave is subjected to an abrupt change of pressure equal to the values in the last column of the table, less 1 atmosphere. For a constant flame speed of 50 m/sec, the change is 0.2 atmospheres. Stoppings and overcasts are subject to this entire pressure change, and usually would fail. Behind the shock wave, air movement imposes a 'dynamic' pressure on objects in the path. For a flame speed of 50 m/sec, this would be 0.01 atmospheres.

(This general description of the mechanism of propagation of an explosion is in agreement with the accounts of A. Hoffman and A. Viljacik in their descriptions of the Appin explosion.)

In practice, explosions rarely travel at constant velocity; they usually are either accelerating or decelerating. As a further complication, the gases behind the flame cool afterwards, and produce a low pressure which can retard the explosion.

2. Extent of Flame Travel at Appin

Two types of sample, collected widely in K and J panels, could be used as an indicator of flame travel. These are

(i) marlin samples (see Appendix E4), and

(ii) roadway dust samples (see Appendix D).

Both materials are affected by heat. The marlin exhibits changes which are visible under a microscope. The coal dust particles in the roadway dust samples undergo chemical changes under the influence of heat. Some components known collectively as "volatile matter" are driven off. The greater the degree of heating, the greater the proportion of volatile matter which is lost. The volatile content of the coal matter in the roadway dusts can be determined, and the original volatile content of the coal is known to be 22.5% (dry basis) within narrow limits; the loss of volatile matter may therefore be used as a measure of the degree of heat to which the dust has been exposed.

Because dust may have been transported over considerable distances during the explosion, it was uncertain whether dust samples would provide a reliable indication of the passage of flame. This question is resolved by comparison, in Appendices E4 and D, of the results of examination of the marlin and the roadway dusts. The results are shown on the plans, pages D3 and E4/3, and on page 8 of this report. It is seen that a high damage rating for the marlin corresponds closely to greater loss of volatile matter from the coal portion of the roadway dust. The location of the marlin during the explosion is certain, since it was tied to the roof. The good correlation obtained between heat damage to the marlin and heat effects on the roadway dusts therefore confirms that the roadway dusts can also be used as an indicator of flame travel.

One roadway - B heading of red panel - still posed a problem. Since this heading had been driven by a Paurat header, and a large amount of roof rock had been cut during the forming of the arched roof, the presence of rock dust in the roadway may have given a lower result for the volatile content of the coal. The heat effect on the marlin in this heading shows clearly that flame has travelled in this heading.

It can be difficult after an explosion to distinguish between the effects of flame and of hot gases. In this case the marlin at first appeared to show a difference. Some test pieces of new marlin were heated in a furnace, without flame, as described in Appendix E4. The outer surface turned to a brown colour. When exposed to flame, the outer surface became black. This was the appearance of the samples received at the laboratory. Microscopic examination has revealed, however, that it is not possible to distinguish between a charred outer layer of rope, and adhered fine particles of dust and soot. Hence it has not been possible to determine whether it is flame or very hot gas which has traversed a region. This finding is in accord with results of work by the US Bureau of Mines (ref. 3, page 9): "The terminal point of flame is difficult to establish. Even in research where photographic and other methods are used, the end of the flame is not precisely defined. At the terminal point flame is "thin" and surrounded by obscuring smoke and dust. Heated gases may discolour paper without flame actually being present."

Other indicators of flame were also noted. These included: conveyor belting, gas sampling lines, power cables, telephone cables, and such materials as paper, brattice and plastic.

With the above limitations, I therefore conclude that flame travelled:

in K panel -

- the full length of B heading,
- the full length of A heading outbye of 4 CT,
- in Longwall 8 Main Gate from 4 CT outbye to D heading, white panel. (The flame may not have traversed the fall at A heading of Blue panel; it may have travelled via white panel back into Longwall 8 Main Gate.)
- in cut throughs 4,3,2 and 1, and the cut through outbye A & B headings of red panel.

in white panel -

- in D heading from B heading K panel to about halfway to 29 CT,
- in 30 CT between D and C headings,
- possibly into C heading between 30 and 29 CT.

in blue panel -

- possibly very weakly into C heading, and less probably B heading.

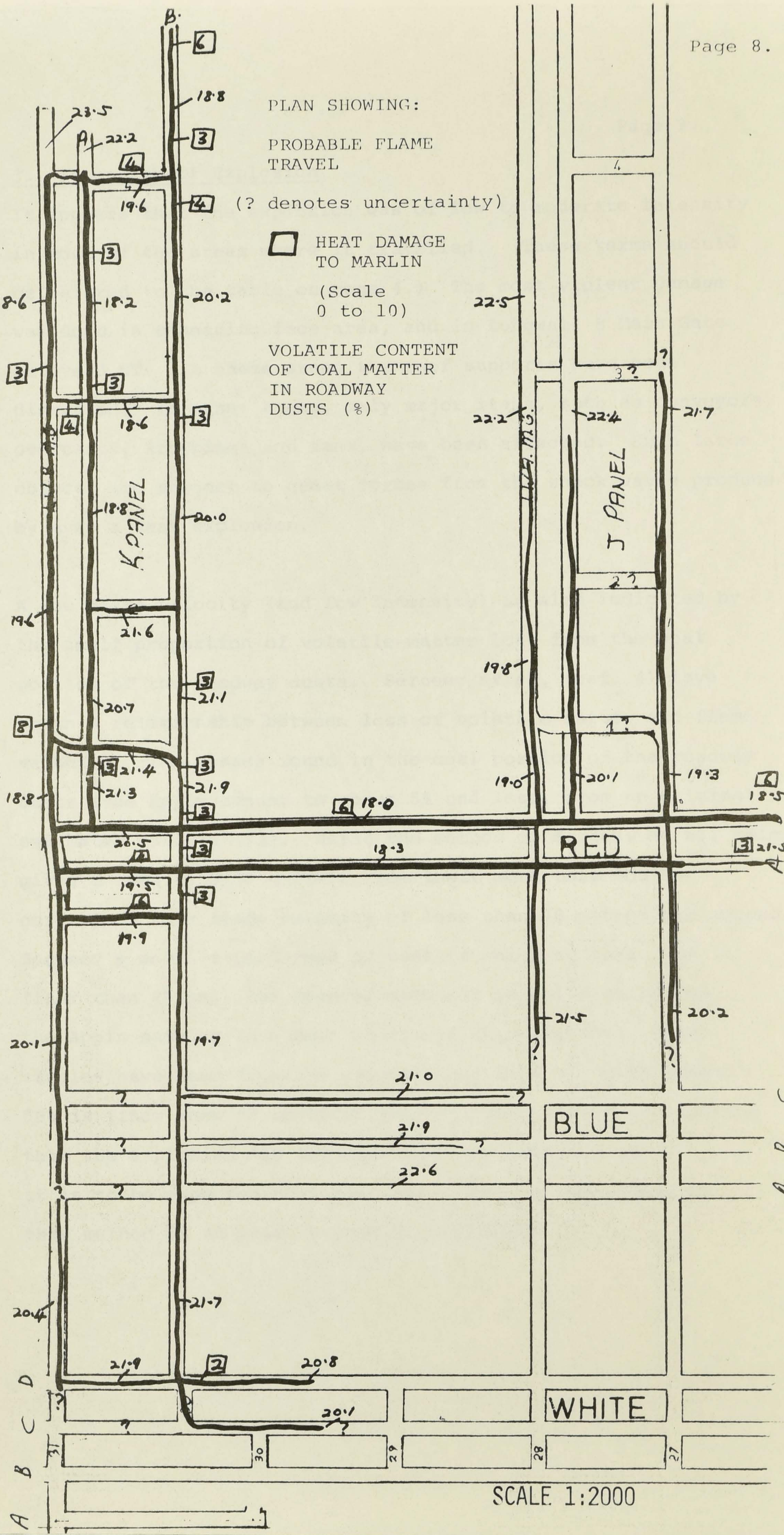
in red panel -

- in B heading at least as far as Longwall 6 Main Gate (H panel),
- in A heading, strongly to B heading J panel, weakly towards H panel. (Protected by wall at B heading J panel).

in J panel -

- in Longwall 7 Main Gate, A heading and B heading inbye to about 3 CT,
- in Longwall 7 Main Gate outbye from red panel weakly towards blue panel,
- in B heading outbye of red panel towards Blue panel.

The plan on page 8 shows the approximate extent of flame travel, together with the heat damage to the marlin, and the volatile content of the coal matter in the roadway dust samples.


PLAN SHOWING:
PROBABLE FLAME TRAVEL
(? denotes uncertainty)
HEAT DAMAGE TO MARLIN
(Scale 0 to 10)
VOLATILE CONTENT OF COAL MATTER IN ROADWAY DUSTS (%)
K PANEL
J PANEL
RED
BLUE
WHITE
SCALE 1:2000
A
B
C
D
31
30
29
28
27
23·5
22·2
18·8
19·6
18·6
18·2
20·2
20·0
21·6
21·1
20·7
21·4
21·3
21·9
18·0
20·5
18·3
19·5
19·9
20·1
19·7
21·0
22·6
21·7
20·4
20·8
22·5
22·4
19·8
19·0
19·3
18·5
21·5
20·2

3. Intensity of Explosion

It appears that the explosion was of low to moderate intensity in most of the areas where it travelled. (These terms should be related to the table on page 4.) The most violent damage was done in B heading face area, and in Longwall 8 Main Gate outbye 3 CT. In these areas the roof supports have been disrupted. In other areas, only major items, such as conveyors, overcasts, stoppings and fans, have been affected. Such large objects are subject to great forces from the shock waves produced by even a weak explosion.

A low flame velocity (and low intensity) is also indicated by the small proportion of volatile matter lost from the coal portion of the roadway dusts. Sergeev et al. (ref. 4) have shown a relationship between loss of volatile matter and flame velocity. The losses found in the coal portion of the roadway dusts from Appin amount to about 5% and less, from an original estimated value of 23%. Using the method of Sergeev et al. this gives a loss of 5/23 = 22%. From their work this would correspond to a flame velocity of less than 70 metres per second. Sergeev's work is performed on dust of which at least 75% is finer than 75 μm. Our determinations of volatile matter on the Appin samples have been on the -250 μm portion. These samples have been found to contain coal dust of which about 50% is finer than 75 μm after the explosion. Even considering that the explosion may have affected the particle size, it is to be expected that the flame velocity determined by this method is at least a good approximation.

4. Means of Initiation

(This section deals, not with the source of ignition, but with the early development of the explosion.)

It is my opinion that:

- the initial explosion was an ignition of methane;
- the ignition occurred in the area of B heading stub; and
- the explosion flame in B heading stub probably travelled from the face end outbye.

I shall discuss these matters in turn.

4.1 The initial explosion was an ignition of methane.

4.1.1 The alternative to a methane ignition is a directly-ignited explosion of coal dust, which is highly improbable. For this to occur, it would be necessary to have two improbable conditions simultaneously:

(a) a coal dust cloud of sufficiently high concentration. The necessary concentration is somewhat greater than those produced in normal mining processes, and would reduce visibility to almost nil. While a major fall or some other violent concussion could raise this amount of dust, it is improbable.

(b) a sufficiently strong source of ignition to ignite dust.

Coal dust from Appin Colliery requires an intense source of ignition. The laboratory-scale explosibility test apparatus used by this Department is incapable of igniting Appin dust directly by electric spark or arc. Similar tests have been carried out by the United States Bureau of Mines using samples of Appin coal, with the same result.

From the above, it is clear that the two prerequisites for direct ignition of a dust explosion are each unlikely to occur; their simultaneous occurence is therefore even more improbable.

4.1.2 A methane ignition is a highly probable means of initiation.

4.1.2.1 The rate of emission of methane would allow the accumulation in B heading face area, within a short time, of sufficient methane to initiate a coal dust explosion.

The measurements given in Appendix C show the rate of emission of methane in B heading face area as 1.5 cubic metres per minute. The rate at the time of the explosion may have been higher, since the measurements were made two weeks later, without any further mining. In Polish experimental work (ref. 2), Cybulski routinely used 50 cubic metres of a 9.5% methane-air mixture for initiation of coal dust explosions. This volume of methane (unmixed) would be available in B heading face area in a time of less than 3½ minutes, if no ventilation were present. The methane may mix with the air, or may form a roof layer, which is nevertheless capable of initiating a dust explosion. The fact that B heading rises to the face aggravates the problem of accumulation of methane. A dangerous quantity of methane in this area is therefore a likely occurrence.

4.1.2.2 An explosive mixture of methane/air almost certainly was present in B heading stub at the time of the explosion. The U.S. Bureau of Mines have shown (ref. 3, page 5) that "flame from a propagating explosion projects into a dead end only if the atmosphere therein contains an explosive gas-air mixture; flame will not project into a dead end containing coal dust alone." Since flame propagated into the (dead end) face area of B heading, it appears that this area must have contained an explosive gas-air mixture.

4.2 The ignition occurred in the area of B heading stub. This follows directly from the previous section. If the initiator was a methane explosion, and an explosive mixture almost certainly was present in B heading stub, then initiation almost certainly occurred in B heading stub. The pattern of damage confirms this as the area of origin of the explosion.

4.3 The explosion flame in B heading stub probably travelled from the face end outbye.

This follows from the results of experiments by the U.S. Bureau of Mines (ref. 3, page 20). It was found that even with a well-mixed 9.5% methane-air mixture, ignition at the outbye end produced very weak shock waves, as low as 7 kPa (1 psi). These were not capable of dispersing enough coal dust for propagation. On the other hand, ignition of the same body of gas at the face can produce a severe explosion, as high as 280 kPa (40 psi).

Although the investigations by Cybulski (ref. 2) do not directly examine this same question, it is significant that his experiments involving initiation of coal dust explosions using roof layers of methane involve ignition at the face end of the roof layer.

The degree of damage produced in B heading near the face and back past 4 CT suggests a violent explosion resulting from ignition of a body of gas near its inbye end.

If this conclusion is correct, it limits the possible locations of ignition of the methane to either the face, or a point from which flame could travel to the face. The vent tubes provide one path by which flame could travel to the face and there ignite a body of gas at its inbye end. I am uncertain that a roof layer of methane could behave in this way. It would seem that flame travelling via a roof layer of methane must ignite a body of gas at its outbye end. It would then produce an explosion which was incapable of initiating a coal dust explosion.
This question needs further investigation.

5. Source of Ignition

The work undertaken at the Laboratory has not indicated any sources of ignition. Laboratory personnel have been involved in discussions with the Londonderry Centre concerning tests on oil flame safety lamps, and have also been involved in some tests at the Southern Mines Rescue Station. These tests are as yet inconclusive.

Tests have been performed on some materials from the auxiliary fan switchbox, an Auer methanometer, and the conveyor starter, to determine whether there is evidence of flame in these items. The results are to be found in Appendix E5.

A brattice cloth found rolled at the intersection of B heading and 4 out through has been discounted as a likely source of a static electric spark.

6. Involvement of Coal Dust

I am of the opinion that the explosion was propagated by coal dust. The following evidence indicates this.

6.1 Trickett's ratio, calculated on the post-explosion gases, using a sample taken late on Wed. 25th July, indicates that coal dust played a major role in the propagation of the flame. Since the gaseous products of a methane explosion differ from those of a coal dust explosion, this ratio may be used to indicate which fuel was involved in an explosion.

Appendix B explains the theory and gives the calculations. Although the analytical results were not as complete as would be desirable, the problem has been examined carefully and solved by mathematical means. In summary, for a methane explosion the ratio calculates to ≤ 0.5; for a coal dust explosion the result is ≥ 0.87. The value obtained in Appendix C is 0.77 ± 0.14. Considering that the sample was taken from an area close to the site of a supposed methane explosion, it plainly indicates the involvement of coal dust.

6.2 The total quantity of volatile matter lost from the coal matter in the roadway dusts indicates that coal dust was a major contributor of fuel for the explosion. Passage of the flame drives off volatile matter from the dust particles, and this lost volatile matter is consumed by the flame. An approximate calculation can be performed using the information obtained from the roadway dust samples. Such a calculation is outlined in Appendix D. It reveals a known loss of coal matter from the dust remaining in K panel (in the area bounded by, but excluding, D heading of white panel and Longwall 7 Main Gate), of about 90 Kg. The result is conservative because it neglects:

- volatile matter lost from coal coarser than 250 µm;
- any fine coal which has been completely burnt;
- any fine coal from which volatile matter has been lost, and which has been transported outbye during the explosion.
- volatile matter lost from coal at a depth greater than about 6 mm.

This quantity of coal matter may be compared with a similar mass of methane. 90 Kg of pure methane would occupy a volume of about 135 cubic metres at 20°C.

It is quite possible that such a quantity of methane had accumulated in K panel; what we have shown is that coal dust provided a quantity of fuel comparable with that likely to have been provided by methane. It must therefore be concluded that coal dust was a major contributor of fuel for the explosion.

6.3 The extent of the flame suggests the involvement of coal dust. A methane explosion under ideal laboratory conditions can reach a temperature of about 2200°K, giving an expansion ratio of about 7:1. Research by the US Bureau of Mines (ref 3, page 22) has shown a practical maximum of 5:1, found to occur with a 12% methane-air mixture.

The volume of roadway traversed by flame in K panel in the area bounded by (but excluding) D heading of white panel and Longwall 7 Main Gate, is calculated to be approximately 30800 m^3. This assumes cross-sectional areas for the roadways of:
28 m^2 for B heading of red panel, 15 m^2 for Longwall 8 Main Gate, and 14 m^2 for other roadways.

If only methane were involved as fuel, at least one fifth of this volume of a 12% well mixed methane-air mixture would be required. That is, over 6000 cubic metres of explosive gas-air mixture would be required, occupying over 430 metres of roadway. This is extremely unlikely. Coal dust must therefore have contributed a major proportion of the fuel.

6.4 The pattern of blast damage suggests that coal dust was involved. In particular, the violent damage in areas such as Longwall 8 Main Gate, outbye 3 CT, remote from the likely point of origin (i.e. B heading, 4 CT and inbye) suggests that a localised methane explosion was not the only phenomenon involved. However such an impression is more difficult to quantify.

7. Stonedust

The results of analysis of roadway dust samples, taken by the Departmental dust sampler after the explosion, may be found in Appendix D. All analyses were performed by the chemical method, and were duplicated.

The results include very few which would comply with the requirements of the Coal Mines Regulation Act, Section 54, General Rule 12B(11)(a). This section specifies a maximum volatile content of the roadway dust sample of 11.5%. If it is considered that the coal dust in these samples has a reduced volatile content, it would at first appear that the situation before the explosion was even worse.

However I believe that it would be quite incorrect to draw conclusions from these results, concerning the adequacy of stonedusting prior to the explosion.

7.1 Transportation of dust during the explosion has altered the situation. Much of the dust - both coal dust and stonedust - raised by the shock wave of an explosion, would be transported outbye by the air movement. Some would return with the return rush of air after the blast. The coarser dust would settle more quickly; the finer dust would remain suspended for longer, and may be carried over considerable distances. It is quite possible, if the particle size distributions of the coal dust and stonedust were dissimilar, that a large proportion of one could be removed by the explosion, and only a small proportion of the other. This would greatly alter the measured volatile content of the roadway dusts.

If transportation of dust were a significant factor in the explosion, it would be expected that the particle size distribution of the roadway dust would be altered by the removal of some of the finer material. Preliminary work on examination of particle sizes has been carried out, using the roadway dust samples. It is plain that there has been a massive loss of the finest stone dust. The stone dust used by Appin Colliery usually has 47% of its mass finer than 45 μm. In sample 8-M-1 (see Appendix D), 5.6% of the stonedust is finer than 45 μm. The question is further complicated by the fact that the roadway dust samples are probably biased towards finer particle sizes. The samples were taken to a depth of about 6 mm. This dust would be the last to settle after the explosion, and therefore contains a greater proportion of small particles.

Of course, it could equally be argued that fine coal dust has been removed. In order to arrive at correct conclusions concerning the situation prior to the explosion, far more information would be needed about the particle size distribution of the coal in the roadway dusts prior to the explosion.

7.2 Mixing of the dust by the explosion has altered the situation. It is possible to envisage a situation existing before the explosion, in which roadway dust would comply with statutory requirements, and where - even if no dust were transported outbye - the dusts after the explosion would fail to comply. This would be the case if a substantial layer of coal dust finer than 250 μm were covered by a substantial layer of stone dust. Sampling to the normal depth of 6 mm would produce a dust sample which could easily comply with regulations. During the explosion, much of the dust could become airborne, thoroughly mixed and re-deposited. Sampling to a depth of 6 mm would produce a dust sample which may no longer comply with regulations.

It would therefore be incorrect to draw conclusions about the adequacy of stonedusting before the explosion, from roadway dust analyses after the explosion.

8. Arrest of Flame

The flame of an explosion may be arrested by a number of influences, usually operating together rather than alone.

These influences include:

(1) lack of fuel;

(2) excess of fuel;

(3) lack of oxygen;

(4) pressure release, provided by openings into multiple roadways;

(5) retardation from the partial vacuum behind the flame as gases cool;

(6) inert material, such as stonedust and water.

At Appin, many of the conditions existing would have been favourable to an extensive propagation of the flame. Such conditions include:

(a) an abundance of coal dust;

(b) dry conditions in the roadways;

(c) a medium (i.e. not too low) volatile content of the coal;

(d) the likely presence in return airways of methane in concentrations which would contribute to the explosibility of roadway dust;

(e) adequate oxygen;

(f) a strong initiator, judging from the damage in B heading face area;

(g) long straight roadways which would permit development of a high flame velocity.

If we examine the influences listed 1-6 above, which may arrest an explosion, we find that items 1 and 3 are not relevant in the Appin explosion. Item 2 (excess fuel), is considered by researchers to be applicable only in artificial gallery experiments (ref 3, p. 19). Item 4 - pressure release into multiple roadways - would have had some influence in retarding the flame, as would item 5 - partial vacuum developed behind the flame.

It is significant that the flame was of low velocity except at its point of origin (B heading inbye 4 CT) and in longwall 8 main gate outbye 3 CT. This fact points to the presence of significant amounts of inert material, which could only be stonedust.

I am therefore of the opinion that stonedust played a major role in limiting the flame speed, and in eventually arresting the flame. I am unable to estimate the quantity of stonedust which was involved.

9. Fan Starter Materials

The results of examination of some materials from the fan switchbox, and from other equipment, are found in Appendix E5. These results have been used by the Londonderry Centre in assessing the involvement of electrical items in the explosion. I have not attempted to draw conclusions from the results.

10. Brattice at No. 3 Cut-Through

Sample no. 2720 is a piece of brattice cloth, cut from a length of about 200 mm of brattice hanging from a roof saddle in 3 cut-through between longwall 8 main gate and A heading. The results of examination of this sample are found in Appendix E2. As described there, the sample shows evidence of having been stretched while heated. This suggests that at the time the flame traversed this area there was a much larger piece of brattice attached to this fragment. However, even if it could be ascertained whether this was the case, it would still not definitely indicate whether the brattice was in place across 3 cut-through. The possibility would remain that the brattice had been torn down on one side and left hanging from the roof saddle on the other. It therefore seems that no conclusion can be drawn from this evidence.

References: 1. Artingstall : On the Relation Between Flame and Blast in Coal-Dust Explosions.
SMRE Research Report 204 Safety in Mines Research Establishment, Ministry of Power, Sheffield. England.

2. Cybulski, W. : Coal Dust Explosions and Their Suppression.
Translated from Polish for US Bureau of Mines.

3. Nagy and Mitchell : Experimental Coal-Dust and Gas Explosions.
US Bureau of Mines
Report of Investigations 6344.

4. Sergeev, V. S., Kulish V. I., and Ploskogolovyi, E. P. : Change in the Properties of Coal Dust After an Explosion.
Solid Fuel Chemistry Vol. 12, No. 2, 1978.

APPENDIX A

Use of the Mobile Gas Laboratory following the Appin Explosion

Following an explosion at Appin Colliery at approximately 10.30 pm, Tuesday, 24th July 1979, the Southern Mines Rescue Station requested the services of the Department's Mobile Gas Laboratory at 12.45 am on the 25th July, 1979 to carry out gas analyses at the mine.

Messes Ellis and MacKenzie-Wood picked up the Mobile Gas Laboratory, the power generator and a station wagon equipped with extra sampling line and a spare nitrogen cylinder from the Lidcombe Laboratories and arrived at Appin Colliery at 2.30 am.

Following consultation with the Chief Inspector and Deputy Chief Inspector, the laboratory was at first installed near the mine buildings, and later relocated at the main fan evassee to continuously monitor the return air. The analyses were required to supplement the results being obtained from three underground points with the Corex Tube bundle system.

Monitoring continued from 6.10 am on 25th to 9.30 am on the 26th with results being given by phone to the main office at 15 minute intervals, this being reduced to 5 minute intervals, when fire gas levels increased concentration.

The monitoring was required as rescue teams attempted to restore ventilation to K panel. Carbon monoxide levels were needed as an early fire detector and methane levels were monitored to ensure contamination did not reach unsafe levels. Carbon dioxide and oxygen levels were also continuously monitored and intermittent analyses for hydrogen were performed. Bag samples brought to the surface by rescue teams, were also analysed.

Although the gases analysed at the return shaft were more dilute than those obtained by the Corex tube bundle system, changes in concentration were detected at the fan approximately 40 minutes before they were reported by the mine's analysers. This delay was caused by the sample transit time in the tube bundle.

The Mobile Laboratory was able to provide earlier warning of changes, and to perform a wider range of analyses than could be obtained from the mine system.

Copies of selected results, and of the chart recorder traces, are attached.

C. Ellis
Senior Scientific Officer
Safety-in-Mines Section

30th August, 1979

MINE ATMOSPHERE MONITORING

MINE: Appin

Sample Number	Time	Comments	CO %	CH_4 %	O_2 %	CO_2 %
1	6.10 am	Fan Shaft	.0042	1.00	20.7	0.03
2	6.35	" "	.0047	1.3	20.5	0.08
Bag 3	5.55	Red Panel Side of Shaft	.0004	0.06	20.8	0.06
Bag 4	5.50	N.E. Intake Side of Shaft	.0120	2.4	20.6	0.13
5	7.35	Fan Shaft	.0038	1.3	20.4	0.08
6	8.00	" "	.0038	1.3	20.5	0.08
7	8.30	" "	.0045	1.3	20.5	0.08
8	8.45	" "	.0063	1.3	20.5	0.08
9	8.55	" "	.0080	1.25	20.5	0.08
10	9.15	" "	.0086	1.25	20.5	0.08
11	9.25	" " (Corex CO still incr.)	.0077	1.25	20.5	0.08
12	9.32	" "	.0072	1.25	20.5	0.08
13	9.37	" "	.0067	1.25	20.5	0.08
14	9.55	" " (Corex CO peak 9.45)	.0054	1.25	20.5	0.08
15	10.30	" "	.0039	1.25	20.5	0.08
16	11.00	" "	.0032	1.25	20.5	0.08
17	12.00	" "	.0024	1.2	20.5	0.08
18	12.50	" "	.0026	1.2	20.5	0.08
19	1.05	" "	.0040	1.3		
20	2.35	" "	.0029	1.25	20.5	0.08
21	3.50	" "	.0022	1.25	20.5	0.08
22	5.20	" "	.0033	1.3	20.5	0.08
23	6.30	" "	.0017	1.25	20.5	0.08
24	7.00 pm	" "	.0018	1.2	20.5	0.08
Bag 27	7.25	(Sample Y - B Heading inbye (3 CT G.B. sample 5.45 pm	.60	>20.0	12.2	1.08
Bag 28	7.30	Sample K Panel 3 CT adj. to B Heading G.B. sample 5.40 pm	.105	12.4	18.0	-
29	9.00	Fan Shaft	.0018	1.3	20.5	0.08
30	9.15	" "	.0021	1.35	20.5	0.08
31	9.55	" "	.0017	1.3	20.5	0.07
32	11.30	" "	.0006	1.25	20.5	0.06
33			.0005	1.2	20.5	0.06
34	3.30 am	" "	.0005	1.25	20.6	0.06
35	4.45	" "	.0005	1.25	20.6	0.06
36	5.35	" "	.0004	1.25	20.6	0.06

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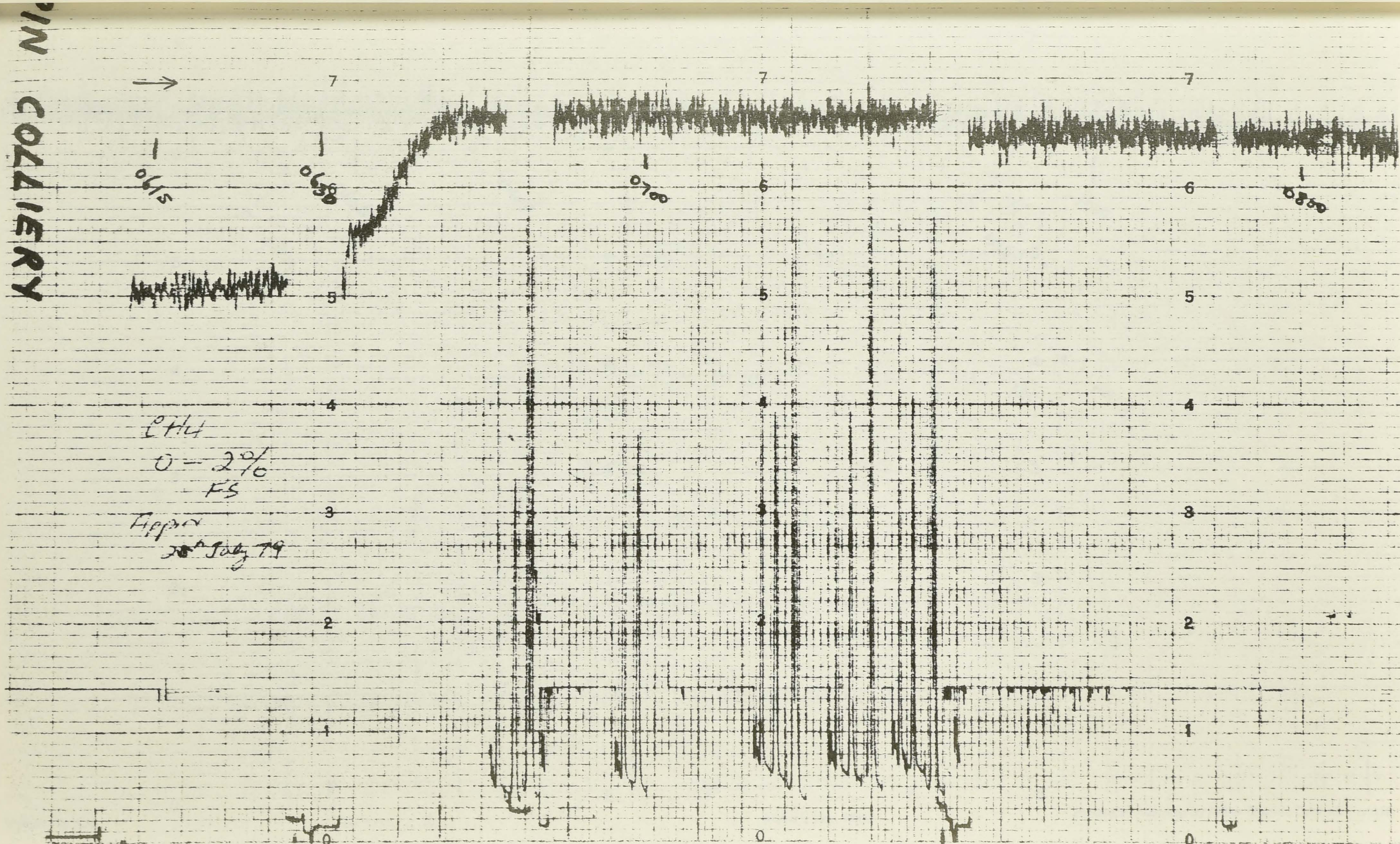
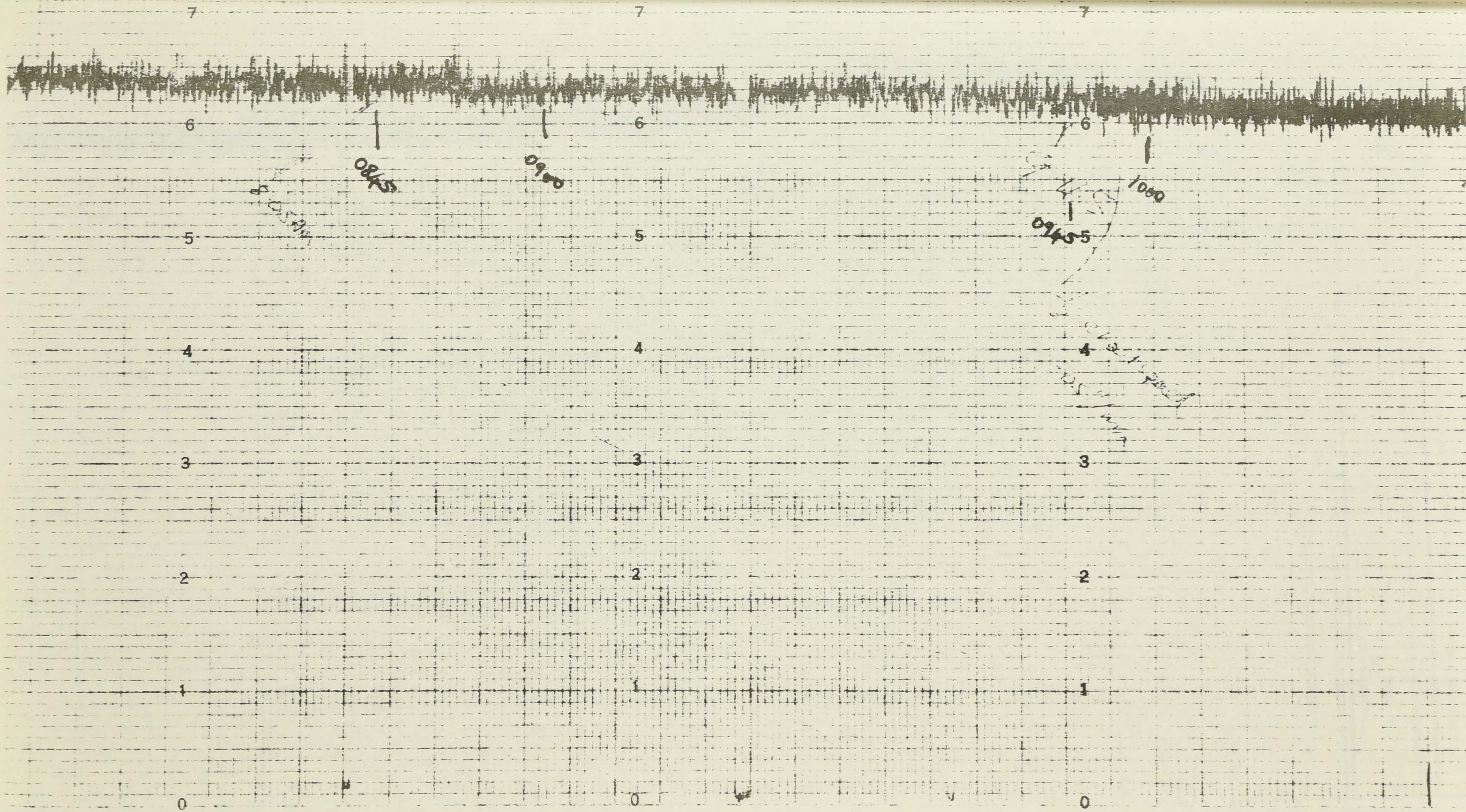
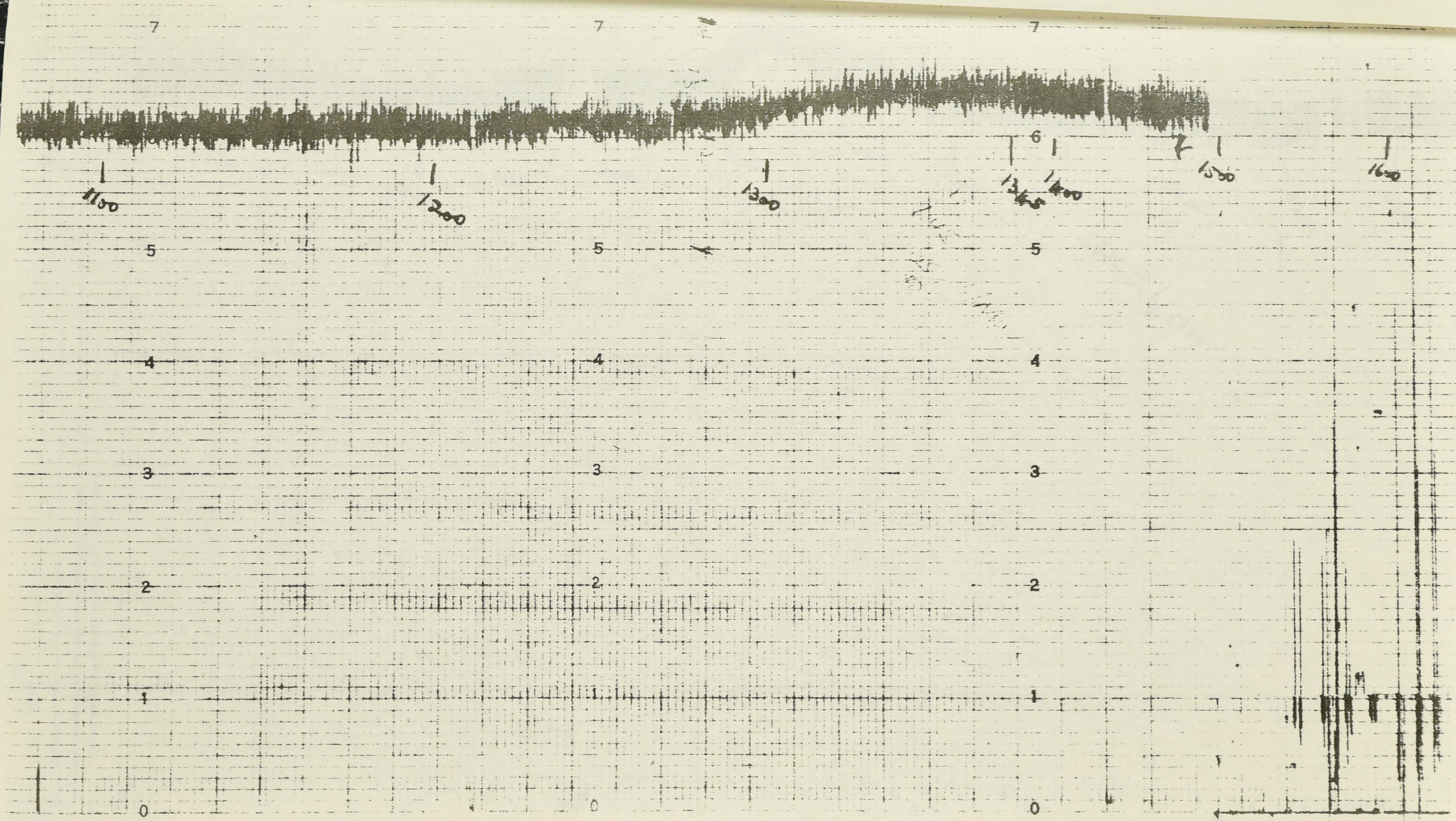


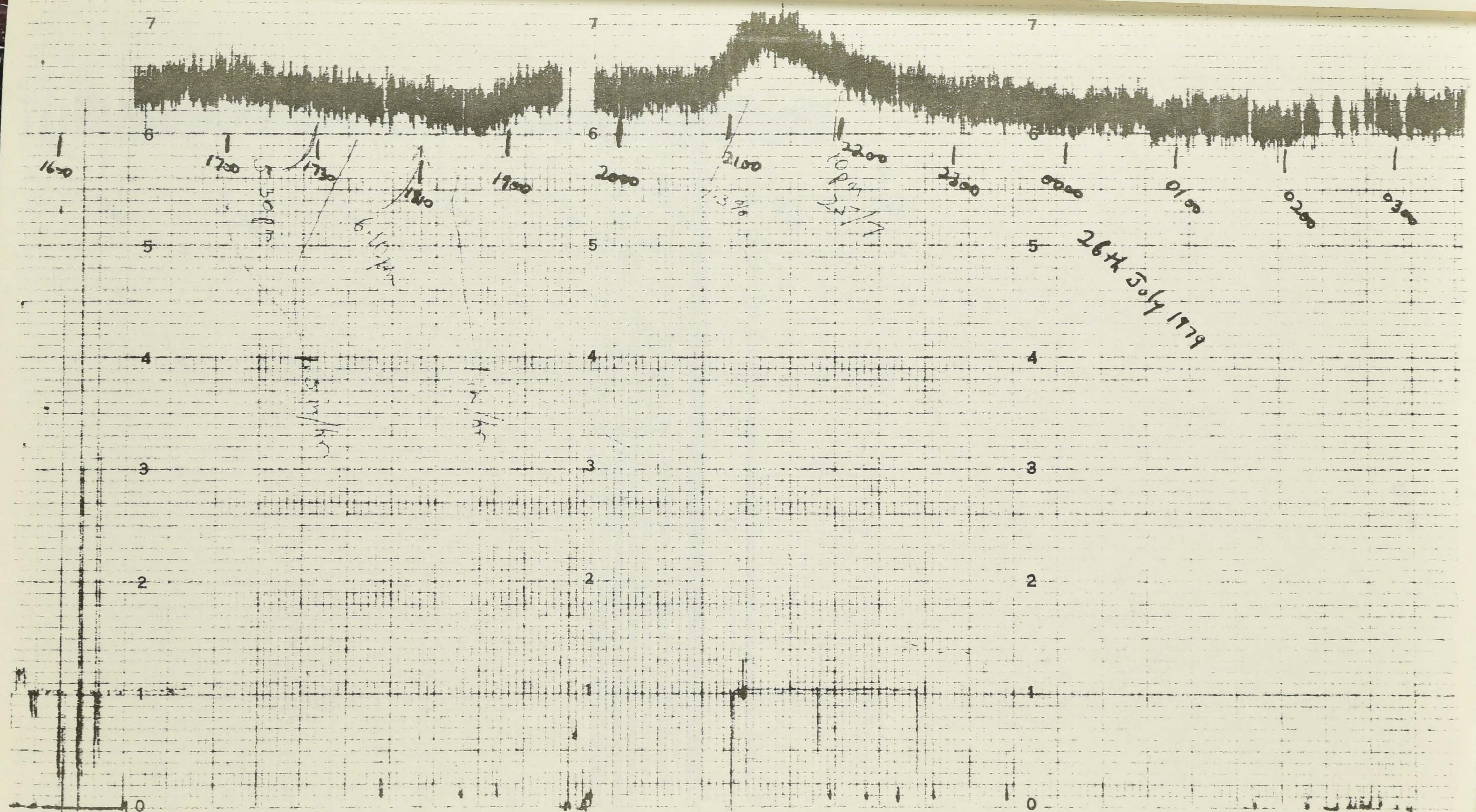
COLLIERY
7
6
5
4
3
2
1
0
0615
0630
0700
0800
CH_4
0 – 2%
FS



Controls Pty. Ltd. HI TYPE C-103 Maker's No. B0253 Printed in Australia by Miller Graphic Controls Pty. Ltd.



ls Pty. Ltd HI TYPE EC-103 Maker's No. 30253 Printed in Australia by Miller Graphic Controls Pty. Ltd.



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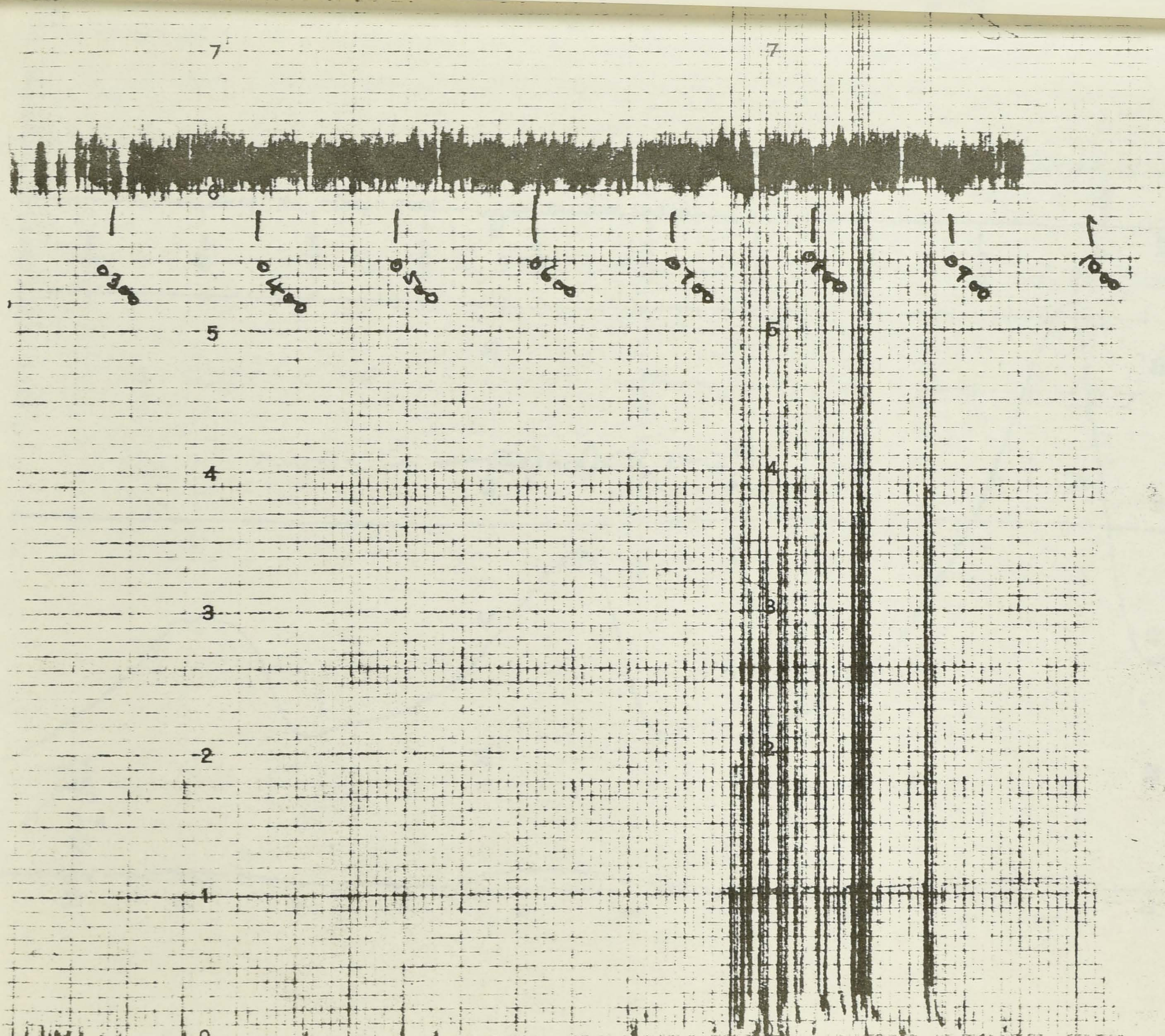


trols Pty. Ltd.

HI TYPE EC-103

Maker's No. 30253

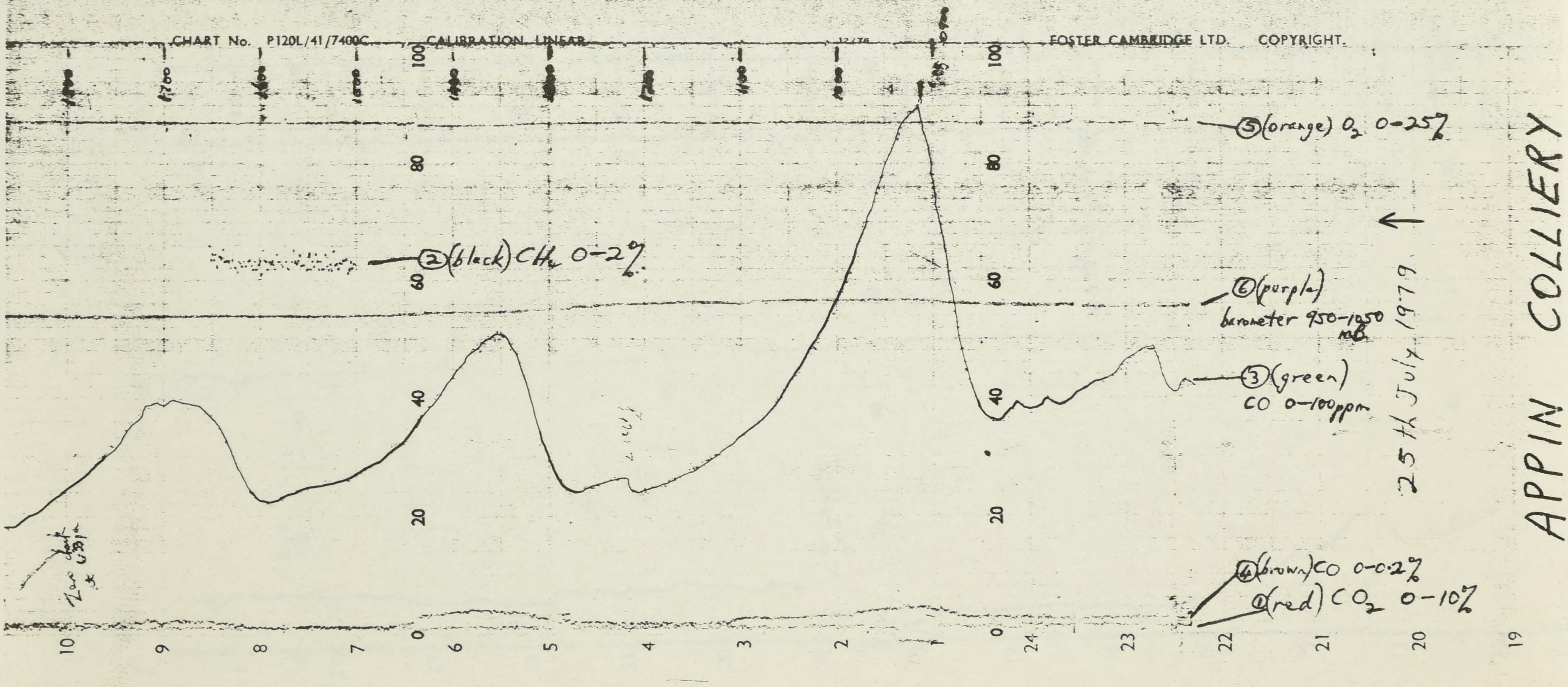


CHART No. P120L/41/7400C
CALIBRATION LINEAR
FOSTER CAMBRIDGE LTD. COPYRIGHT.
100
80
60
40
20
0
5 (orange) O2 0-25%
2 (black) CH4 0-2%
6 (purple) barometer 950-1050 mB
3 (green) CO 0-100ppm
4 (brown) CO 0-0.2%
1 (red) CO2 0-10%
10 9 8 7 6 5 4 3 2 1 24 23 22 21 20 19
25th July 1979
APPIN COLLIERY

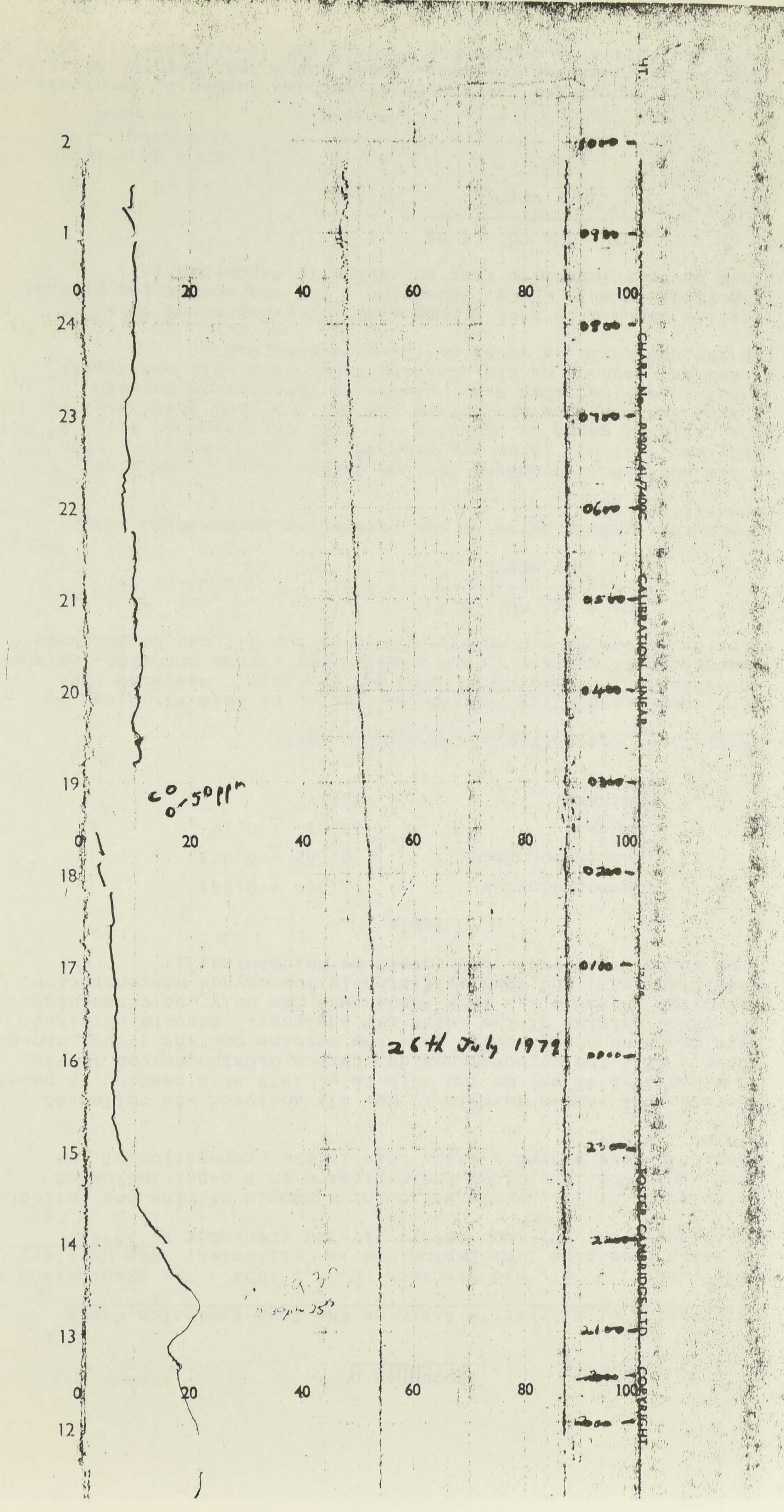


CHART No. ... CALIBRATION LINEAR FOSTER CAMBRIDGE LTD COPYRIGHT
0 20 40 60 80 100
CO 0-50ppm
26th July 1979

APPENDIX B

Calculation of Trickett's Ratio on the Post-Explosion Gases

Ref:- Jones, J. H., and Trickett, J. C., 1954. The Examination of Gases Resulting from Explosions in Collieries. The Colliery Guardian, 1954, 189 (No. 4893), 717-722 (December 9, 1954).

Calculation of Trickett's Ratio for a sample of mine gas collected from Appin Colliery after the explosion in K panel indicated that coal dust played a major role in the propagation of the flame.

The mine gas sample (sample Y, No. 27) analysed was collected in a bag at 5.45 pm, on the 25th July, 1979 at B heading, K panel, inbye 3 CT. The carbon monoxide, carbon dioxide, oxygen levels were measured using mobile van; the methane content (>20%) exceeded the range setting of the infra red analyser. Results obtained are given in table 1. This sample was the only one containing sufficient gas, and with sufficiently low oxygen concentration, from which Trickett's ratio could be calculated.

Table 1

Carbon dioxide	1.08% ± 0.06%
Carbon monoxide	0.60% ± 0.03%
Oxygen	12.2% ± 0.1%
Methane	>20%

Theoretical Derivation of Trickett's Ratio

More complete details for the derivation of this ratio can be obtained in the report by Jones and Trickett. Assuming that combustion of methane in air yields only carbon monoxide, carbon dioxide, hydrogen and water, then equation (1) can be derived:-

$$\frac{CO_2 + 3/4\ CO - \frac{1}{4} H_2}{O_2 \text{ used}} = 0.5 \quad .... \ (1)$$

where the symbols refer to the percentage composition after combustion.

Other additional products include carbon black, ethane and ethylene. If all three are produced in the combustion, then the ratio of gases in equation (1) will be less than 0.5. If only ethane and ethylene are formed the ratio of the gases will be equal to or less than 0.5. Similarly interaction between steam and methane or its combustion products will not result in the gas ratio in equation (1) exceeding 0.5.

Coal is assumed to have a composition corresponding to an empirical formula CHxOy. Equation 1 for the combustion of coal then becomes (assuming that no carbon is deposited):-

$$\frac{CO2 + 3/4\ CO - \frac{1}{4} H2}{O_2 \text{ used}} = \frac{4}{4 + x} + \frac{4 - x}{4\ (4+x)} \cdot \frac{CO + H_2 + 4CH4}{O_2 \text{ used}} \quad ..... \ (2)$$

where CH_4 represents the amount of methane formed by pyrolysis of the coal. Jones and Trickett (1954) state that for the majority of coals 4/(4+x) approximates to 0.87 and (4-x)/(4/(4+x)) to 0.18.

...B2/

For the majority of explosions the value of the second term in equation (2) is relatively small and can be disregarded, equation (2) then becomes:-

$$\frac{CO_2 + 3/4\ CO - \frac{1}{4}\ H_2}{O_2 \text{ used}} \geq 0.87 \quad \ldots\ldots\ldots \ (3)$$

Carbon deposition will reduce this ratio, however Jones and Trickett showed that approximately 75% of the coal would need to be deposited to reduce the value of the ratio to 0.5.

Determination of Trickett's Ratio for Sample No. 27

To calculate Trickett's ratio for the mine gas sample collected at Appin Colliery, the values for carbon dioxide, carbon monoxide, Hydrogen, oxygen and methane (seepage from coal seams) content are required. There was insufficient sample available to determine the hydrogen or accurate methane content. Estimates were made of these values and hence the theoretical and used oxygen values calculated as shown below, the effect on Trickett's Ratio is given and results summarised in table.

Assumptions made:-

(1) Volume of the gaseous products of combustion is equal to the volume of reactant gases.

(2) The hydrogen content is equal to or less than the carbon monoxide content.

(3) The composition of air used was:-

$\% N_2 = 78.09$

$\% O_2 = 20.95$

$\% Ar = 0.93$

(4) The methane present arose from seepage with no contribution from combustion of coal.

The gaseous combustion products (i.e. CO, CO_2 and H_2 - water is removed before analysis) correspond to about 2% by volume of the mine gas. If the carbon monoxide and hydrogen were produced by reaction between coal dust and steam, the maximum increase in the volume of products at the same pressure after combustion would be about 1%, this would have a negligible influence on the values for theoretical oxygen and Trickett's ratio by comparison with variation in gas composition (actual CO, CO_2, H_2 and O_2 values).

In the examples cited in the literature, the hydrogen content is generally lower than the carbon monoxide content (some of the higher hydrogen values are suspect). For the purpose of calculation of Trickett's Ratio, hydrogen values of zero, one half and equal to the carbon monoxide content were assumed.

During combustion (or explosion), the nitrogen and argon content of the air will remain unchanged. If in the sample collected, the air component is reconstituted to its composition prior to combustion, the combined nitrogen plus argon content would equal 79.02% (i.e. 78.09 + 0.93%) and oxygen 20.95% of the air. If the methane present as a diluent equals D% of the mine gas sample analysed, then the combined nitrogen-argon content (N-Ar) will be related to the methane content by equation 4.

...B3/

$$N\text{-}Ar = 79 \cdot \frac{(100-D)}{100} \qquad \ldots\ldots\ldots\ldots (4)$$

Assuming that the volume of the combustion products is the same as the reactants, the sum of nitrogen, argon plus methane values equals 100% minus the residual oxygen, carbon monoxide, carbon dioxide and hydrogen content (equation 5).

$$N\text{-}Ar + D = 100 - (O_2 + CO + CO_2 + H_2) \qquad \ldots\ldots\ldots (5)$$

i.e. $$79 \frac{(100-D)}{100} + D = 100 - (O_2 + CO + CO_2 + H_2) \qquad \ldots\ldots\ldots (6)$$

Calculations

(a) From table 1, % CO_2 = 1.08
% CO = 0.60
% O_2 = 12.2

Let % H_2 = 0, D = % methane,
then, from equation 5,

N-Ar + D = 100 - 13.88
= 86.12

substituting equation 4;

$$79 \cdot \frac{(100-D)}{100} + D = 86.12$$

0.21 D = 7.12

D = 33.9% methane

N-Ar = 52.22%

$$\text{Theoretical oxygen} = \frac{20.95 \times 52.22}{79.02}$$

= 13.84%

Actual oxygen = 12.2%

Oxygen used = 1.64%

Σ (CO_2 + 3/4 CO - ¼ H_2) = 1.08 + 3/4 x 0.60 - 0

= 1.53

$$\text{Trickett's Ratio (T.R.)} = \frac{1.53}{1.64} = 0.93$$

(b) Calculations repeated as in (a) using values and yielding results as listed below:-

(b) (i)

Values Used	Results
% CO_2 = 1.08	% CH_4 = 31.0
% CO = 0.60	% Th. O_2 = 14.44
% H_2 = 0.60	% O_2 used = 2.24
% O_2 = 12.2	T.R. = $\frac{1.38}{2.24}$ = 0.62

...B4/

(b) (ii)

Values Used	Results
% CO_2 = 1.08	% CH_4 = 32.4
% CO = 0.60	% Th. O_2 = 14.17
% H_2 = 0.30	% O_2 used = 1.97
% O_2 = 12.2	T.R. = $\frac{1.45}{1.97}$
	= 0.74

(c) Maximum tolerance values used for all gases, for minimum and maximum oxygen levels and variation in hydrogen content.

(c) (i)

Values Used	Results
% CO_2 = 1.14	% CH_4 = 30.0
% CO = 0.63	% Th. O_2 = 14.66
% H_2 = 0.63	% O_2 used = 2.36
% O_2 = 12.3	T.R. = $\frac{1.53}{2.36}$
	= 0.65

(c) (ii)

Values Used	Results
% CO_2 = 1.14	% CH_4 = 31.0
% CO = 0.63	% Th. O_2 = 14.45
% H_2 = 0.63	% O_2 used = 2.35
% O_2 = 12.1	T.R. = $\frac{1.53}{2.35}$
	= 0.65

(c) (iii)

Values Used	Results
% CO_2 = 1.14	% CH_4 = 33.0
% CO = 0.63	% Th. O_2 = 14.05
% H_2 = 0	% O_2 used = 1.75
% O_2 = 12.3	T.R. = $\frac{1.61}{1.75}$
	= 0.92

(c) (iv)

Values Used	Results
% CO_2 = 1.14	% CH_4 = 33.9
% CO = 0.63	% Th. O_2 = 13.85
% H_2 = 0	% O_2 used = 1.75
% O_2 = 12.1	T.R. = $\frac{1.61}{1.75}$
	= 0.92

...B5/

(d) Minimum tolerance values for all gases, for minimum and maximum oxygen levels and estimated hydrogen content.

(d) (i)

Values Used	Results
% CO_2 = 1.02	% CH_4 = 31.0
% CO = 0.58	% Th. O_2 = 14.46
% H_2 = 0.58	% O_2 used = 2.16
% O_2 = 12.3	T.R. = $\frac{1.31}{2.16}$ = 0.61

(d) (ii)

Values Used	Results
% CO_2 = 1.02	% CH_4 = 32.0
% CO = 0.58	% Th. O_2 = 14.26
% H_2 = 0.58	% O_2 used = 2.16
% O_2 = 12.1	T.R. = $\frac{1.31}{2.16}$ = 0.61

(d) (iii)

Values Used	Results
% CO_2 = 1.02	% CH_4 = 33.7
% CO = 0.58	% Th. O_2 = 13.89
% H_2 = 0	% O_2 used = 1.59
% O_2 = 12.3	T.R. = $\frac{1.45}{1.59}$ = 0.91

(d) (iv)

Values Used	Results
% CO_2 = 1.02	% CH_4 = 34.7
% CO = 0.58	% Th. O_2 = 13.69
% H_2 = 0	% O_2 used = 1.59
% O_2 = 12.1	T.R. = $\frac{1.45}{1.59}$ = 0.91

Summary:

The maximum errors expected in the composition of the mine gas sample supplied have been used in the calculation of Trickett's Ratio. The range of values for the ratio was 0.61 to 0.92, mean value 0.77, standard deviation 0.14.

Clive Ellis
Senior Scientific Officer
Safety-in-Mines Section

29th August, 1979

APPENDIX C

METHANE EMISSION FROM K PANEL

On 9th August 1979 accompanied by C. Ellicott (Scientific Officer) I undertook an investigation of methane concentrations and air flows in K Panel of Appin Colliery. The purpose of the investigation was to obtain an estimate of the volumes of methane, with time, produced by different sections of K Panel. Particular attention was paid to the vicinity of B Heading face, believed to be the initiation point of the explosion of 24th July, 1979.

Sampling locations are shown on the attached plan of K Panel and are described in the accompanying Table 1. At each location (with the exception of lcations 8 and 9): readings of methane concentration in the upper and lower half of the roadway were obtained with an MSA D6 methanometer; a "bag" air sample was obtained from the centre of the roadway for subsequent analysis; and a reading of air velocity in the roadway was taken, at the centre, by means of a calibrated anemometer.

It was realised that such "spot" readings could provide only an indication of air volume (and therefore methane volume) through a cross section of roadway, for two reasons. First, methane concentration within a roadway exhibits a "layered" effect, methane being more concentrated near the roof, due to its lower density than air. The extent of this effect is a function of the overall methane concentration, the degree of turbulence, and distance (or time) from point of emission. Secondly, air velocity is not constant across a roadway cross section, variations being produced by frictional drag at the roof, floor and walls and the presence of obstacles creating turbulence.

Sampling locations 5 and 6 constituted the current intake and return airways to B-Heading face and a more detailed sampling scheme was employed at these sites. In order to obtain an accurate measure of the methane volume passing points 5 and 6 a 0.5 metre sampling grid was established across each roadway. Methane concentration and air velocity readings were then taken in the centre of each grid square. Methane concentrations were again obtained with a methanometer and air velocity with a calibrated anemometer. In each case a "bag" air sample was collected at the centre of the roadway for later analysis.

...C2/

Table 2, below, shows the dimensions, methane concentrations and air velocities obtained for each spot sampling point. Figures 1 and 2, show results obtained for each sampling grid at locations 5 and 6. A summary of air and methane volumes passing each sampling point is to be found in Table 3.

TABLE 1

Location Number	Description	Comments
1	Longwall 8 main gate, 30 m inbye 2-CT	Due to very low air velocity, anemometer reading may be in error
2	Longwall 8 main gate, 20 m outbye 4-CT	
3	4-CT between Longwall 8 main gate and A-heading	Very tubulent location and therefore air velocity reading may not be representative
4	A-heading, 10 m outbye 4-CT	
5	4-CT 10 m from B-heading	0.5 metre square sampling grid
6	B-heading, 10 m outbye 4-CT	0.5 metre square sampling grid
7	B-heading, 30 m inbye 2-CT	
8	B-heading, 20 m inbye 1-CT	
9	B-heading, 20 m outbye 1-CT	

TABLE 2

Location	Roadway Width (metres)	Roadway Height (metres)	Methane[a] Concentration (Vol %)		Air Velocity at centre of roadway (metres/min)
			Methan-ometer	IR[e]	
1	5.2	2.77	0.5	0.47	9
2	4.5	2.56	1.0	0.61[d]	18
3	4.5	2.5	1.25	1.24	9.1[b]
4	3.9	2.4	0.25	0.3	11.3
5	3.5	2.5	0.9	0.83	34.1
6	3.8	2.5	1.4	1.21	32.0
7	3.8	2.6	1.65	1.42	43.4
8	3.7	2.65	1.6	1.47	43.4
9	3.7	2.65	1.35	1.24	60.2[c]

Notes:

(a) Concentration obtained by averaging readings taken for top and bottom half of roadway.

(b) See comment in Table 1.

(c) Velocity reading possibly influenced by presence of blast debris and conveyer belting, would tend to cause a high result.

(d) Analysis rejected because of leak in sampling bag.

(e) Infra-red analyser result from Mobile Laboratory.

...C4/

Figure 1

Sample Grid Results at Location 5

(metres)							
0.5	(.9) 27.4	(.9) (27.4)	(.9) 26.8	.9 (30.5)	.9 35.1	(.9) (33.5)	(.9) 30.5
0.5	(.9) (24.4)	(.9) (27.4)	(.85) 32.9	.8 (33.5)	.85 36.6	(.85) 38.1	(.85) 36
0.5	(.9) 21.9	.9 (22.9)	(.85) 24.4	.9 34.1	.7 27.4	(.75) (27.4)	.8 21.9
0.5	.9 (18.3)	.8 (21.3)	.8 26.5	.7 (33.5)	.6 30.5	(.6) 30.5	.6 19.2
0.5	.9 12.8	.8 (21.3)	.7 0	.7 (24.4)	.6 30.5	.6 22.9	.6 3.4
	0.5	0.5	0.5	0.5	0.5	0.5	0.5

(metres)

Figure 2

Sample Grid Results at Location 6

(metres)							
0.5	(1.65) (18.3)	1.65 25.9	(1.65) (33.5)	1.7 (42.7)	1.6 (36.6)	(1.65) (27.4)	1.65 21.9
0.5	(1.5) 13.1	1.5 31.4	(1.5) (36.6)	1.5 41.1	(1.5) (36.6)	(1.5) (33.5)	(1.5) 29.9
0.5	(1.4) (12.2)	(1.4) 29.0	(1.4) (29.0)	1.4 32.0	1.4 (30.5)	(1.4) (29.0)	1.4 27.4
0.5	(1.3) 10.1	1.3 24.4	(1.3) 28.3	1.3 (27.4)	(1.3) (25.9)	(1.3) (21.3)	1.3 18.3
0.5	(1.2) (12.2)	(1.2) 21.9	(1.2) (19.8)	1.2 19.2	1.2 (18.3)	(1.2) 18.3	(1.2) 17.4
	0.8	0.5	0.5	0.5	0.5	0.5	0.5

(metres)

N.B. In each Figure:-

Top figure is Methane concentration (Vol %)

Bottom figure is Air velocity (metres/min)

Interpolated values are indicated: ( ).

Calculations for Locations 5 and 6

	Location 5	Location 6
A	8.75 m^2	9.5 m^2
$\overline{CH_4}$	0.8 Vol %	1.41 Vol %
$\overline{AV}$	26.9 m min^{-1}	25.7 m min^{-1}
$\Sigma AV \times a$	280 m^3 min^{-1}	235 m^3 min^{-1}
$\Sigma AV \times a \times CH_4 \times 0.01$	1.85 m^3 min^{-1}	3.38 m^3 min^{-1}
$\overline{AV} \times A$	235.4 m^3 min^{-1}	244.2 m^3 min^{-1}
$\overline{AV} \times \overline{CH_4} \times A \times 0.01$	1.88 m^3 min^{-1}	3.17 m^3 min^{-1}
$\overline{AV}/AV_{centre}$	0.79	0.8
$AV_{centre} \times CH_{4centre} \times A \times 0.8$	1.96 m^3 min^{-1}	3.40 m^3 min^{-1}

Where A = Cross section area of roadway

$\overline{CH_4}$ = Average methane reading for grid

$\overline{AV}$ = Average air velocity reading for grid

a = Area of each cell in grid

centre = Subscript to indicate reading at centre of roadway

In both locations, above, the average air velocity across a roadway is related to the velocity at centre of roadway as follows:-

$$\overline{AV} = 0.8\ AV_{centre}$$

This factor was then used to obtain a more reliable estimate of total air flow through the other roadway sections from a measurement at roadway centre. From this, total air volume and methane volume were estimated.

...C6/

Total Air Volume and Methane Volume Passing Roadway Cross-Sections

Location	Air Volume[a] ($m^3\ min^{-1}$)	Methane Volume[b] ($m^3\ min^{-1}$)
1	130	0.5
2	166	1.7
3	82	1.0
4	85	0.25
5	239	1.9[c]
6	243	3.4[c]
7	343	4.9
8	341	5.0
9	472	5.9

Notes: (a) $0.8\ AV_{centre} \times A$.

(b) $0.8\ AV_{centre} \times A \times CH_{4centre} \times 0.01$.

(c) Calculated from 'grid' results.

Conclusions

The emission of methane from various parts of K panel can be assessed from the figures given above. In particular it may be seen that methane was issuing from the face area in B heading at a rate of about 1.5 cubic metres per minute.

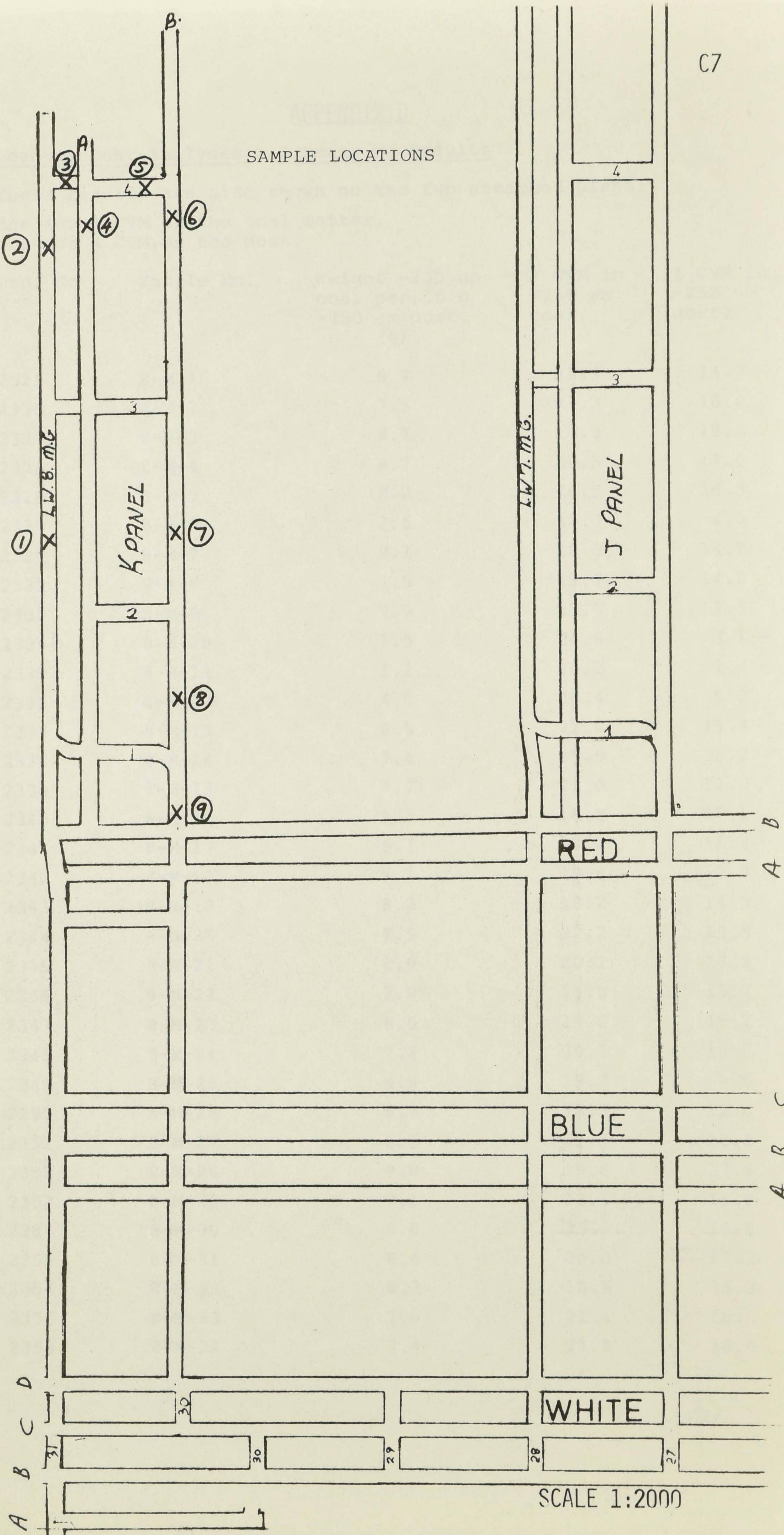
While the figures above give a good indication of methane emission rates, the following matters should be remembered using them:

1. The air flows varied continuously while measurements were being taken.
2. Except at locations 5 and 6, detailed measurements of flows and methane concentrations across the roadway were not taken. In some locations (especially 3 and 9), irregularities in flow may cause inaccuracies.
3. These measurements were taken on 9th August, two weeks after the explosion. No mining had taken place in the interim. The methane emissions rates are therefore almost certainly lower then at the time of the explosion. Particularly would this be the case in the face areas in A and B headings.
4. The emission rates may vary considerably with changes in air flow past the coal.

Using these figures, it is possible to calculate the time necessary for the build-up of various gas concentrations in the different areas of K panel. These calculations will be included in a later report.

Clive Ellis
Senior Scientific Officer
Safety-in-Mines Section

SAMPLE LOCATIONS



APPENDIX D

Roadway Dust Analyses : Summary of Results

These results are also shown on the two attached plans:

one for % CVM of the coal matter,
one for % CVM of the dust.

Reg. No.	Sample No.	Weight -250 µm coal per 10 g -250 µm dust. (g)	% CVM in -250 µm coal.	% CVM in -250 µm dust.
2325	8-M-1	6.7	21.9	14.7
2326	8-M-2	7.5	21.3	16.0
2327	8-M-3	8.7	18.8	16.3
2328	8-M-4	8.7	19.5	17.0
2329	8-M-5	8.2	20.5	16.8
2330	8-M-6	2.5	18.0	4.5
2331	8-M-7	8.1	18.3	14.8
2332	8-M-8	7.5	19.7	14.8
2333	8-M-9	7.9	21.7	17.1
2334	8-M-10	1.5	20.8	3.1
2335	8-M-11	1.2	20.1	2.4
2336	8-M-12	4.0	20.4	8.2
2337	8-M-13	6.8	22.6	15.4
2338	8-M-14	7.4	21.9	16.2
2339	8-M-15	5.7	21.0	12.0
2340	8-M-16	9.1	18.8	17.1
2341	8-M-17	9.1	20.2	18.4
2342	8-M-18	9.1	19.6	17.8
2343	8-M-19	8.2	18.2	14.9
2344	8-M-20	8.9	22.2	19.8
2345	8-M-21	8.9	20.1	17.9
2346	8-M-22	7.9	19.9	15.7
2347	8-M-23	8.0	19.0	15.2
2348	8-M-24	7.8	20.1	15.7
2349	8-M-25	4.9	19.3	9.5
2350	8-M-26	6.5	18.5	12.0
2351	8-M-27	6.1	21.5	13.1
2352	8-M-28	9.0	19.6	17.6
2353	8-M-29	9.1	18.6	16.9
2354	8-M-30	8.6	23.5	20.2
2355	8-M-31	8.6	20.0	17.2
2356	8-M-32	8.2	18.6	15.3
2357	8-M-33	7.8	21.1	16.5
2358	8-M-34	7.4	21.6	16.0

...D2/

Reg. No.	Sample No.	Weight -250 µm coal per 10 g -250 µm dust. (g)	% CVM in -250 µm coal.	% CVM in -250 µm dust.
2359	8-M-35	6.8	18.8	12.8
2360	8-M-36	6.1	20.7	12.6
2361	8-M-37	5.7	21.4	12.2
2362	8-M-38	4.9	19.8	9.7
2363	8-M-39	1.5	21.9	3.3
2813	8-M-72	1.8	21.7	3.9
2814	8-M-73	2.9	22.4	6.5
2815	8-M-74	5.6	22.2	12.4
2816	8-M-75	6.7	22.5	15.1
2817	8-M-76	2.3	20.2	4.6
2818	8-M-77	2.2	21.5	4.7

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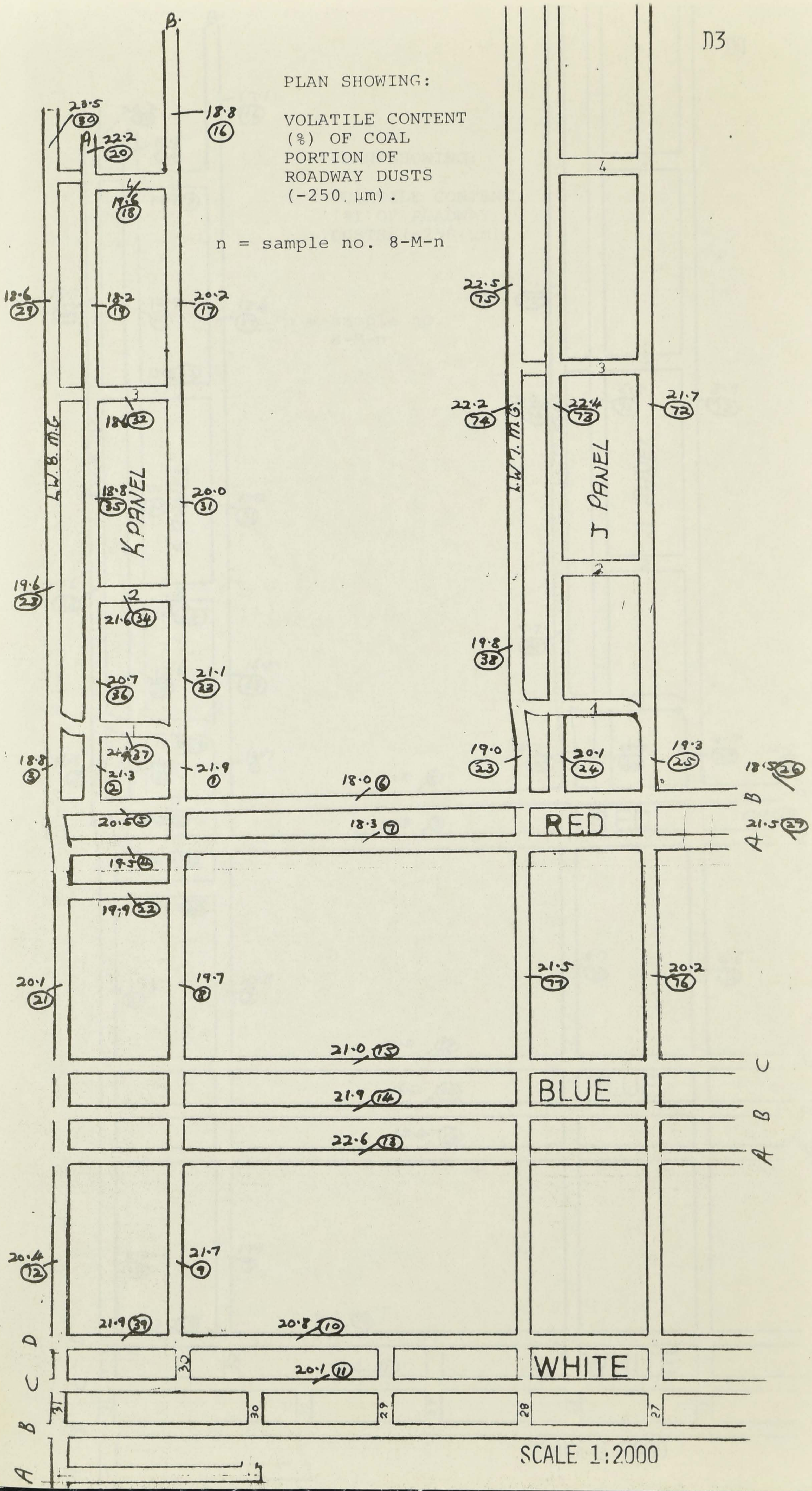
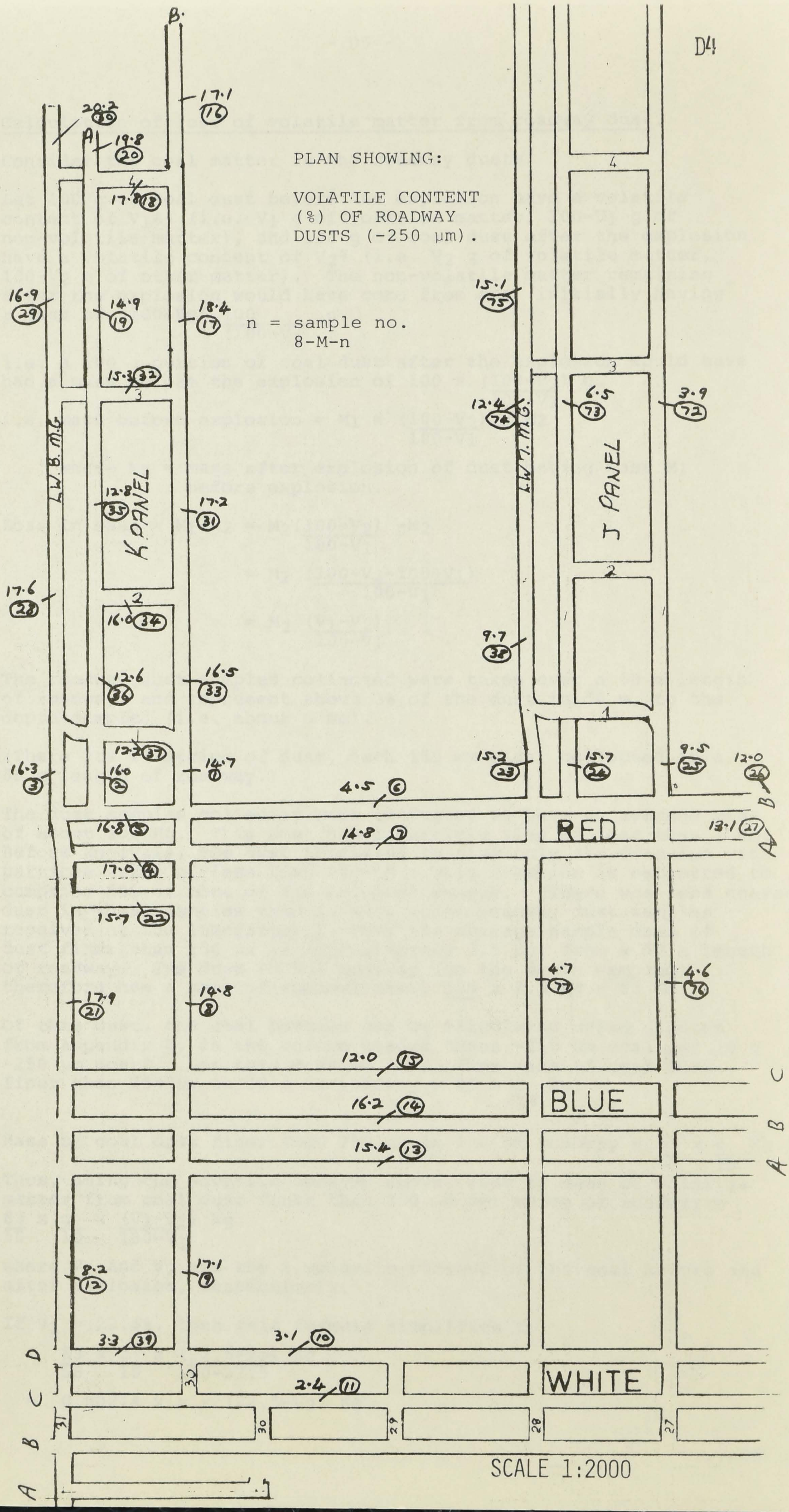

PLAN SHOWING:
VOLATILE CONTENT (%) OF COAL PORTION OF ROADWAY DUSTS (-250 µm).
n = sample no. 8-M-n
K PANEL
J PANEL
L.W.8. M.G.
L.W.7. M.G.
RED
BLUE
WHITE
SCALE 1:2000


PLAN SHOWING:
VOLATILE CONTENT (%) OF ROADWAY DUSTS (-250 µm).
n = sample no. 8-M-n
SCALE 1:2000
K PANEL
J PANEL
L.W.8. M.G.
L.W.7. M.G.
RED
BLUE
WHITE
A
B
C
D
1
2
3
4
27
28
29
30
31
32
20.2 (30)
19.8 (20)
17.1 (16)
17.8 (18)
16.9 (29)
14.9 (19)
18.4 (17)
15.3 (32)
12.8 (35)
17.2 (31)
17.6 (28)
16.0 (34)
12.6 (36)
16.5 (33)
12.2 (37)
16.3 (3)
16.0 (2)
14.7 (1)
4.5 (6)
16.8 (5)
14.8 (7)
17.0 (4)
15.7 (22)
17.9 (21)
14.8 (8)
12.0 (15)
16.2 (14)
15.4 (13)
8.2 (12)
17.1 (9)
3.3 (39)
3.1 (10)
2.4 (11)
15.1 (75)
12.4 (74)
6.5 (73)
3.9 (72)
9.7 (38)
15.2 (23)
15.7 (24)
9.5 (25)
12.0 (26)
13.1 (27)
4.7 (77)
4.6 (76)

Calculation of loss of volatile matter from roadway dust.

Consider the coal matter in the roadway dusts.

Let 100 g of coal dust before the explosion have a volatile content of V_1%, (i.e. V_1 g of volatile matter, 100-V_1 g of non-volatile matter), and 100 g of coal dust after the explosion have a volatile content of V_2% (i.e. V_2 g of volatile matter, 100-V_2 g of other matter). The non-volatile matter remaining after the explosion would have come from coal initially having a mass of $(100-V_2)\ \frac{100}{(100-V_1)}$ g.

i.e. a 100 g portion of coal dust after the explosion would have had a mass before the explosion of $100 \times \frac{(100-V_2)}{100-V_1}$ g.

i.e. mass before explosion = $M_1 = \frac{(100-V_2)}{100-V_1} \times M_2$

where M_2 = mass after explosion of dust having mass M_1 before explosion.

$$\text{Loss in mass} = M_1-M_2 = M_2\frac{(100-V_2)}{100-V_1} - M_2$$

$$= M_2\ \frac{(100-V_2-100+V_1)}{100-V_1}$$

$$= M_2\ \frac{(V_1-V_2)}{100-V_1}$$

The roadway dust samples collected were taken over a 50 m length of roadway, and represent about 3% of the dust in 50 m, to the depth sampled (i.e. about 6 mm).

(There are 10 strips of dust, each 150 mm wide, collected in a 50 m length of roadway.)

The dust samples collected were estimated to have an average mass of about 3.2 Kg. This dust has a particle size of less than 1 mm. Before analysis, the dust is sieved to give only the fraction with particle sizes of less than 250 μm. This fraction is estimated to comprise 80% or more of the original sample. (There was less coarse dust in these samples than in many other roadway dust samples received at the laboratory.) Thus the average sample mass of dust finer than 250 μm is approximately 2.5 Kg, from a 50 m length of roadway. The dust in the roadway (to the depth sampled) therefore has a mass of approximately $\frac{100}{3} \times 2.5$ Kg = 83 Kg.

Of this dust, the coal portion can be calculated using figures from Appendix D, in the column headed "Mass -250 μm coal per 10 g -250 μm dust". Let this mass be 'c'. Then mass of coal dust finer than 250 μm in 50 m of roadway = $83 \times \frac{c}{10}$ Kg.

Mass of coal dust finer than 250 μm in 1 m of roadway = $\frac{83}{50} \times \frac{c}{10}$ Kg.

Thus, using the equation derived above, loss in mass of volatile matter from coal dust finer than 250 μm per metre of roadway = $\frac{83}{50} \times \frac{c}{10} \times \frac{(V_1-V_2)}{100-V_1}$ Kg.

where V_1 and V_2 are the % volatile content of the coal before and after explosion, respectively.

If V_1 = 22.5%, then this formula simplifies to:

$$\frac{83}{50} \times \frac{c}{10} \times \frac{(22.5-V_2)}{100-22.5}\ \text{Kg}$$

$$= 0.00214 \times c \times (22.5-V_2)\ \text{Kg}$$

.../D6

The values obtained may be multiplied by the length of roadway being considered, to give a total loss in mass of volatile matter.

Roadway	Location	Length (metres)	Volatile content of coal portion %	Mass of coal in 10 g of -250 μm dust (g)	Loss of volatile matter (Kg)
K Panel, B Hdg.	inbye 4 CT	70	18.8	9.1	5.04
	3-4 CT	90	20.2	9.1	4.03
	2-3 CT	90	20.0	8.6	4.14
	1-2 CT	60	21.1	7.8	1.40
	A red to 1 CT K	50	21.9	6.7	0.43
	B blue to A red	120	19.7	7.5	5.39
	D white to B blue	100	21.7	7.9	1.35
K Panel A Hdg.	3-4 CT	90	18.2	8.2	6.79
	2-3 CT	90	18.8	6.8	4.85
	1-2 CT	60	20.7	6.1	1.41
	B red to 1 CT	40	21.3	7.5	0.77
4 CT	A-B	35	19.6	9.1	1.98
3 CT	A-B	35	18.6	8.2	2.40
2 CT	A-B	35	21.6	7.4	0.50
1 CT	A-B	35	21.4	5.7	0.47
LW8 MG	3-4 CT	90	18.6	9.1	6.84
	1-3 CT	140	19.6	9.0	7.82
	A red to 1 CT	60	18.8	8.7	4.13
	A blue to A red	140	20.1	8.9	6.40
	D white to A blue	80	20.4	4.0	1.44
Red Panel, B Hdg.	LW8 MG to B/K	60	20.5	8.2	2.10
	B/K to LW7 MG	150	18.0	2.5	3.61
A Hdg.	LW8 MG to B/K	55	19.5	8.7	3.07
	B/K to LW7 MG	150	18.3	8.1	10.92
CT Outbye A red	LW8 MG to B/K	45	19.9	7.9	1.98

.../D7

By summing the losses calculated in the table, we find a total loss in mass of volatile matter of 89 Kg.

This represents the loss in mass of volatile matter from the remaining coal finer than 250 μm, in K panel and the roadways bounded by D heading of white panel and longwall 7 main gate (excluding blue panel), to a depth of about 6 mm.

This result must be considered as an approximation since:

(i) the sample mass is only an estimated average;

(ii) the portion of the sample finer than 250 μm is an estimate (believed to be conservative);

(iii) the initial volatile content of the coal may have varied slightly from the figure used (i.e. 22.5%), from one area to another;

(iv) the dust in B heading of red panel may contain some rock dust, since this heading is of greater height than the coal seam.

(v) the entire sampling procedure is not an exact one.

The result is probably conservative since it ignores:

(i) loss of volatile matter from coal dust coarser than 250 μm;

(ii) loss of volatile matter from fine coal dust which may have been transported outbye after the explosion;

(iii) the loss of coal dust resulting from the complete combustion of some of the finest coal dust. Cybulski (ref. 2, p. 76) has found that this does occur during explosions.

(iv) loss of volatile matter from coal dust at a depth greater than 6 mm.

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APPENDIX E

List of Materials Received at the Chemical Laboratory for Examination. (In addition to roadway dust samples in Appendix D).

Locations of some materials are shown on the attached plan.

2701 Bolt rope suspended from roof, K panel B hdg, 12 m back from face.

2702 Soot from prop lying on floor, K panel B hdg, 17 m back from face.

2703 Soot stringers from props and structures, K panel B hdg, approx. 20 m back from face.

2704 Bolt rope suspended from roof, K panel B hdg, 45 m back from face.

2705 Stone dust from open bag on shuttle car, K panel, intersection of B hdg and 4 CT.

2706 Bolt rope suspended from roof, K panel B hdg, 14 m outbye 4 CT (centre line).

2707 Roadway dust, K panel B hdg outbye 4 CT. (Portion of sample taken by S. Mason).

2708 Bolt rope suspended from roof, K panel 4 CT, midway between A & B headings.

2709 Bolt rope suspended from roof, K panel A hdg between 3 & 4 CT.

2710 Coal from shuttle car, K panel A hdg.

2711 Bolt rope suspended from roof, K panel B hdg between 1 and 2 CT.

2712 Bolt rope suspended from roof, K panel crib room.

2713 Bolt rope suspended from roof, K panel, A hdg red panel, between LW8MG and B hdg K panel.

2714 Bolt rope suspended from roof, K panel, 1st CT outbye A hdg red panel.

2715 Bolt rope suspended from roof, B hdg red panel between B hdg K panel and LW7MG.

2716 Bolt rope and brattice, intersection of B hdg red panel and B hdg J panel.

2717 Bolt rope suspended from roof, J panel, B hdg red panel between B hdg J panel and LW6MG.

2718 Bolt rope suspended from roof, red panel, A hdg red panel near LW6MG, between LW6MG and B hdg J panel.

2719 Brattice from floor, K panel 3 CT.

2720 Brattice from roof saddle K panel, 3 CT, between LW8MG and fall.

2721 Edge of brattice, K panel, LW8MG, 70 m outbye 3 CT. (From roll of brattice with burnt edges.

2722 Bolt rope suspended from roof, K panel LW8MG, 20 m inbye 3 CT.

.../E2

2723 Paper from stone dust bag (full of stone dust), from floor just inbye 3 CT in LW8MG (K panel).

2724 Vent rubber hanging over rib sprag at "North-West" corner, intersection of A hdg and 4 CT, K panel. (Origin uncertain).

2725 Dust/soot from top of tyre of loader, K panel, 10 m inbye 3 CT, A hdg.

2726 Bolt rope suspended from prop, K panel, A hdg, 5 m inbye fall at 3 CT.

2727 Brattice from roll, K panel, B hdg and 4 CT, "North-West" corner.

2728 Brattice, burnt edge from roll, as for (2727) above.

2729 Soot from ledge of I beam roof support, K panel, 4 CT between A and B hdgs. B hdg side.

2730 As for (2729) above, A heading side.

2731 Brattice cloth, K panel, A heading just outbye 4 CT, behind props under rib fall.

2732 Piece cut from unravelled vent ducting, K panel, 4 CT between A and B hdgs. (Not rusty).

2733 Description and location as for (2732) above. (Rusty).

2734 Bolt rope suspended from roof, K panel B hdg, 10 m outbye 3 CT.

2735 Bolt rope suspended from roof, K panel B hdg, 10 m outbye 1 CT.

2736 Brattice cloth, K panel LW8MG, inbye 4 CT on A hdg side of roadway.

2737 Bolt rope suspended from roof, K panel B hdg, just inbye B hdg red panel.

2738 Bolt rope suspended from roof, K panel B hdg, 10 m outbye B hdg red panel.

2739 Bolt rope suspended from roof, K panel B hdg, 10 m outbye A hdg red panel.

2740 Bolt rope suspended from roof, white panel D hdg, 10 m outbye K panel B hdg.

2741 Charred newspaper found in K panel crib room.

2742 Charred report sheet (blank) found near K panel crib room.

2743 Electrician's brush (possibly singed) found in B heading.

2744 Notice in plastic cover previously attached to K panel crib room notice board. Has been subjected to heat.

2745 Notice similar to that in item (2744). In new condition.

2746 Plastic used as cover in notice, item 2744.

2747 Rope and insulation tape samples from switchbox (as supplied) check for presence of sooting or burning.

.../E3

2748 Rope and insulation tape samples from switchbox (after explosion) check for presence of sooting on burning comparison with item 2747.

2749 Dust sample from auer methanometer check for presence of coking.

2750 Grease sample from cover of switchbox(age determination).

2751 Grease sample from bolt holes of switchbox comparison with item 2750.

2752 Switchbox cover retaining bolt (as supplied)

2753 Switchbox cover retaining bolt (after explosion) comparison with item 2752.

2754 Dust sample from switchbox

2755 Dust sample from conveyor starter comparison with item 2754.

2756 Brattice (heated) in CT outbye A and B headings in Red Panel.

2757 Brattice + plaster wrapped around cable in crib room. Possibly from plaster stopping in 1 CT between A heading and LW8MG.

2758 Charred stonedust bags in CT outbye A and B headings in Red Panel.

2759 Same as 2758 above plus other cindered paper.

2760 Six soot samples taken in LW8MG (not labelled) plus another bag of cindered? coal taken off prop in LW8MG.

2761 Roll of insulating tape (heated) 7 metres outbye fan in B heading.

2762 Piece of vent tube outbye shuttle car in B heading.

2763 Electrician's tool bag in B heading.

2764 Heated brattice with plaster? adhering in CT outbye A and B headings Red Panel.

2765 Fine pieces charred paper and brattice from items found in CT outbye A and B headings Red Panel (Disintegrated in transport out of mine).

2766 Piece of charred wood (1 edge in particular) in CT outbye A and B headings, Red Panel.

2767 Roll of electrician's tape. B heading 16 metres outbye fan.

2768 Helmet in A heading, believed to be that of K Staats. A heading (fitter).

2769 Helmet in B heading believed to be either deputy or electrician's (Think undermanager had a different type helmet).

2770 Piece of glass believed to be from oil flame safety lamp. B heading.

2771 Undermanager's oil flame safety lamp adjacent to body in B heading.

2772 Deputy's oil flame safety lamp plus piece of glass plus composite washer, all found in shuttle car adjacent to body.

.../E4

2773 10 self rescuers (used). From Longwall?

2774 Two oil flame safety lamps (non relightable) in crib room.

2775 Allan key case + keys + piece of emery cloth + small drill case. B heading.

2776 Biro (heated) found outbye electrician's body in B heading.

2777 Piece of copper tube found in B heading. One end burred or crimped.

2778 Piece of denture in B heading.

2779 One relighter key in B heading.

2780 Coal dust ex Appin fan control box after experiment explosion. 20.8.79.

2781 Ex Appin fan control box. (after 2nd experiment). Samples of ties, insulation. 20.8.79.

2782 Pieces of helmet. B heading 62 to 74M outbye B4 intersection.

2783 Piece of marlin tied to roof bolt 6M inbye fall in No. 1 CT. LW8MG.

2784 Marlin hanging. LW8MG side of No. 3 CT.

2785 Burnt Paper 20 metres inbye No. 3 CT in LW8MG.

2786 Pieces of vent tube just outbye miner in B heading.

2787 Burnt brattice and string in No. 3 CT B to A headings.

2788 Brattice from face of LW8MG.

2789 Brattice from face of LW8MG.

2790 Piece of vent tube and Titan wedge tin inbye fall at No. 1 CT intersection in LW8MG.

2791 Stone dust bag caught in roof support. J panel B hdg, 25 m outbye 3 CT. Thrown inbye.

2792 Water barrier trough from 20 m outbye 3 CT in LW7MG.

2793 Stonedust from new bag. Southern Limestone, F70 Superfine.

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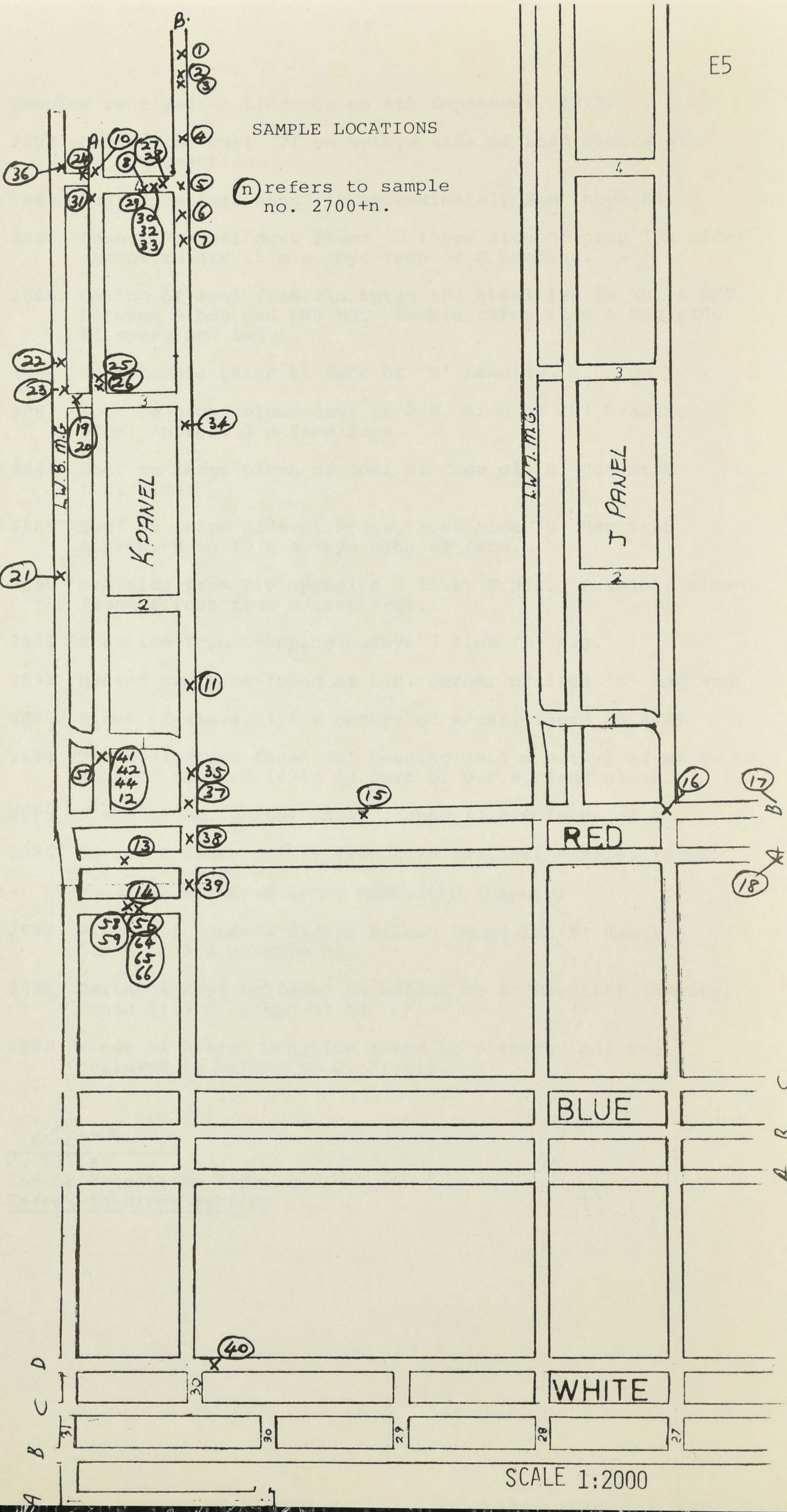
E5


SAMPLE LOCATIONS
n refers to sample no. 2700+n.
K PANEL
J PANEL
L.W.B. M.G.
L.W.T. M.G.
RED
BLUE
WHITE
SCALE 1:2000

APPENDIX E1

Miners Helmets from Appin Colliery

Helmets recovered from Appin colliery were "Protector TUFF MASTER" brand. They are made of Acrylonitrile Butadiene Styrene (ABS) which has a heat softening point of from 165^o to 225^oC.

A sample of plastic from an identical new helmet was subjected to heat treatment in a muffle furnace. With the application of heat the plastic was noted to first soften and then bubble at the surface due to decomposition/boiling. Microscopic examination of an ignited sample of the plastic showed that the surface was covered with a very fine carbon coating and showed extensive pitting due to the decomposition/boiling of the plastic beneath.

Sample 2768

The helmet showed extensive heat buckling. The helmet support cradle was almost totally either melted or burnt out. The exterior was covered with a grey dust which appeared to be fused into the surface of the plastic. There was some evidence of abrasion after the coating had been placed (this may be due to handling during removal). The exterior shows blistering at the rear of the helmet and under the visor (prefferential blistering may be due to partial burial or orientation in final resting place; photographic evidence?). The reflective sticker at the rear of the helmet was still present.

Microscopic Examination showed grains of coal and stonedust fused into the plastic surface. There was no evidence of finely divided carbon or surface pitting to indicate combustion of the plastic itself.

Sample 2769

Extensive heat buckling. Support cradle was largely burnt/melted out. The exterior was coated with black dust which appeared fused into the plastic surfaces. There was no blistering apparent on the exterior. The reflective sticker at the rear of the helmet was still present.

Microscopic Examination showed the exterior heavily coated with grains of coal dust - stonedust was absent. Again the coal appeared fused into the surface. There was no evidence of combustion of the plastic.

Sample 2782

Helmet fragments. Showed extensive heat buckling. Black/greyish powder covering the exterior apparently fused to surface. The shape of the fragments and the still concoidal appearance of the fracture lines indicated that they were heated after the helmet had been shattered.

Microscopic Examination. Heavy coating of grains of both coal and stonedust fused to surface. No indication of the combustion of the plastic beneath.

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APPENDIX E2

Brattice Cloth Samples from Appin Colliery

Sample 2716

Appearance

Covered with loose coal dust rather than adherent soot. Displays very little curling due to heating. Edges frayed but body intact. Attached piece of rope shows no evidence of burning.

Microscopic Examination

Covering mainly limestone coated with coal dust. Slightly brown tinge may indicate partially sintered pitch.

Sample 2719

Appearance

Moderately soot covered. Displays heat curling principally at the edges. Attached piece of rope shows no evidence of burning.

Microscopic Examination

Brattice impregnated with stone-dust (Approx. 50%) and sintered coal dust consisting of fused globules (possibly coke grains).

Sample 2720

Appearance

Heavily soot covered. Shows evidence of stretching while heated and shredding possibly due to schrapnel. Extensively heat damaged.

Microscopic Examination

Fused brattice, impregnated with stone dust and sintered coal. A scraping sample showed approx. 50% limestone with rounded brown particles of strongly heat affected coal. (Coke).

Sample 2721

Appearance

Heavy covering of adherent soot. Evidence of shredding. Extensive heat damage leaving brattice very brittle.

Microscopic Examination

Fused coal containing approx. ¼ limestone heavily impregnated in brattice. Sintered coal appears as round dark brown fragments, possibly coke grains.

...E2/1

Sample 2728

Appearance

Heavily soot covered and brittle with evidence of shredding. Extensively heat damaged.

Microscopic Examination

Heavily sintered coal coating of rounded dark brown amorphous particles. Approximately 30% road dust component.

Sample 2731

Appearance

Moderately soot covered. Brattice was heat curled but still pliable and intact.

Microscopic Examination

Coating of stone-dust (approx. 50%) and coal dust mixture which showed slight sintering only. Coating mostly on one side, was non-adherent and easily brushed off.

Sample 2736

Appearance

Variable light-heavy soot covering. Some evidence of tearing and shredding. Extensive heat curling with medium to heavy heat damage.

Microscopic Examination

Scraped sample of soot coating contained approx. 30% stone dust, approx. 50% high reflectance dark brown globules (coke grains) and dull amorphous powder (soot).

Sample 2756

Appearance

Variable light-heavy soot coverage. Extensive heat curling at the edges but body of the brattice largely undamaged.

Microscopic Examination

Scraped soot sample contained approx. 70% stone-dust and sintered coal dust, not strongly heat affected. The coating of a second subsample showed predominantly fused globules (coke grains).

Sample 2757

Appearance

Moderate soot covering and evidence of tearing at the edges. Variable degree of heat curling from none to moderate.

Microscopic Examination

Coating of stone and coal dust (50%, 50%) strongly adhered to brattice. Sintered coal dust contained only minor amounts of coke grains.

...E2/2

Sample 2765

Appearance

Heavily soot covered. Brattice very brittle with evidence of tearing and extensive heat damage.

Microscopic Examination

Rounded dark brown fragments of sintered coal. Sample brushed from surface showed approx. 50% stone-dust mixed with sintered coal and with fused globules (coke grains) abundant.

Sample 2787

Appearance

Moderately heavy soot covering. Evidence of tearing. Moderate heat curling. Attached marlin rope showed no evidence of burning.

Microscopic Examination

Scraping sample contained approx. 70% stone-dust, sintered coal dust (approx. 20%) and partially converted coke grains (approx. 5%).

Sample 2788

Appearance

Light soot covering with moderate heat curling. Attached wood showed no sign of burning.

Microscopic Examination

Coating mainly on one side of brattice approx. 50% stone-dust. Coal component showed no evidence of sintering.

Sample 2789

Appearance

Extensive shredding and covered with stonedust and/or sand. No soot covering. Suspect may have been damaged by machinery.

Microscopic Examination

Does not appear to have been heated. Scraping sample was approx. 90% stone-dust and no evidence of sintering on coal grains.

Scale of Heat Damage for Brattice Samples

In order to establish an arbitrary scale of heat damage, subsamples of sample number 27 were subjected to varying heat exposure in a muffle furnace. Sample 27 was chosen since it came from inside a roll of brattice found in B-Heading and was an undamaged sample of the brattice then in use.

...E2/3

Heat Exposure*	Scale
Sample 27	0
250°C	1
300°C	2
350°C	3
400°C	4
450°C	5
500°C	6

* Samples subjected to each temperature for 5 secs.

To estimate the heat damage to other samples they were visually compared with the above series as to the degree of heat curling, fibres shrinkage and overall appearance.

The attached plan of K-panel shows the location and estimate of heat damage for the brattice samples.

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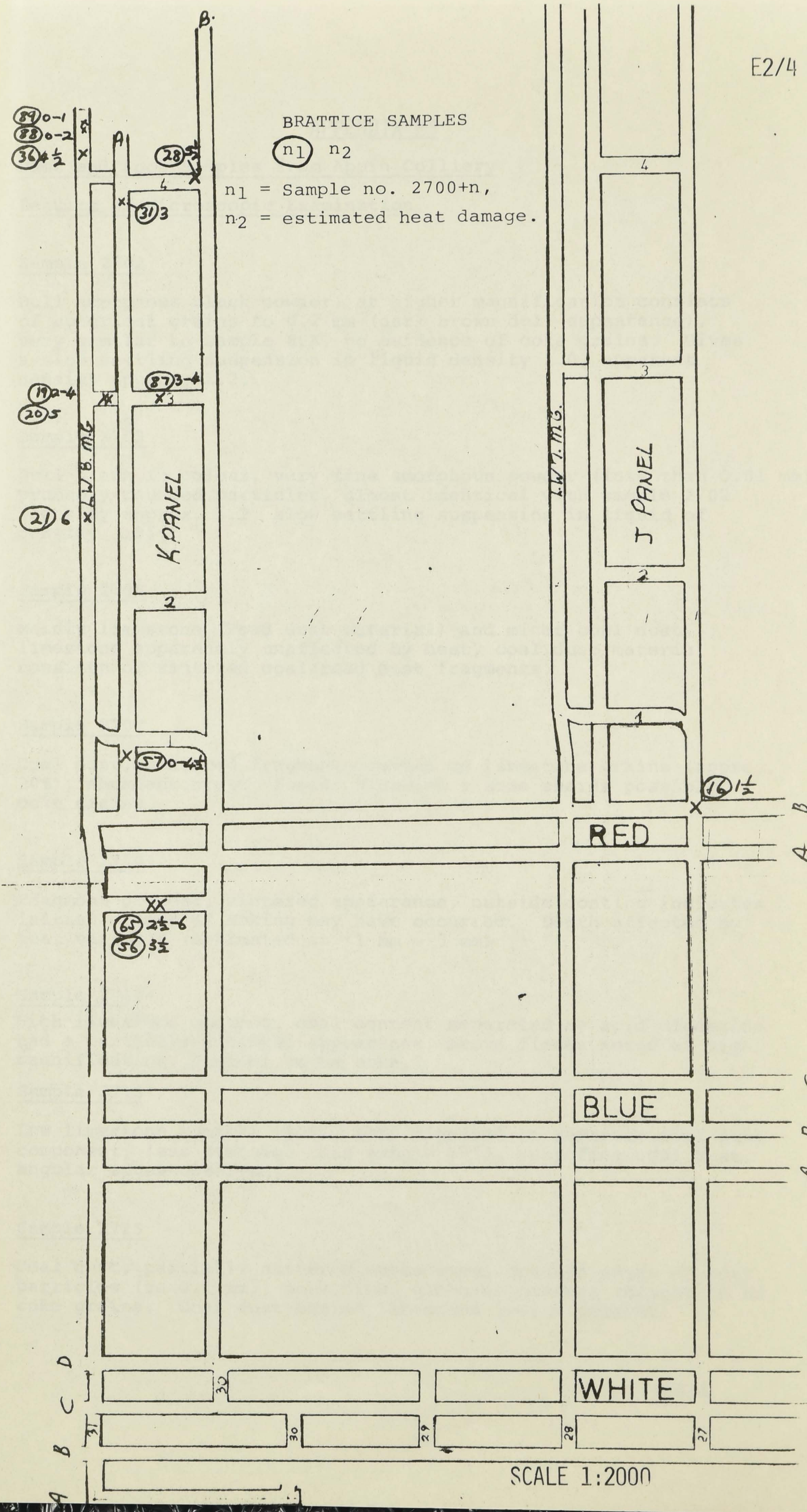
BRATTICE SAMPLES
n1 n2
n1 = Sample no. 2700+n,
n2 = estimated heat damage.
B.
A
89 0-1
88 0-2
36 4½
28 5½
31 3
87 3-4
19 2-4
20 5
21 6
57 0-4½
65 2½-6
56 3½
16 1½
K PANEL
J PANEL
L.W.B. M.G.
L.W.T. M.G.
RED
BLUE
WHITE
SCALE 1:2000

APPENDIX E3

Dust and Soot Samples from Appin Colliery

Results of Microscopic Examination

Sample 2702

Dull amorphous black powder, at higher magnification consists of spherical grains to 0.2 mm (dark brown dull appearance), very similar to sample 60A, no evidence of coke grains. Gives a slow settling suspension in liquid density 1.0, apparent density approx. 1.2.

Sample 2703

Dull black in colour, very fine amorphous powder (less than 0.01 mm), probably rounded particles, almost identical with sample 2702 (density approx. 1.2, slow settling suspension in liquid of density 1.0).

Sample 2705

Mainly limestone (road dust material) and minor coal dust, limestone apparently unaffected by heat, coal dust material consists of sintered coal/road dust fragments.

Sample 2707

Coal dust, sintered fragments coated on limestone grains (approx. 20%), abundant brown (fused) globules + some shards possibly coke grains.

Sample 2710

Fragment of coal, sintered appearance, outside coating indicates initial stages of coking may have occurred. Depth affected by heat variable (estimated at <1 mm - 5 mm)

Sample 2713*

High limestone content, coal content separated by acid digestion had a partially sintered appearance, brown flecks noted at high magnification, thought to be coke.

Sample 2716*

Low limestone content (10%), acid digested to separate coal dust component, less sintered than sample 2713, very fine coal dust, angular edges observed.

Sample 2725

Coal dust, partially sintered appearance, rounded edges of coal particles (to 0.1 mm), some brown globules present thought to be coke grains. Coal dust coated limestone grains present.

...E3/1

Sample 2728*

Low limestone content; the coal dust separated by acid digestion was partially sintered, rounded edges on coal dust fragments and dark brown flecks (coke grains) apparent at high magnification, appeared to have been more heat affected than samples 2713 and 2716.

Sample 2729

Coal dust partial sintering evident as a surface coating, fused globules with higher reflectance possibly coke grains. Limestone (approx. 20%) coated sintered? coal dust.

Sample 2730

Coal dust, perhaps less sintering evident than for sample 2729, general appearance similar to sample 2729, presence of limestone (approx. 20%) makes assessment of degree of sintering of coal dust difficult.

Sample 2749

Dull black amorphous appearance at low magnification, coarser fragments than in sample 2754, much finer than sample 2755, some reflectance at higher magnification, some sintering evident, also fused globules (similar appearance to coke).

Sample 2754

Dull, black amorphous material, fine particle size (approx. 0.1 mm). Sintered coal dust, rounded grains with higher reflectance, possibly coke noted at high magnification. Limestone grains (approx. 20%?) mixed with coal material.

Sample 2755

Coal dust with some limestone content. Coal particles much coarser than sample 2754(>1 mm) angular (fractured) particles, high reflectance no indications of sintering (rounded edges) in coal fragments.

Sample 2760

Six samples of "soot" (2760A to 2760F) and sample (2760G) of sintered coal examined using a binocular reflectance microscope. The samples were ranked on degree of sintering (subjective visually) in the order A>B>C>D=E>F.

Sample 2760A

Dull amorphous powder, dark brown to black with some reflectance at higher magnification (limestone grains <5%?) uniform particle size (approx. 0.01 mm), possibly spherical, material has sintered appearance, similar to soot sample No. 2702.

Sample 2760B

Dark brown to black in colour, dull at low magnification but higher reflectance than sample 2760A, also coarser; sample has been sintered; fused brown globules (to approx. 0.1 mm) abundant. (Possibly coke grains), contains small amount of limestone (10%).

...E3/2

Sample 2760C

Similar in appearance to sample 2760B, although more granular than A or B. Definite sintered appearance, fused brown globules (and shattered globules) present in sample, appearance like pitch; possible coking?, some limestone present.

Sample 2760D

Predominantly black in colour slightly coarser than sample 2760C, less fused brown globules observed than sample C, possible coking, definite sintered appearance, higher reflectance than C, higher limestone content.

Sample 2760E

Similar to sample 2760D.

Sample 2760F

Overall appearance similar to sample 2760D and 2760E, coarser, higher limestone content (30%), less evidence of sintering, fused globules, possible coke grains mixed with coal dust.

Sample 2760G

Sintered (black) coal fragments, edges rounded by fusion, brown globules, brown shards (conchoidal fracture) with a pitch-like appearance interspersed, evidence of coke formation (50% density <1.2).

Sample 2780

Dull black appearance at low magnification, some limestone (approx. 10%) present, particle size (0.2 mm) similar to sample 2749. Sintering of coal dust evident, reflectance at higher magnification associated with fused globules (possibly coke grains).

Sample 2792 - Water Barrier

Coating on water barrier was dark grey in colour, consisted of predominantly limestone (approx. 90%), the remainder being coal dust with no indication of sintering.

* = Road dust samples Degree of sintering 2728>2713>2716.

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APPENDIX E4

Samples of Marlin (Bolt Rope) from Appin Colliery

The rope is used to support vent tubing during the driving of headings and is left in place. Samples were collected from many parts of K and J panels to provide an indication of fire damage in different areas. The position of the ropes during the explosion is not in doubt, since they were tied to fixed structures. In contrast with this, other heat damaged materials (such as paper and brattice) may have been transported by the explosion.

Method of Examination

Pieces of new rope were exposed to varying amounts of heat to provide a scale of damage from 0 to 10. Each sample was cut through with a sharp knife to expose a new cross section. This permitted an assessment of the extent of fire damage in each rope, by microscopic examination.

Damage scale:
- 0 - still greasy - no singeing.
- 1 - some singeing, almost entirely green, not more than slightly greasy.
- 2 - heat affected to depth of about 1/10 of diameter.
- 3 - <½ affected by heat, surface blackened.
- 4 - ½ affected by heat, 1/10 blackened.
- 5 -
- 6 - almost all heat affected, <½ blackened.
- 7 -
- 8 - Approx. ½ black.
- 9 - >½ black.
- 10 - all black.
- 10+ - some or all ashed.

Sample No.	Damage Scale	Sample No.	Damage Scale
2701	6*	2718	3
2704	3	2722	3
2706	4	2726	3
2708	4	2734	3
2709	3	2735	3
2711	3*	2737	3
2712	3*	2738	3
2713	4*	2739	3
2714	6	2740	2
2715	6	2783	8
2717	6	2784	4

All rope samples are covered with black dust except sample 2718 which is covered with 50-50 black and white dust, and sample 2740 which is covered with almost white dust. The samples marked with * contained red crystals in the dust. The nature of these is not known. Sample 2709 contained white crystals.

...E4/2

A piece of new rope was held in a bunsen burner flame 50 mm high without blue cone. The rope caught fire after 5 seconds.

Further new pieces were held separately in a muffle furnace; at 500°C the rope caught fire; at 450°C it was burned without flame and at 400°C its colour changed to become similar to the samples collected from the mine.

The locations and heat damage to the samples of marlin are marked on the attached plan.

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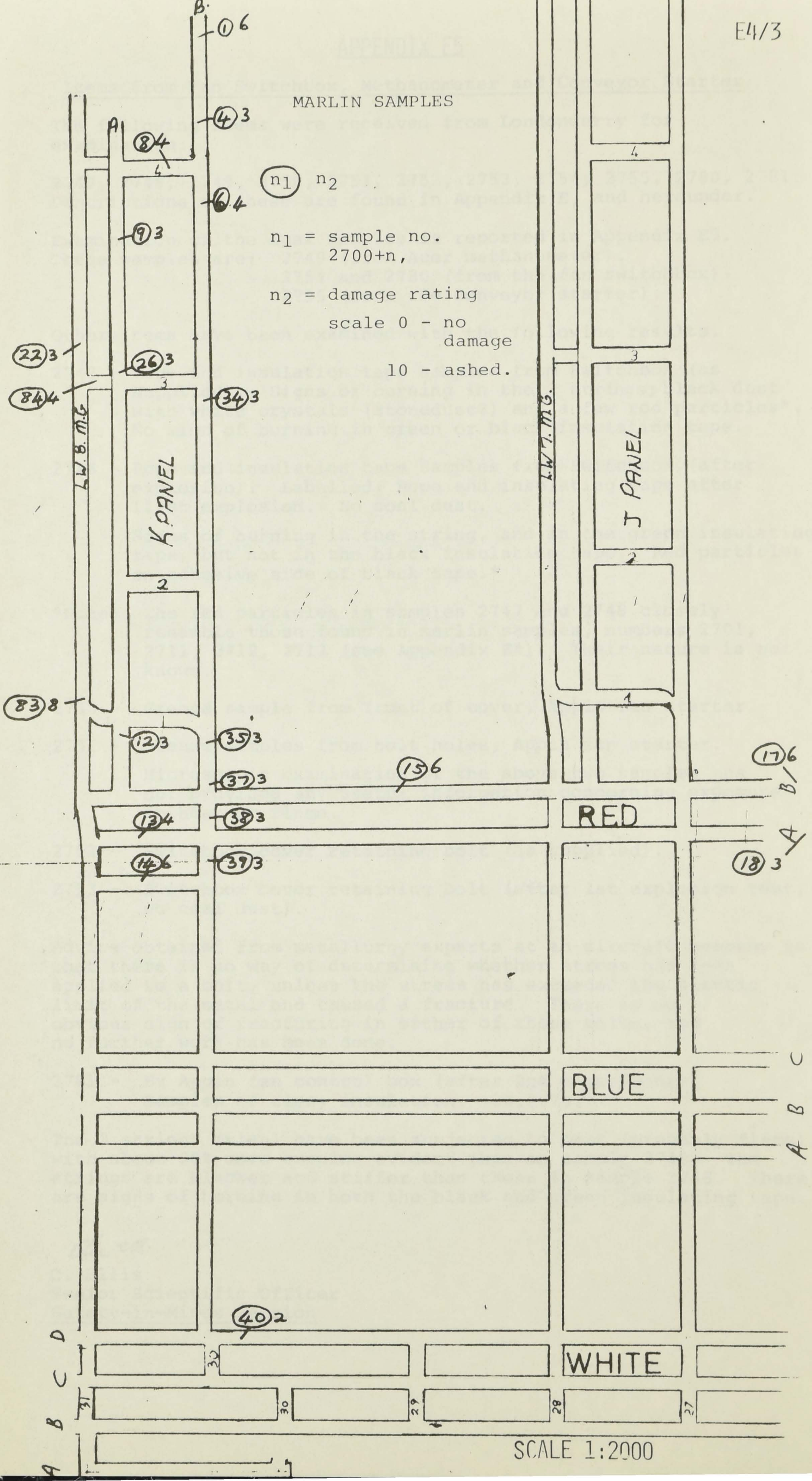
MARLIN SAMPLES
n_1 n_2
n_1 = sample no. 2700+n,
n_2 = damage rating
scale 0 - no damage
10 - ashed.
K PANEL
J PANEL
L.W.B.M.G
L.W.T.M.G
RED
BLUE
WHITE
SCALE 1:2000
1 6
4 3
8 4
6 4
9 3
22 3
26 3
84 4
34 3
83 8
12 3
35 3
37 3
15 6
13 4
38 3
14 6
39 3
17 6
18 3
40 2
A
B
C
D
1
2
3
4
27
28
29
30
31
32

APPENDIX E5

Items from Fan Switchbox, Methanometer and Conveyor Starter

The following items were received from Londonderry for examination:

2747, 2748, 2749, 2750, 2751, 2752, 2753, 2754, 2755, 2780, 2781.
Descriptions of these are found in Appendix E, and hereunder.

Examination of the dust samples is reported in Appendix E3.
These samples are: 2749 (from Auer methanometer).
2754 and 2780 (from the fan switchbox)
2755 (from the conveyor starter).

Other items have been examined with the following results.

2747 - Rope and insulation tape samples from Switchbox (as supplied). Signs of burning in the 3 strings; black dust with white crystals (stonedust?) and a few red particles*. No sign of burning in green or black insulation tape.

2748 - Rope and insulation tape samples from Switchbox (after explosion). Labelled: Rope and insulating tape after first explosion. No coal dust.

Signs of burning in the string, and in the green insulating tape, but not in the black insulating tape. Red particles on adhesive side of black tape.*

*Note: the red particles in samples 2747 and 2748 closely resemble those found in marlin samples, numbers 2701, 2711, 2712, 2713 (see Appendix E4). Their nature is not known.

2750 - Grease sample from front of cover, Appin fan starter.

2751 - Grease samples from bolt holes, Appin fan starter.

Microscopic examination of the above two samples has not provided any useful information concerning exposure to heat or flame.

2752 - Switchbox cover retaining bolt (as supplied).

2753 - Switchbox cover retaining bolt (after 1st explosion test, no coal dust).

Advice obtained from metallurgy experts at an aircraft company is that there is no way of determining whether stress has been applied to a bolt, unless the stress has exceeded the elastic limit of the metal and caused a fracture. There is no obvious sign of fracturing in either of these bolts, and no further work has been done.

2781 - Ex Appin fan control box (after 2nd experiment). Samples of ties, insulation. 20.8.79.

The 3 strings (ties) have been subjected to heat (probably flame), with about 20% more burning evident than on sample 2748. The strings are blacker and stiffer than those in sample 2748. There are signs of burning in both the black and green insulating tape.

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APPENDIX E6

Pieces of Glass, and Pieces of Helmet from Appin Colliery

Glass. Items 2770 (see page E3), and 2893 and 2894 (see page E5) have been examined. All were found to have both thickness and curvature similar to glasses from oil flame safety lamps. They are therefore presumed to come from one (or more) oil flame safety lamp(s).

Helmet. Items 2782 (see page E4) and 2897 (see page E5), have been examined. Some of the pieces of helmet are large, and it has been possible to fit them together (with allowance for distortion). They are found to come from two separate helmets.

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