MINISTRY OF POWER

EXPLOSION AT CARDOWAN COLLIERY LANARKSHIRE

REPORT

On the causes of, and circumstances attending, the explosion which occurred at Cardowan Colliery, Lanarkshire, on 25th July, 1960

BY

H. R. HOUSTON, C.B.E.

H.M. Deputy Chief Inspector of Mines and Quarries

Presented to Parliament by the Minister of Power
by Command of Her Majesty
January 1961

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HER MAJESTY'S STATIONERY OFFICE

FIVE SHILLINGS NET

Cmnd. 1260

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TABLE OF CONTENTS

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20th December, 1960.

The Right Honourable Richard Wood, M.P.,
Minister of Power.

SIR,

I.—INTRODUCTION

(1) In accordance with your direction given under the terms of Section 121 of the Mines and Quarries Act, 1954, I have the honour to submit my report on the causes and circumstances of the accident which occurred at Cardowan Colliery in the County of Lanark on the 25th July, 1960, shortly before 7 p.m. when three persons were killed and seven others injured, one of them so seriously that he died on the 31st July, 1960.

(2) The accident was due to an explosion which occurred during operations following the breaking open of stoppings erected some months previously to seal off an underground fire. Sections IV, V and VI of this report describe, respectively, the fire which broke out on 29th January, 1960, and the method of sealing it off; the attempt to re-open the area affe
explosion. Section VII discusses the air samples which were taken after the seals were broken until the time of the explosion, and Section VIII comments on the planning of the re-opening operations.

II.—DESCRIPTION OF THE COLLIERY

(3) Cardowan Nos. 1 and 2 Colliery is situated at Stepps in the County of Lanark about five miles north-east of Glasgow. It produces a daily output of approximately 1,500 tons of coal from four seams, the Meiklehill Main, the Meiklehill Wee, the Cloven and the Kilsyth Coking Coal. The latter, in which the explosion occurred, lies at a depth of approximately 700 yards from the surface. The mine is served by two shafts, No. 1 the downcast and No. 2 the upcast. In addition a third shaft, No. 3, has been sunk to a depth of 700 yards for the future development of the colliery but its existence has no bearing on this accident. During normal working prior to the accident a total of some 1,400 men were employed underground and 250 on the surface. The mine is gassy and safety-lamps are used throughout the workings. It is ventilated by a double inlet Sirocco fan situated on the surface at No. 2 Pit, which before the fire in January circulated a total quantity of 450,000 cubic feet of air per minute with a water gauge of 5·14 inches.

(4) The mine has a history of heavy gas emission. An explosion of firedamp occurred in No. 2 Shaft while it was being sunk in 1927, a second explosion occurred in 1931 while an underground fire in the Meiklehill Main Coal was being sealed off, and a third, in which 11 men were killed, occurred in 1932 in

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the same seam. This latter explosion was the subject of a formal investigation under Section 83 of the Coal Mines Act, 1911, conducted by Sir Henry Walker, then H.M. Chief Inspector of Mines, and a report Cmd. 4309 was published in 1933.

(5) The colliery is situated in the No. 3 (Central West) Division of the National Coal Board. The Colliery Manager was J. MacMaster and there were three undermanagers of whom J. B. Henderson was in charge of the part of the mine where the accident occurred. The Group Manager was W. G. Neilson, one of the injured persons; the Deputy Area Production Manager (Operations) and the Area General Manager D. Lang.

III.—THE NORTH SIDE COKING COAL

(6) The explosion occurred in the Kilsyth Coking Coal in No. 4 East District which lies to the north of the shafts. A big upthrow fault runs approximately east and west about 200 yards to the north of the shafts and the seam was developed beyond this from a pair of large stone drifts which were driven across it on a rising inclination. The seam was worked by a series of longwall faces to right and left of the main development which was pressed forward in an approximately north-easterly direction (see plan) undercut and filled on to belt conveyors on the face which in turn delivered on to gate belts and thence on to a trunk belt in the main intake with the loading point in the vicinity of No. 2 West Junction. At the time of the fire in January the only face being worked was No. 4 East. The face of No. 3 West had been cut out by a fault and a new face was in process of being won out beyond it, while another new face was being opened up along its right-hand ribside. The main developing face going to the north had been rising on an ever increasing gradient beyond No. 4 East and it had been standing for a considerable time before the fire occurred. Of the old roads on the east side access was maintained, through ventilation doors, to No. 1 East where a borehole had been put down into the Hurlet Seam and had been connected to the methane drainage pipe system. No. 2 East Intake was maintained right down to the old face line where a pump was situated in order to deal with a make of water said to amount to 30 gallons per minute. The intake and return of No. 3 East were also accessible. On the west side the old roads leading into No. 1 West had been sealed with stoppings but the roads into No. 2 and No. 3 West were maintained and ventilated with a view to re-opening the faces beyond the fault. The return on the left-hand side of the old north face was sealed up just above its junction with the return from No. 3 West but a flow of air had been maintained up the intake and down the right-hand return, the amount being controlled by a regulator in the latter.

(7) The Kilsyth Coking Coal is notoriously gassy and at this colliery the emission amounted to 1,060 cubic feet per ton. In order to improve the quality of the ventilation a system of methane drainage had been adopted and firedamp was being extracted from the roof of the left-hand return of No. 4 East. The gas drainage pipes were laid in the return airway and up the Upcast Shaft.

(8) Air measurements taken during December, 1959, in the ordinary course, before the fire showed that 46,300 cubic feet of air per minute were passing into the North Side Coking Coal Districts. Of this, 12,600 cubic feet per minute

entered No. 4 East Intake with 7,300 cubic feet per minute coming back out the right-hand return (which was regulated) and 5,000 cubic feet per minute out the left-hand return. Firedamp determinations taken at the same time showed 0·15 per cent. in the left-hand return and 0·43 per cent. in the right-hand return.

(9) No. 4 East District consisted of a double unit longwall conveyor face approximately 200 yards in length and 27 inches in height. The coal was undercut at floor level by a chain machine to a depth of 4 feet 6 inches and filled on to face belts which were fire resistant. The face belts delivered at the centre (intake) roadhead on to a gate belt. All the machinery was electrically driven. The face had advanced some 300 yards to the east at the time of the fire. The roof at the face was supported by wooden props and lids and strip packs were built in the wastes. A stone dust barrier was installed in No. 4 East Intake between the air crossing and the Trunk Road.

IV.—THE UNDERGROUND FIRE ON 29TH JANUARY, 1960

(10) On the 29th January, 1960, while coal cutting was in progress on the left-hand side of the face in No. 4 East District in the Coking Coal, firedamp was ignited in the undercut. All attempts to extinguish the resulting fire, which had spread on to both sides of the face and in which the coal, gummings and wooden props were involved, proved unavailing, and after several small explosions of firedamp had occurred in the waste, the workmen engaged in fire-fighting had to be withdrawn. To smother the fire seals had to be built and these were put in at the lower (outbye) ends of the two stone drifts which gave access to the North Side Coking Coal Districts. The intake seal was situated at a distance of 1,420 yards out from the face. The area enclosed by the seals rapidly filled with firedamp and such was the make of gas that a total volume of more than 40 million cubic feet of methane was drained off from behind the seals during the time they were in position.

(11) In the early part of June, 1960, it was considered that the time would soon arrive when the workings in the North Side Coking Coal could safely be recovered and it was during these recovery operations that the explosion occurred. Immediately after the survivors had been rescued and the three bodies recovered, the seals were replaced because of the risk of further explosions and the district has not been re-opened since. It has not been possible, in consequence, to investigate thoroughly either the fire in January or the explosion in July.

V.—THE ATTEMPT TO RE-OPEN THE NORTH SIDE DISTRICTS

(12) After the fire in No. 4 East had been sealed off for five months, it was felt that it would then be safe to re-open the district while the pit was idle for the annual holidays in the latter part of July. Samples taken from behind the seals from the bottom of the drifts had shown that the atmosphere had rapidly become extinctive once the seals were completed and it was felt that sufficient time had elapsed to allow all heated material to cool off sufficiently so that it would not re-ignite when exposed to the normal atmosphere.

(13) It was estimated that a volume of 1¾ to 2 million cubic feet of methane was contained behind the seals and this had to be swept out, diluted to a harmless concentration and removed to the surface by restoring the ventilation. An operation of this nature and magnitude obviously calls for careful and detailed planning beforehand. The potential risk of disaster is indeed ever present until the last of the gas has gone.

(14) The two stoppings at the bottom of the drifts presented a somewhat unusual problem. It was known that the atmosphere immediately behind them was practically pure methane and they had been strengthened with masonry walls, together with injections of considerable quantities of neat cement. Any attempt to remove the stoppings by manual labour was out of the question because of the risk of igniting gas by sparking from tools, and because of the risk, particularly at the return stopping, that the workmen might become enveloped in an irrespirable atmosphere. After extensive enquiries and consultations with experts it was decided to breach the seals by blasting, the charges being fired electrically from the surface while no one was underground. In order to ensure that the gas could not come into contact with the explosive while it was being fired, considerable quantities of water were pumped through the stoppings, and the drifts behind them filled to such an extent that there was a head of water of at least five feet above the tops of the seals. The seals were safely, though only partially, breached when the charges were fired at 10.40 a.m. on Saturday, 16th July. Inspection later in the day showed that a hole had in fact been blown through the return seal but that the wall on the inbye side of the intake seal was only cracked. The latter was not really opened up until 2 a.m. on Sunday, 17th July, when the fractured brickwork was pushed over with a hydraulic prop.

(15) Before operations started the National Coal Board's Divisional Mobile Laboratory was brought to the colliery and in addition air sampling apparatus was set up in the electricians shop. This enabled samples to be analysed immediately they were brought to the surface and the results were in the hands of the management at the earliest possible moment.

(16) The methane drainage pipe range had been opened up close to the outbye wall of the seal in the return so that samples of atmosphere from the return could be drawn off at the surface without exposing anyone to the risk entailed in collecting them on the spot. This arrangement proved very successful and samples taken in this way showed that about three-quarters of an hour after the blast 11 per cent. of firedamp was present in the return and that it rose to just over 20 per cent. one hour after the blast. Air samples were drawn (and analysed) from this pipe at regular intervals until it was re-connected with the inbye methane drainage range at 1.30 p.m. on Monday, 25th July, a few hours before the explosion. All these samples were analysed for carbon monoxide but " NIL " results were obtained except on three occasions, all within eleven minutes of the blast, when small percentages were found (0·034, 0·011 and 0·003), and these were considered (rightly I think) to have originated from the firing of the explosive.

(17) I consider that as soon as the water had drained away from the fire seals some air started to circulate through them. The doors in No. 1 East Air Crossing had been deliberately left open when the districts were sealed up in

January, so that once the seals were breached very little ventilation pressure would be needed to cause some air to flow in the drifts. By 10 a.m. on Sunday, 17th July, air measurements indicated that 2,100 cubic feet per minute were passing in through the intake seal and indeed samples containing up to 68 per cent. methane were collected at the " Breach in the Return Stopping ". By noon the quantity had risen to 5,500 cubic feet per minute. It was not, however, until the afternoon of Monday, 18th July, that a really clear passage was made through the stopping in the return drift. At the time the seals were inserted, doors were built in the drifts near the inbye ends of the stoppings and the door in the return had jammed shut. In order to open this door a team, wearing breathing apparatus, had to be sent round through No. 1 East Air Crossing into the return drift to take it off its hinges and this was accomplished by 3.30 p.m. Meanwhile air measurements taken by the Area Ventilation Engineer showed that 6.200 cubic feet per minute were passing inbye through the hole in the seal. Whether any of this fresh air reached the face of No. 4 East at this time is problematical since later inspection showed that the doors in the air crossing at No. 4 East had been destroyed by an explosion, which it would appear, happened when the district was sealed off in January. Later the same day, doors in the road connecting the two drifts on the outbye side of the stoppings were closed and a " fresh air base " established at No. 1 East Junction. A rescue team then explored the main intake and found it flooded inbye from No. 3 East Junction and that the edge of the water in the right-hand common return was lying at its junction with the Peeler House. The doors at No. 1 East Air Crossing were then closed (in the early hours of Tuesday, 19th July) and it was possible to walk down the intake to the edge of the water without breathing apparatus.

(18) In the meantime air samples had been systematically collected (1) from the site of the return stopping by means of the methane drainage pipe, (2) from the Fan Drift on the surface and (3) a few were also obtained, at much longer intervals, from the breach in the return stopping. As already indicated the results of the analyses of these samples did not give cause for any uneasiness. An additional sampling point was then established in the main return from the east side at No. 1 East Overcast and samples were collected once every hour from 1 a.m. on the 19th July, until 11 a.m. on the 20th. The analyses again seemed to indicate that all was well. In the morning of Wednesday, 20th July, the Area Ventilation Engineer took measurements showing there was a current of air passing inbye over the water, and that this had risen to 4,700 cubic feet per minute. The doors in the Peeler House were replaced by a Rescue Brigade, and an electric pump was taken inbye to the edge of the water, arriving on the site about 4 p.m.

(19) There was systematic sampling at four points from that day. The results were considered to be satisfactory at the time, but, as shown in Section 7 of the Report, I consider that the implication of those results was not properly appreciated.

(20) The electric pump was started up at 1.10 a.m. on Thursday, 21st July, and at once the level of the water began to fall. At 11.25 a.m. the Area Production Manager, J. Lawrie, and F. Tootle, H.M. District Inspector of Mines, made their way in through the water and reached the intake of No. 4 East. They found the doors at the air crossing completely smashed on the

right-hand side and partly damaged on the left-hand side, and such fresh air as was reaching the air crossing appeared to be short circuiting directly into the return on the south side. Tests made with a flame safety-lamp showed that the flame was extinguished at a point in the intake 30 feet inbye of the air crossing. It was at this time that signs of a previous explosion, which had probably occurred at the time when the district was sealed off in January, were found. In addition to the damage to the air crossing doors a stone dust barrier installed near the end of the intake was found to be discharged, the planks at the outbye end were lying on the floor, but those inbye were still in position although with no dust left on them. Some metal ventilation tubing which had been used before the air crossing had been constructed, and which had been left hanging up in the road, was also found flattened. Later the same day a canvas screen was erected in an attempt to restrict the leakage through the air crossing doors, and the Area Ventilation Engineer, wearing breathing apparatus, made a measurement in No. 4 East right-hand return showing that about 700 cubic feet per minute was coming out.

(21) On Friday, 22nd July, at 7.30 a.m. an attempt was made to restrict the leakage at the doors of No. 3 East and No. 4 East with canvas, and measurements taken by the Area Ventilation Engineer showed that 11,000 cubic feet per minute were now passing inbye over the water, and 7,500 cubic feet per minute were coming out at No. 4 sampling point. The flow in the right-hand return of No. 4 East had risen to 2,000 cubic feet per minute. Between 12.25 and 1.15 p.m. the right-hand return was explored by a rescue brigade wearing apparatus, who took temperatures getting readings of 72° F. dry bulb, and 71° F. wet bulb. Work continued to improve the doors at the overcast. At 2 p.m. another rescue team moved a tub, filled with rubbish from under the " back brushing " in the common return, which had been a considerable obstruction to the free flow of air in the return. This brigade then explored the intake of No. 4 East. In the evening another rescue brigade collected samples from the left-hand return when it was estimated that about 1,000 cubic feet per minute were coming outbye and being diluted with a leakage of approximately 3,000 cubic feet per minute of fresh air at the air crossing. Between 6.45 and 7.25 p.m. a rescue team went into the face of No. 4 East left-hand return, and by using their electric lamps were able to see down the face as far as the cutting machine. Everything seemed to be in order, the atmosphere was clear and the props were standing.

(22) On the same day special air samples were collected in the No. 4 East District. The results, set out in Section VII of the report, show that all except one contained carbon monoxide in measureable quantities.

(23) On Saturday, 23rd July, further improvements were effected to various doors along the intake, including those between the intake and the West side return.

(24) On Sunday, 24th July, the openings through the stoppings at the outbye ends of the main drifts were expanded by clearing the passageways up to the roof. By 1 p.m. the return had been dealt with, and by 4 p.m. the intake. A measurement made at 8 p.m. that day showed that the amount of air passing inbye had increased to 17,752 cubic feet per minute.

(25) On Monday, 25th July, at 9.30 a.m. an exploration was made by a party without breathing apparatus, and they were able to get as far as the face of No. 4 East intake. The roadway thus far was clear of gas, though the atmosphere felt warm. Tests with a flame safety-lamp through the north side doors at No. 4 air crossing showed that the atmosphere in the left-hand return was explosive. The party also travelled the right-hand return finding some 2 per cent. of firedamp in the general body of the air at the outbye end, rising to 3 per cent. in the general body at the roadhead. A quantity of 11,000 cubic feet per minute was passing inbye over the water in the Trunk Road.

(26) In the afternoon an attempt was made to run the methane drainage plant in order to draw gas from the left-hand return in No. 4 East. The attempt failed, apparently because the pipes were blocked with water. Two mechanics, J. Dewar and T. Stenzel, together with W. Murphy, an experienced deputy, were sent into the return to see if they could find out what was wrong, and to drain off any accumulation of water they could find. A party consisting of W. G. Neilson, the Group Manager, F. Tootle, District Inspector, J. Henderson, an overman and rescue man, W. Hamilton, a deputy, T. Davidson, a deputy, A. Bridges, a rescue man, D. Scott Snr. and D. Scott Jnr., workmen (and two others) were sent into No. 4 East in order to clear an airway through the fall which was known to have occurred on the left bank of the face at the time of the fire. The two rescue men wore breathing apparatus but it was not "coupled up". Tootle went with the mechanics into the return and left, after watching them for some time, when he was satisfied that they would finish their work within a matter of 20 minutes. He then went round and assisted the party at the face. By 6.30 p.m. an airway had been opened up through the fall 3 to 4 feet in width and approximately 18 inches in height. Tootle and Neilson crawled through the hole, looked up the face using their cap lamps, and saw that conditions appeared to be normal. The atmosphere was clear and the props were standing.

(27) In the meantime the two other workmen had been sent to do further repairs at the ventilation doors. These workmen, fortunately for themselves, ran out of material and had to return to the surface. In the return the mechanics had also finished their work on the methane drainage pipes and reported progress to the surface on the telephone at No. 2 West. They received instructions from the Deputy Area Production Manager to go back into the return and make a further examination of the range. They did so but so far as is known they did not take any tools with them on this occasion. The deputy, Murphy, again accompanied them.

(28) Having opened up the passage through the fall the party at the face turned for home, and were making their way outbye along No. 4 East intake. Such was the state of affairs immediately before the explosion.

VI.—THE EXPLOSION

(29) As already indicated, the party working on the fall on the left bank of the face had made better progress than had been expected. A hole 3 to 4 feet in width and 12 inches to 18 inches in height had gradually been opened up over the 38 feet to which distance the fall had extended. The quantity of air

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passing over the fall had gradually increased as the work progressed, and in fact had been greatly increased by the time it was finished. Beyond the fall everything appeared to be quite normal, the temperature, though warm, did not appear to be higher than usual and the ground did not appear to be warm to the touch. The whole party made their way outbye more or less leisurely, looking for signs of the previous explosion as they went. The two workmen had been sent on ahead with instructions to tighten up the doors at No. 4 East air crossing, in order to reduce the leakage. As is quite understandable under the circumstances none of the survivors is now able to say in what order the party was proceeding, and indeed all are not quite certain whether or not they had passed the air crossing when the explosion occurred, though the balance of the evidence leads me to believe they were in fact between the air crossing and the Trunk Road. All are agreed, however, that they were suddenly enveloped in flame, that there was a tremendous concussion and that they were thrown about violently. One of the first to recover his senses was Bridges, one of the rescue men, whose lamp unfortunately was broken. He found himself in an atmosphere of smoke and dust. He was wearing breathing apparatus, although it was not coupled up, and his arm having been injured he was unable to turn on the oxygen. He shouted and hearing a reply crawled in the direction of the voices. He found two persons, one of whom was Henderson. Bridges managed to switch on Henderson's oxygen supply, but Henderson's hands were so badly burned that he could not do likewise for Bridges, who had to instruct the other man how to turn on the oxygen. Bridges then fixed his nose clip and mouthpiece, and after taking a few breaths of oxygen recovered and became clear headed again. Bridges then shouted telling everyone to switch on their cap lamps, but the visibility was very bad owing to the amount of dust in the air. He then gave the second man oxygen from his apparatus for a short time. Recollecting that if he kept the gate belt on his right-hand side he would be going outbye, he shouted this to all the others who could hear him and set off. However, he soon found that they were going in the wrong direction and turned back. Tootle, who had been examining some dust on the web of a girder, was badly injured about the face at the time of the explosion and was found in a semi-conscious state sitting on the floor. Bridges helped Tootle out on to the Trunk Road where they found the atmosphere clear. Another man was sitting on the trunk belt in a dazed condition, and Bridges revived him by shaking him and indicated the way out. All were burned and badly shocked. Neilson and Henderson were left sitting on the trunk belt near No. 4 East Junction while the others straggled outbye. At this time they were quite unaware that the three other men were still in the return. Meanwhile D. Scott Jnr. who had preceded the main party, carrying reviving apparatus with him, had reached No. 3 East Junction when the explosion occurred. The force of the explosion blew him to the floor and he lost the reviving apparatus. He picked himself up and made his way out to the telephone at No. 2 West where he found F. McTigue. He told McTigue to telephone to the surface and let them know what had happened. McTigue, who was at the telephone at the time says that he was also knocked over by the explosion and when he recovered himself he telephoned to the surface and informed them that there had been a terrific blast and that help was needed.

(30) W. Adams, a Rescue Brigade Instructor, arrived at the colliery at 6.55 p.m. to take charge of the rescue " cover " for the oncoming shift. As he

walked into the Incident Room the telephone rang, and when he answered it a voice said " Blast, need assistance, I am choking ". He did not know who spoke, nor where the message came from because the person making the call immediately rang off. He at once told the four rescue men and J. Simpson, the Instructor, who had been standing by from the previous shift, to go straight down underground and give what assistance they could. He then telephoned the Coatbridge Central Rescue Station saying there had been an explosion at Cardowan and asked for assistance. On coming out of the Incident Room at approximately 7 p.m. he met W. Dyer, the Rescue Station Superintendent, who instructed him to go underground with the others. Adams put on his apparatus, arranged for reviving apparatus to be sent underground and proceeded inbye with the others. At the intake stopping he met two men whose names he did not know, but whom he could see had been involved in the incident, and he allowed them to carry on outbye. The doors at No. 1 East air crossing were found blown open. Adams had been informed of the three men in the return and having seen all the survivors on their way outbye, he realised that three men were still unaccounted for and that they must be those in the return airway. An attempt was made to enter the return airway at No. 3 East but the overcast had been destroyed, the roof of the resulting cavity was still falling heavily so that it was not possible to get into the return at that point. The six-man team was then split up into two parties, one going in through the Peeler House and the other round through the doors at No. 4 East air crossing. The men going through the Peeler House found the three bodies of Murphy, Stenzel and Dewar in the return between the right-hand return and the back brushing at the points A, B and C, indicated on the plan.

(31) The injured persons having been removed to the surface the work of recovering the bodies was then organised, and within half an hour the last body had been brought out on to the Trunk Road. The flame safety-lamp belonging to Murphy, the deputy, was found lying on the floor in the return near the back brushing, and it was recovered and taken to the surface. Signs of blast were seen in the Peeler House indicating that the blast came from the return towards the intake. A stool near the junction of the right-hand return with the common return had been blown into the right-hand return, seeming to indicate that the blast had come out along the common return. The doors at No. 4 East air crossing had again been completely destroyed, but the direction of the blast was not noted in the limited time while the Rescue Brigade men were looking for the bodies. A hutch of dirt in the common return near No. 4 East air crossing seemed to have been moved in an inbye direction, but there is some doubt about this as its precise position before the explosion is not known. Three flame safety-lamps, one cap lamp and the canary cage were found in No. 4 East intake road within a few yards of the junction with the Trunk Road. Their positions were noted, though they were not recovered, and they seem to indicate the whereabouts of the survivors when they were overwhelmed by the explosion.

(32) As soon as the bodies had been brought to the surface it was decided that in view of the danger of another explosion the district should be abandoned and the seals replaced at the foot of the main drifts. The passageways through the stoppings were filled in with sandbags by 7 a.m. on the 26th July, and the seals finally completed by 1 p.m. on Saturday, 30th July.

VII.—AIR SAMPLING AND ITS RESULTS

(a) Systematic samples collected 20th–25th July

(33) From midday on Wednesday, 20th July, systematic sampling was established at points marked 1, 2, 3 and 4, on the plan. Sampling at point No. 1 was stopped after 2.30 a.m. the next morning. These air samples were taken by rescue brigade men who had been trained not to operate the relief valves on their breathing apparatus when there was any possibility that such action might vitiate the samples. Bladders were inflated by taking increments systematically over the cross section of the roadway so that a representative sample of the "general body" of the atmosphere was obtained. The results of the analyses of these samples are shown on the three graphs. At first samples were taken every two hours and the results of analyses gave no cause for concern until the early hours of Thursday, 21st July, when 0·0013 per cent. of carbon monoxide was found in a sample from No. 3 Point, *i.e.*, in the right-hand return from No. 4 East. From that time on until the explosion it was only on rare occasions that "NIL" or even "trace" results were obtained from this airway. It is true that the percentages were never anything but small but their presence at all should, I think, have led those responsible to look more closely into the matter. When the percentages of carbon monoxide and the oxygen deficiencies are as small as these were, it is really doubtful if a reliable and truly indicative figure can be obtained when the "ratio" is worked out. I do feel, however, that they were "straws in the wind" and that they should have been followed up, not only by sampling at shorter intervals, but by attempts to obtain other samples taken at different points in the cross-section of the roads and at points nearer to the site of the January fire. It is contended that this carbon monoxide was a constituent of the gases left in the wastes after the fire and explosion in January but I cannot altogether accept this. A glance at the graphs shows that the shapes of the "curves" for methane and carbon dioxide are substantially similar, *i.e.*, that when one is high the other is high and when one is lower the other is lower. The shape of the carbon monoxide curves are however quite different, clearly indicating that this gas was not a "residual". Moreover, it has been calculated that the total volume of atmosphere enclosed within the seals was something between 1¾ and 2 million cubic feet. As already noted, some 40 million cubic feet of firedamp were drained from the area during the time the seals were in position so that in effect the "bottle" must have been "washed out" about 20 times and the likelihood of any residual carbon monoxide remaining at the time of re-opening is indeed remote.

(34) The Kilsyth Coking Coal is not regarded as being subject to spontaneous heating so I am convinced that fresh air was coming into contact with carbonaceous matter which was at such a temperature that oxidation was taking place. Once oxidation starts the temperature rises causing in its turn an increase in the rate of oxidation and, unless the flow of air is sufficiently great to carry away the heat thus generated, open combustion eventually results. Something of this nature was, I think, happening on either or both banks of No. 4 East face—probably on or near the edge of the waste. Apart from the members of the party who cleared a passage for the air over the fall on the left bank, no one had examined or even travelled the face, and fresh air had had access to it for several days.

(35) It was said that No. 4 sampling point was chosen because it was readily accessible to men wearing breathing apparatus. While this is a valid consideration, the site was open to considerable objection on the ground that very heavy leakage of fresh air was taking place at No. 4 East Air Crossing, thus diluting the atmosphere in the return and rendering the detection and measurement of carbon monoxide much more difficult. Under prevailing circumstances, and indeed in any case where firedamp is being cleared from an area after a fire has been smothered by sealing off, it should be recognised that nothing should be allowed to stand in the way of collecting the most informative samples of the atmosphere. Had samples been collected from the Left-hand Return of No. 4 East it is not altogether improbable that a much more definite picture of the state of affairs on the Left Bank of the face would have been obtained. As it was, the " traces " and small percentages of carbon monoxide which were found should have excited more interest and curiosity. In this particular road only a very small amount of air was circulating and high percentages of firedamp were present. The road rose gently towards the face and the face itself rose gently from the intake up to the left-hand corner.

(36) Observations by the Area Ventilation Engineer wearing breathing apparatus made as late as Monday morning (the day of the explosion) in No. 4 East Left-hand Return showed that the atmosphere in the upper part of the road was stagnant; while there was a flow, estimated to lie between 500 and 1,000 cubic feet per minute, along the floor of the road. It is a pity that spot samples were not taken entirely from this moving current instead of from the general body of the air. They might well have been much more informative.

(*b*) *Additional Samples in No. 4 East District, 22nd July*

(37) As already explained, special samples were collected from No. 4 East District on 22nd July.

(38) Shortly after midday half-a-dozen samples were taken spaced out at intervals along the right-hand return; about 3 p.m. three were taken similarly in No. 4 East Intake and about 7 p.m. three (one at the face, one midway and one at the outbye end) were collected from the left-hand return. The results of the analyses are set out in the table below:—

CO_2	CO	O_2	N_2	CH_4	*Black Damp*	CO/O_2 *Def. Ratio*	*Remarks*
			Sampling Point—No.				
1·91	0·0008	9·79	42·63	45·67	7·57	0·0005	At face
1·91	0·0014	10·11	43·85	44·13	7·55	0·0009	150′ from face
1·95	0·0015	10·04	44·27	43·74	8·28	0·0009	300′ „ „
1·62	0·0021	12·12	51·17	35·09	7·01	0·0015	500′ „ „
1·40	0·0011	13·16	55·15	30·29	6·83	0·0008	700′ „ „
0·96	0·0010	15·82	63·43	19·79	4·60	0·0010	900′ „ „
			Sampling Point—No.				
2·02	0·0009	8·61	37·92	51·45	7·43	0·0006	At face
0·15	0·0003	20·57	78·67	0·61	1·09	0·0012	450′ from face
0·06	NIL	20·80	79·03	0·11	0·51	NIL	900′ „ „
			Sampling Point—No.				
2·95	0·0005	1·08	11·17	84·80	9·99	0·0003	At face
2·98	0·0005	1·12	9·42	86·48	8·14	0·0004	450′ from face
2·94	0·0007	5·46	30·42	61·18	12·70	0·0003	900′ „ „

It will be noted that all except one contained carbon monoxide in measureable quantity.

(c) *General Comments on Sampling Procedure*

(39) The samples, other than those drawn off from the methane drainage pipe, were collected in bladders which were inflated by a hand-operated syringe. At the chosen places increments were collected from different points carefully distributed over the cross-section of the roadway, a squeeze of the bulb being given at each point. This ensured that a representative sample of the general body was obtained. The samples were collected by rescue men wearing Proto self-contained breathing apparatus, who had been trained not to use their relief valves while taking them.

(40) It was known that the atmosphere in the left-hand return of No. 4 East contained a high percentage of firedamp and that only a small quantity of air was circulating. The flow of air was confined to the lower part of the cross-section of the roadway. Had samples been taken entirely from this moving air current it is possible that much more informative results would have been obtained. Those increments taken from the upper parts of the road, being mostly stagnant methane, had not passed over the site of the fire and merely served to dilute the increments of atmosphere which had. The net result was to reduce the percentage of carbon monoxide in the sample and to render its measurement a more difficult matter for the chemist. The same applied to samples taken in the right-hand return, particularly in the earlier stages. As the quantity of air passing increased, so of course, did the dilution by fresh air, but samples taken from near the floor might have been easier from the chemist's point of view.

(41) In view of the amounts of carbon monoxide which were found it is a pity that attempts were not made to discover their origin by sampling further inbye, even to the extent of going on to the face for them.

(42) Analysis was carried out on a Graham Lawrence apparatus which enabled the carbon monoxide content to be determined to within 0·0002 per cent. I am satisfied that the results of the analyses were made available as soon as possible.

VIII.—COMMENTS ON THE PLANNING OF THE RE-OPENING OPERATIONS

(43) The exploration and, in particular, the re-establishment of the ventilation appears to have been carried out on an *ad hoc* basis and there seems to have been little sense of urgency. The plans for breaching the stoppings in the drifts were excellent and had been laid down beforehand in detail, but what was to happen after that seems to have been left to be decided upon in the light of the state of affairs at the time. The result was delay, amounting to days, in restoring the ventilation and in clearing the accessible workings of firedamp. The contours of the area were known and flooding of the airways in the " swilley " should have been anticipated and the necessary pumping gear should have been ready. It does not seem to have been realised that once fresh air reached the top of the drifts it would flow downhill under the lighter, less dense, firedamp and that it would not all enter the return where the doors at No. 1 East Air Crossing had been left open in January. For lack of a definite plan to restore the ventilation right into No. 4 East on a fixed time-table of *hours*, together with the provision of the necessary materials to

eal off leakage at the various connections between intake and return, a period of no less than nine days elapsed before anything approaching a sufficient volume of air was supplied to begin to clear the gas from the rise side of No. 4 East District. Had the plan been to clear the roadways in stages (as it might very well have been in view of the large volume of firedamp involved) this could have been settled beforehand; the points at which temporary stoppings were to be erected decided upon and the necessary materials provided. (This method was adopted successfully in 1926 at Birchenwood Colliery in Staffordshire)*. Even if it was intended to make one clean sweep I am unable to understand why progress was not more rapid. It has long been recognised as a cardinal principle when a working is to be cleared of firedamp that gas and air must not be allowed to mix slowly and that the gas should be removed as nearly as possible in the form of a " plug " and a close examination made immediately on its " heels ". This is particularly important when the gas has accumulated because the area has had to be sealed up in order to smother a fire. In these circumstances there is no air current to carry away the heat generated by the fire and it can only disappear by dissipation into and through the strata. As ordinary coal measure rocks are very poor conductors of heat this process is of necessity a slow and lengthy business, and indeed if the fire has been one of some magnitude it is questionable if a period of six months is sufficient to allow the surroundings to cool to something approaching normal strata temperature. If one bears in mind the fact that very few substances oxidise more rapidly than coal, particularly " half burned " coal or " half coked " coal, when it is only slightly warm, the importance of this rate of cooling becomes apparent.

IX.—CONCLUSIONS

(44) Sufficient evidence to ascertain the exact cause and course of the explosion is not available. The only persons to travel the affected parts of the mine after the explosion were the survivors and the rescue brigades. The survivors, quite understandably, were in no shape to make detailed observations. The rescue brigades were, quite rightly, pre-occupied with their prime task of searching for survivors and recovering the bodies of the dead men. They are, however, to be commended on the extent to which they did observe useful signs while going about their business. In these circumstances any conclusions must of necessity be largely a matter of opinion.

(45) In my opinion firedamp was ignited somewhere on the face of No. 4 East District by the reheating of carbonaceous material which had been on fire in January. The explosion spread outbye through the district and up the common return airway increasing in violence as it went. It had, however, died down very considerably by the time it reached No. 1 East Air Crossing where it merely blew open the doors. I am also satisfied that although an electrically-driven pump was in use in the intake, effective steps were taken to ensure that current was not supplied to any cables or apparatus beyond it. The safety-lamps used by the party working in the return were recovered and thoroughly examined, and I am satisfied that they were not the cause of ignition.

(46) In relation to the presence of firedamp progress in stopping substantial leakages through the various connections between intake and return seems to have been slow and somewhat haphazard. Although some air had been

* *See* Transactions of Institution of Mining Engineers, Vol. 75, page 62.

travelling along the right bank of No. 4 East face, it would have little effect on the accumulation in the waste. The fall of roof on the left bank materially restricted the flow of air to such an extent that the left-hand return contained a high percentage of firedamp shortly before the explosion. As a passage for the air was cleared over and through the fall on the left bank the amount passing out of the left-hand return was increased, and so a steadily increasing amount of firedamp was carried out through the common return. The increased flow of air along the left bank may well have been accompanied by a corresponding decrease on the right bank, and it is just possible that this resulted in the concentration of firedamp therein passing into the explosive range. I am also satisfied that sufficient firedamp was present on the face to cause flame to come out of the intake as far as its junction with the trunk road when it exploded. It was not necessary to have an explosive mixture in either or both the returns from No. 4 East to account for the known extent of the explosion. It is obvious that there was an explosive mixture in the common return.

(47) A large number of air samples were taken and analysed without delay. The results did not cause alarm at the time, but although the percentages of carbon monoxide and the oxygen deficiencies were too small to enable reliable and informative ratios to be calculated, the concentrations of carbon monoxide were often definitely above normal level. The method of collecting the air samples ensured a representative sample of the general body of the air in the roadway at the sampling points but I consider that it left something to be desired in the circumstances. The presence of the carbon monoxide should have prompted a review of the situation of the sampling points and of the method of collecting the individual samples.

(48) It is well known that half burned coal or half coked coal are very liable to reheat spontaneously when exposed to fresh air, especially if the temperature is slightly above the normal. The rate of reheating is slow at first but accelerates very rapidly in its later stages, especially as the point of open conflagration is reached. In the present case, fresh air reached the No. 4 East District (at any rate the outbye parts of it) very soon after the seals were breached, and some of it traversed both sides of No. 4 East face for several days. During this time there was ample opportunity for reheating to start and develop. I consider that it is very much more likely that this happened than that the igniting cause originated in something which was done by the men working in the return.

(49) The deputy and two mechanics who lost their lives at the time of the explosion were sent to work in the return while large accumulations of firedamp still existed on roadways on the inbye side of them. While they were in the return work was in progress to clear the fall of roof on the face, which might well have sent gas on to them.

(50) Rescue men, with breathing apparatus, were used to provide support for persons working underground and, at least at the time of the explosion, they accompanied them closely. I consider it would have been better practice for the rescue men to have remained not too far away but under cover in some shelter so as to avoid the risk of their being all overwhelmed simultaneously.

X.—RECOMMENDATIONS

(51) Because of the scarcity of concrete evidence I must again emphasise that my findings are largely a matter of opinion. In this particular case due regard was paid to many of the following recommendations but I have included them in order to draw attention to items which, obvious though they may appear when read in the calm atmosphere of everyday life, may well be overlooked in the stress of an actual re-opening operation.

(1) *Planning of Re-opening Operations*

All phases of work involved in re-opening a district which has been sealed off following a fire, and in restoring conditions to normal, should be covered by a detailed plan, drawn up in consultation with all interested parties. This plan should not be varied materially, except as may be necessary to deal with an emergency, without fresh consultation with those parties. The scheme should provide for the appointment of one senior official to be in charge of all operations on each shift, and for the provision of ample supplies of necessary materials and apparatus such as tools, canvas brattice, materials for temporary stoppings, etc.

(2) *Timing of Re-opening Operations*

Great care is needed in deciding when to attempt to re-open a district which has been sealed off because of fire. A period of longer than six months may well be necessary to allow heated material, particularly coal, to cool down sufficiently. Firedamp will be present in large quantities and in order to ensure that its concentration does not fall into the explosive range it is necessary to consider whether to attempt to recover the whole of the affected area in one stage, or whether to proceed in several stages.

(3) *Restoration of the Ventilation*

This must always be treated as a matter of the greatest urgency. As far as possible, accumulations of inflammable gas should be removed as a "plug" and not diluted with fresh air until they are well clear of any ground which may have been affected by the fire. All possible sources of ignition in the path of the gas must be eliminated. The possibility of an exploration by a team wearing self-contained breathing apparatus and operating through an air lock, should be considered before any attempt is made to restore the ventilation. Steps should be taken to ensure that electric power cannot be supplied to cables or signalling apparatus in the affected part of the mine until the ventilation has been completely restored.

(4) *Sampling the Atmosphere*

The scheme referred to in paragraph (1) above should include the provision of suitable laboratory equipment on the surface at the mine for the analyses of air samples, in particular for estimating percentage concentrations of carbon monoxide to four places of decimals. It should also include the specification of points where air samples should be taken at fixed intervals, bearing in mind that the most significant results will be obtained by taking samples near to any possible, or suspected, site of heating, and that separate spot samples should be taken at different points in the cross section of a roadway in which only a small quantity of air is flowing. The results of the analyses of these samples should be plotted at the earliest possible moment on a graph, in such a way that the percentages of the different gases at any time are plainly indicated. These

graphs should be kept constantly available to the manager and the senior officials. Where air samples are collected by men wearing breathing apparatus they should be instructed how to avoid contamination with gas exhausted from the relief valve of their apparatus. In every case where carbon monoxide is found in measureable quantity, and where the oxygen deficiency can be reliably determined their ratio should be calculated and shown on the graph.

(5) *Safeguarding of Personnel during Re-opening Operations*

A physical examination of the district should be made as the fresh air first advances, and no one should be allowed to work without breathing apparatus in a return airway until the whole area is clear of accumulations of gas. The number of men working underground at any time should be kept down to the absolute minimum. Where a rescue brigade is used underground as support for workmen it should remain in some place, not too far away from where the work is proceeding, but under sufficient cover as will make it unlikely that the rescue men would be seriously affected should an explosion occur. Consideration should be given to the possibility of providing " self-rescuers ", *i.e.*, small gas masks which give protection to the wearer against carbon monoxide, for all persons engaged underground in re-opening operations where there is any risk of explosion.

XI.—ACKNOWLEDGMENTS

(52) I would like to record my appreciation of the willing help and co-operation I received from all concerned in this unfortunate occurrence; from the Area General Manager and his staff; from the Management, Officials and Workmen of the Colliery; from the representatives of the Workmen's and Officials' Unions and from H.M. Inspectors of Mines in the Scottish Division.

I have the honour to be, Sir,

Your Obedient Servant,

H. R. HOUSTON.

APPENDIX

LIST OF CASUALTIES

(a) Killed

Name	*Age*	*Occupation*
John Dewar	40	Engineer
Theodore Stenzel	32	Engineer
William Murphy	54	Deputy

(b) Injured

William Hamilton	58	Deputy (died 31/7/60)
William Gale Neilson ..	55	Group Manager
Fred Tootle	40	H.M. District Inspector of Mines and Quarries
Thomas Davidson	43	Deputy
Allan Bridges	29	Rescue Brigade
John Henderson	44	Overman
Duncan Scott Snr.	55	Repairer

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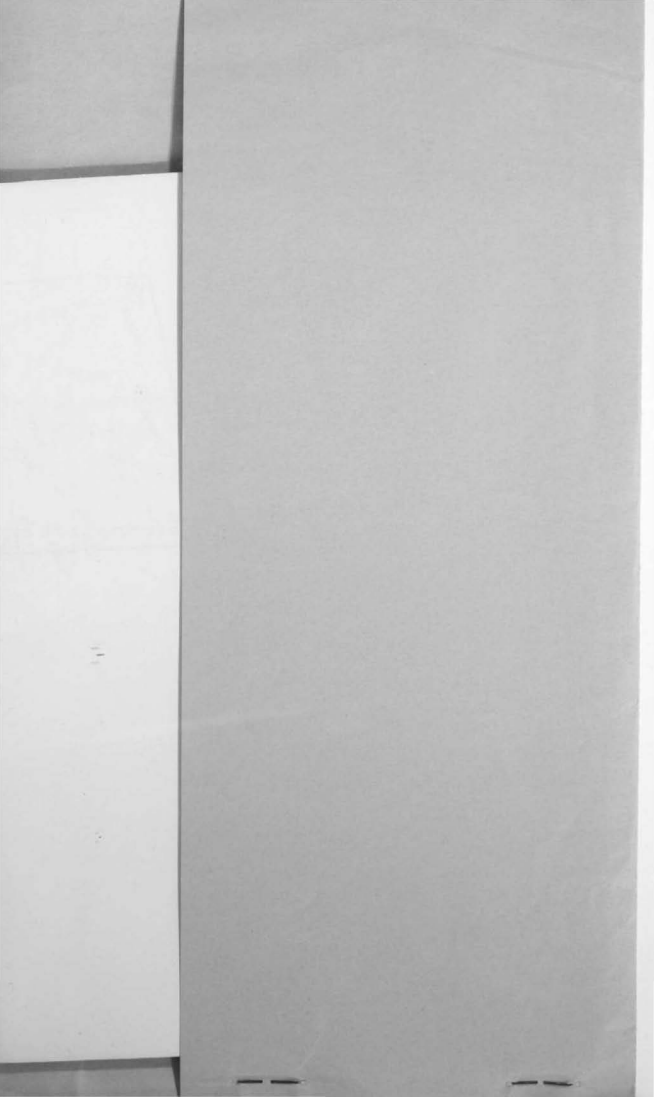

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