M.O. 524q

AIR MINISTRY

METEOROLOGICAL OFFICE

PROFESSIONAL NOTES NO. 117

(Seventeenth Number of Volume VII)

BAROMETRIC CHANGES AND THE EFFLUX OF GAS IN MINES

By C. S. DURST, B.A.

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

Decimal Index
551.543 : 622.81

NINEPENCE NET

Prof. Notes Met. Off., London, 7, No. 117, 1955

BAROMETRIC CHANGES AND THE EFFLUX OF GAS IN MINES

By C. S. DURST, B.A.

Summary.—A relation is obtained connecting the variation of atmospheric pressure and the efflux of methane in a coal mine. In one particular mine experiments were undertaken with the aid of which the constants in the relation have been determined. Light is shed on the type of mine which is liable to suffer from efflux of methane due to sharp pressure falls.

Experiments were undertaken in forecasting high emission of methane, and it was found that the forecasts from the Central Forecasting Office, Dunstable, are effective for this purpose on 65 per cent. of occasions.

Historical.—The origin of this research was a letter from Mr. C. P. Soppet in 1946; in this he asked about the possibility of forecasting the state of combustible gas in mines from the variation of atmospheric pressure. For many years there has been a supposition that the rate of efflux of methane gas in mines was related to the barometric pressure, though it was not known how the relation could be expressed in such terms that useful forecasts could be issued from the knowledge of coming pressure changes. In "Forecasting weather"[1*] Sir Napier Shaw reviews current theories and suggests the possibility of a warning organization, quoting a reply which he sent to the Royal Commission on Mines in 1908; in this he pointed out that the barometric conditions which were of special importance from the point of view of accidents in mines were not yet clearly understood, and he expected that a considerable period of investigation would be required before forecasts could be issued. Early work on the relation between pressure and gas is associated with the name of Mr. Henry Harries. He was convinced that the occurrence of accidental explosions was associated with the prevalence of high atmospheric pressure. His theory was set out in a paper[2] read before the Royal Astronomical Society.

Introduction.—There are two principal systems on which the getting of deep coal is conducted at the present time, the pillar-and-stall working, and the long-wall-face working. In the first, galleries are run in a pattern through the coal seam, sufficient coal being left in the pillars between the criss-cross of galleries to support the roof above. Sometimes the pillars are whittled away until the roof collapses or the pillars may be crushed by the weight of the overburden, so that the whole roof sinks down. Fig. 1 shows a diagrammatic plan of such a mine. A pillar is about 30 ft. square, the main road about 15 ft. across and the coal-getting galleries about 15 ft. across. Eventually the pillars may be cut away. In the long-wall-face method (Fig. 2) the coal is cut along the whole of a face, perhaps 600 ft. long at the same time. Two retaining walls are built of stone (perhaps 45 ft. across) as shown in the diagram so as to shut off the approach and return roads from the goaf where the roof has been allowed to collapse. There are also narrower internal stone packs made between the retaining walls which are eventually buried. As the face advances the retaining walls are extended and eventually the roof collapses, except near the retaining walls, and, it is believed, closes down so tightly that there is little or no space left between roof and floor.

In both systems of working, ventilation is arranged along the main roads and ventilation currents are controlled in some cases by screens and doors so that there is little area in which gas can accumulate near the working.

---

* The index numbers refer to the bibliography on p. 15.

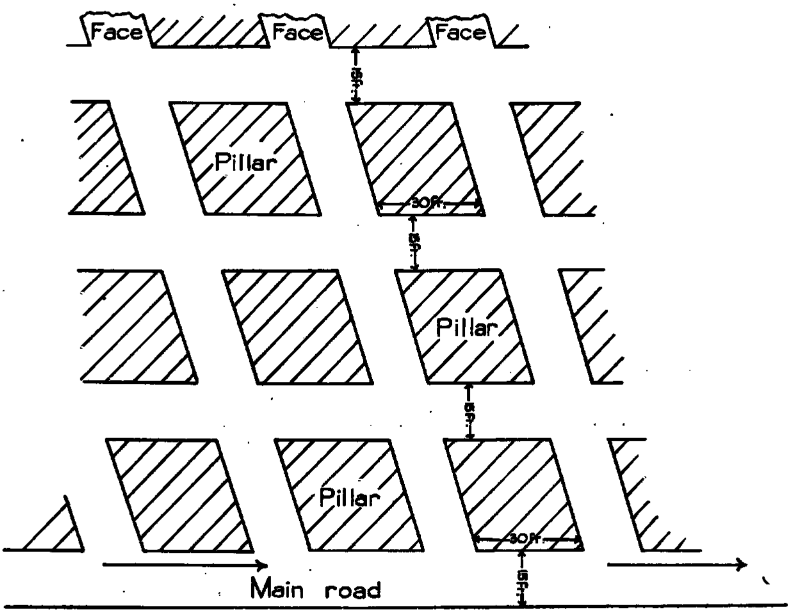


FIG. 1—DIAGRAMMATIC PLAN OF A SEAM WORKED BY PILLAR-AND-STALL METHOD

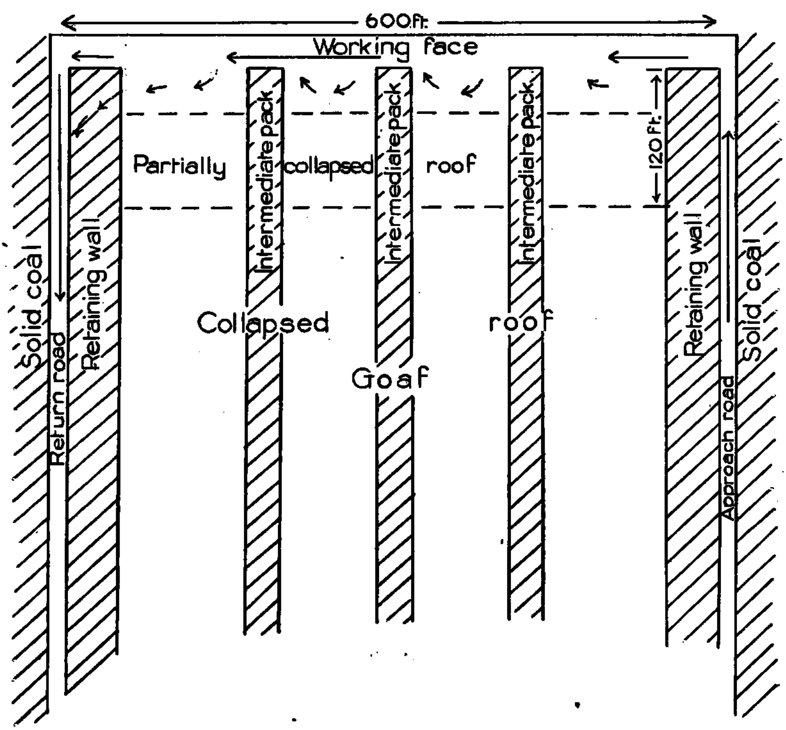


FIG. 2—DIAGRAMMATIC PLAN OF A SEAM WORKED BY LONG-WALL-FACE METHOD

However, the coal seams are found lying in layer upon layer separated by great strata of sandstone, shale or other rock which may be many feet thick. The seams are usually worked from the top downwards, the upper seam being worked out before the next one is opened up. Thus there may be a large volume of a mine, particularly of an old mine, which is left derelict above the present workings and may become filled with methane. These waste areas may or may not be accessible to the part of the mine where work is progressing. If they are accessible they are liable to be a vast reservoir in which the gas expands and contracts with changes in atmospheric pressure and at times overflows into the ventilation system of the mine.

Experiments.—The idea that the efflux of methane gas in mines was associated with changes in barometric pressure has long been canvassed. A review of the history of this line of thought and of the early observations obtained in the present investigation is included in a paper[3] presented to the Institution of Mining Engineers, and it is not proposed to repeat it here. The type of results obtained are shown in Fig. 3 as well as in Figs. 5–7 which are referred to later.

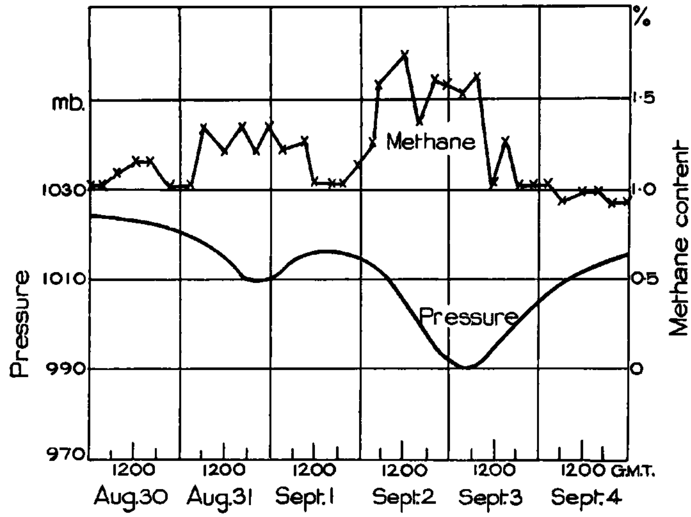


FIG. 3—PRESSURE VARIATION AND METHANE CONTENT AT A COLLIERY FROM WHICH A LARGE QUANTITY OF COAL HAS BEEN EXTRACTED BY PILLAR-AND-STALL WORKING

All these diagrams include a curve showing the pressure at the surface at a meteorological station in the neighbourhood of the coal mine and also a curve representing the fluctuation of the methane content at a suitable point in the mine. This methane content is expressed as a percentage of the air. In some cases the measurements were made in the main fan drift of the mine and in some cases in the return road from a working face. The methane content fluctuates considerably from one place to another in a mine, but of course in the comparative trials described in the Institution of Mining Engineers' paper each series of samples was taken at the same point. It stands out at once to the eye how in Figs. 3 and 5–7 the curve of methane content rises while pressure is falling. That paper also discusses various effects which have been observed during the course of these trials. Broadly, it is found that the relation between atmospheric pressure falls and an increase in methane content is marked in old mines where wastes are extensive and sealing cannot be made very effective.

The relation can be found in mines worked on the long-wall-face system as well as in those on the pillar-and-stall system, but the volume of waste near the working face in the long-wall-face system is generally too small for the effect to be apparent unless the waste is connected by fissures and channels to other enclosed unventilated areas. The recent observations were made most intensively at a colliery A where coal has been mined for about 100 years and where the coal is being extracted by pillar-and-stall working in a seam 5½ ft. thick in galleries about 12 ft. wide with pillars about 36 ft. square left between. Above this seam were four others all 6 ft. or more in thickness, which had been worked similarly. The highest three had been abandoned and the fourth, 70 ft. above, was nearly exhausted.

During a pressure fall, some observations showed that in this mine rather more than half the increase in fire damp in the main ventilation stream came from drifts (cross-measure roads) connecting with the old workings despite the attempts made to seal them off. In one case when pressure fell 6 mb. in 4 hr. before sampling, there was an increase in methane of 650 cu. ft./min. over normal in the fan drift; 140 cu. ft./min. came from workings in the present seam, 410 cu. ft./min. from near the stoppings to the next seam above the workings and 100 cu. ft./min. from the higher seams.

Forecasting experiments.—A system of warning has been established for this colliery since December 1949 in which the Central Forecasting Office of the Meteorological Office has issued special forecasts when sharp falls of pressure were expected, a sharp fall being defined as one of 4–8 mb. in 3 hr. and a very sharp fall one of more than 8 mb. in 3 hr.

The results of these forecasts have been checked for two periods. In one period (March 1951 to April 1952) warnings were issued on 36 occasions. It was found that they were successful on 50 per cent. of occasions in that pressure falls occurred in good agreement with the warning; on 10 occasions (28 per cent.) they were only partially successful in that either the fall did not attain the expected severity or the timing was inaccurate; on 8 occasions (22 per cent.) failures occurred. Moreover there were 5 additional falls which just came into the sharp category of which no warning was issued. As regards the length of warning there were 3 occasions when warnings were issued between 13 and 15 hr. before the beginning of the pressure fall, 14 occasions between 6 and 12 hr., 5 between 5 and 6 hr. and 4 in which there was less than 5 hr. between the issue of the warning and the onset of the fall.

In the other period, February 1950 to March 1951, a comparison was made between the issue of warnings and the occurrence of gas. During this period the warning procedure was carried out on 40 occasions, but on 6 of them, for various reasons, insufficient observations of methane were made to check the result. On 1 occasion there was no definite rise in methane content, on 7 occasions the fall did not eventuate, but on 26 occasions (65 per cent.) there was a definite increase of methane content during the progress of the forecast pressure fall.

Theory.—It is possible to draw up a model of a gas-producing mine in the manner shown in Fig. 4. The waste cavity (goaf) is fed by gas produced in fissures F running back into the rock. A wall (stopping) divides the cavity from the gallery which has leaks represented by the gap at P. The form of the leak varies greatly; in a mine in which there are several superposed seams the cavity of the worked-out area may be cut off from the working area by great thickness of solid rock and the sealing may be almost complete; in a mine where the old working is on a higher level than that of the present day and so is approached by a rising road there may be no stopping at all, the methane gas occupying all the old working, the fringe of rich fire damp moving up and down as atmospheric pressure varies, the expansion and contraction obeying Boyle's Law. There may, however, be a vast area of the worked-out mine which is shut off by stoppings which, however carefully they are made, are liable to leak and to be bypassed by fissures in the rock surrounding the stoppings.

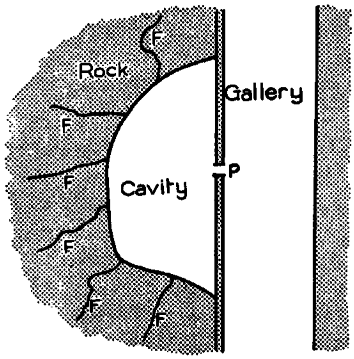


FIG. 4—DIAGRAMMATIC PLAN OF A CAVITY

F = Fissure P = Leak into cavity

In the long-wall-face workings, the diagram in Fig. 4 must be imagined without the stopping wall and with the cavity consisting of more and more tightly packed debris further and further away from the working gallery (or face). Nevertheless there are liable to be fissures and passages communicating back to areas that have been worked out, and thus the gas holder to which access is available may still be large.

Gas is continuously being given off from the solid rock, though no doubt there is some falling off with time over long periods. The effect of stopping the cavity is to increase the pressure P_1 in the cavity. However the variation in the pressure in the cavity will not in general affect the rate of flow of gas from the rock, for the gas pressure in the fissures of the coal is of the order of 2,000 mb. or more and a change in P_1 of 20 or even 30 mb. is comparatively small.

Some gas permeates the stopping and is carried away in the general current of air passing along the gallery. The amount which permeates is directly proportional to the pressure difference p between P_1 and the pressure in the gallery P_2 so that

$$f = b(P_1 - P_2) = bp \quad \ldots . (1)$$

where f is the rate of flow in cubic feet per hour and b is the constant inversely dependent on the efficiency of the stopping. This follows from Poiseville's formula[4] which is true for stream-line flow. In the case of slow movement through small crevices of stopping the flow of gas will be non-turbulent, and even in the movement in and out of a disused tunnel the speed of flow will be so slow that no eddies are created.

Some methane will be released in the portion of the mine which is actually in operation. This amount varies with the operation, e.g. coal cutting or the withdrawal of props. Let the methane which arises from all causes outside the stopping be at a rate of c' cu. ft./hr. If the rate of ventilation remains constant at L cu.ft./hr. and if density variations in the ventilation stream, despite variations in P_2, are insignificant, the total rate of escape of methane (through the stopping and from the actual workings) is proportional to the percentage content x of methane in the ventilating stream. So

$$c' + bp = \frac{Lx}{100}. \qquad \ldots . (2)$$

It is assumed that the value of b is chosen to correspond to p being measured in millibars.

Let it be assumed that at any instant the mass of methane in the cavity is proportional to the pressure in the cavity P_1 (assuming constant temperature). Then the mass can be written P_1V/RT where V is the volume of the cavity, R the gas constant and T the absolute temperature. Let the rate of generation of methane in the cavity be c cu. ft./hr. at a density P_1/RT and the rate of outflow through the stopping be bp also at a density P_1/RT.

Then the equation for the rate of change of mass of the gas in the cavity can be written as

$$\frac{d}{dt}\left(\frac{VP_1}{RT}\right) = \frac{P_1}{RT}\left\{c - bp\right\}. \qquad \ldots . (3)$$

Since changes in P_1 and P_2 are small in comparison with P_1, V/P_1 can be written as a constant a which is approximately $V/1000$. Then equation (3) becomes

$$a\frac{dp}{dt} = c - bp - a\frac{dP_2}{dt}. \qquad \ldots . (4)$$

In what follows the units used are pressure in millibars, time in hours, a in cubic feet per millibar, b in cubic feet per millibar per hour, and c in cubic feet per hour. We will consider the solutions of this equation in the following cases—

(i) When conditions are quiet.

(ii) When a sudden increase of gas occurs inside the cavity, such as might be caused by a fall of rock within the old workings.

(iii) When a steady fall of atmospheric pressure occurs (from the normal).

(iv) The most general case of variations in atmospheric pressure, with in particular a harmonic variation.

Quiet conditions.—In this case $dP_2/dt = 0$ and

$$a\frac{dp}{dt} + bp = c. \qquad \ldots . (5)$$

The solution to this, with initial conditions $p = 0$ when $t = 0$, is

$$bp = c\,(1 - e^{-bt/a}). \qquad \ldots . (6)$$

Thus bp approaches asymptotically the value c, and after a sufficient time

$$bp_0 = c, \qquad \ldots . (7)$$

where p_0 is the normal difference in pressure between cavity and gallery; from equation (2) we see that in the steady state the rate of flow of methane into the gallery is equal to the rate of emission from the walls of the cavity, though the percentage content of methane in the gallery will, of course, be affected by the rate of ventilation and by the methane generated in the course of coal working, etc. Thus equation (7) gives the value of the constant b, when c and p_0 are known.

The value of p_0, the pressure gradient across the stoppings under steady conditions, varies greatly according to the condition of the stoppings in the different mines. Clearly it is increased as the rate of escape of methane c from the interior walls becomes greater, and also when the constant b is made less, i.e. when the stoppings are made tighter.

Sudden increase of gas inside the cavity.—Again $dP_2/dt = 0$ but the pressure difference suddenly increases to p' and the solution of equation (4) is

$$bp = bp_0 + (bp' - bp_0)e^{-bt/a}, \quad \ldots \quad (8)$$

where p_0 is the pressure difference between the atmosphere and the cavity under normal quiet conditions. We then find that the time taken for p to sink from p' to $\frac{1}{2}(p' - p_0)$ (i.e. from its peak value half way back to normal) is $0{\cdot}70\ a/b$. Now in an old mine there may be a cavity of the order of 10^6 cu.ft. or more, in which case a is 10^3 cu.ft./mb. and with a tight stopping such that b is 20 cu.ft./mb./hr. it will take 36 hr. for the pressure difference to fall halfway back to normal; if b is 500 cu.ft./mb./hr. it will take $1\frac{1}{2}$ hr. So we can take a very tight stopping to be such that b is less than one tenth of a and a loose stopping to be such that b is greater than a.

Steady fall of atmospheric pressure (from the normal).—Here $dP_2 dt$ is constant, i.e. $P_2 = P_0 - mt$ where P_0 is the pressure at the beginning of the fall (assumed to have been steady for some time before the fall) and m is the rate of fall of pressure in the gallery in millibars per hour. The solution of equation (4) is then

$$bp = bp_0 + ma\,(1 - e^{-bt/a}). \quad \ldots \quad (9)$$

General and harmonic variation of atmospheric pressure.—The general solution of equation (4) is

$$p = \frac{c}{b} - e^{-bt/a}\int\frac{dP_2}{dt}e^{bt/a}dt + Ae^{-bt/a}, \quad \ldots \quad (10)$$

where A is a constant; in the particular case of $P_2 = P_0 + m\cos nt$ it becomes

$$p = \frac{c}{b} + m\sin\alpha\sin(nt - \alpha) + m\sin^2\alpha\,.\,e^{-bt/a} \quad \ldots \quad (11)$$

provided $pb = c$ when $t = 0$ and $\tan\alpha = na/b$.

Application of theory.—Now if, for a particular mine, we can estimate the volume of the cavity, the average methane content of the galleries under the normal ventilation system due to the leaking of the stoppings, and the pressure gradient across the stoppings, we can introduce suitable constants into equation (4) and solve it either in the form of equation (9) for a steady pressure fall, in the form of equation (11) for a periodic pressure change, or in the most general form of equation (10). But it is unlikely that the pressure gradients across all the obstructions and stoppings in the mine can be measured accurately.

We now need to review what are possible and probable values of the constants a ($= V/1000$), b ($= f/p$) and c. For the exact computation of a little seems to be known of the actual magnitudes of the cavities which have access to the mine galleries, but Patteisky[5] has estimated that there may be a moving gas container of about 5×10^6 cu.ft. in a mine with a daily output of 1,000 tons and a permanent cavity of 3–5 per cent. of the total excavation from the mine. This means that after 25 years of extraction at the rate of 1,000 tons/day there would be a permanent cavity of 10^7 cu.ft. and a moving cavity of half that amount, though, of course, not all this cavity would be accessible by paths traversable by fire damp. At Colliery A, which is a very old mine worked for a hundred years and more and in which there are four worked-out seams above the present working, it is possible that the gas container is of the order of 5×10^7 cu.ft. Thus we may expect a to be of the order of 5×10^4 as a maximum, and to drop to 10^3 as a value for many mines of fairly long life worked on the pillar-and-stall system.

It is of interest to note that we can write the percentage methane content, by using equations (2) and (11), in the form

$$x = \frac{100}{L}(c' + c) + \frac{100}{L} mb \left\{ \sin \alpha \sin (nt - \alpha) + \sin^2 \alpha \,.\, e^{-bt/a} \right\}, \quad . \; . \; . \; . \quad (12)$$

and clearly the effects due to pressure variation are independent of how much of the total methane content is generated inside the stopping and how much by the operations in the modern workings. In colliery A the ventilation current is run at a rate of 100,000 cu.ft./min. (6×10^6 cu.ft./hr.) in the main fan drift, and the normal methane production is about $3{\cdot}5 \times 10^4$ cu.ft./hr. At some mines the ventilation may be much less, 10^5 cu.ft./hr., and the methane production down to 10^3 cu.ft./hr. or less. Sometimes a district or only a gallery of a mine has to be considered and then the ventilation rate may be much smaller.

If we take equation (9) and suppose that there is a steady fall of pressure at the rate of 1 mb./hr. after a period of steady pressure then the rate of gas emission after different intervals is given in Table I for various cavities and various tightnesses of stopping.

TABLE I.—EFFLUX OF GAS UNDER VARIOUS CONDITIONS CAUSED BY A STEADY FALL OF PRESSURE OF 1 MB./HR.

Pressure difference across stopping under quiet conditions		Gas emission under quiet conditions c	Constants in equations a	b	Gas emission after time intervals: 2 hr.	5 hr.	10 hr.	20 hr.
	mb.	cu. ft./hr.	ft./mb.	cu. ft./mb./hr.	*cubic feet per hour*			
No stopping	0	0	10^4	Very large	**10,000**	**10,000**	**10,000**	**10,000**
	0	0	3×10^3	Very large	**3,000**	**3,000**	**3,000**	**3,000**
Loose stopping	½	300	10^4	1,200	**2,400**	**4,800**	**7,300**	**9,300**
	½	3,000	10^4	12,000	**12,000**	**13,000**	**13,000**	**13,000**
	2½	3,000	10^4	1,200	5,100	**7,500**	**10,000**	**12,000**
	2½	3,000	3×10^3	1,200	4,700	5,600	5,900	**6,000**
Moderately tight stopping	15	3,000	10^4	200	3,400	3,900	4,800	**6,300**
	15	6,000	10^4	400	6,800	7,800	9,300	11,500
	15	3,000	3×10^3	200	3,400	3,900	4,500	5,200
Tight stopping	35	3,000	10^4	86	3,200	3,400	3,800	4,600
	35	6,000	10^4	171	6,300	6,800	7,600	8,900
	35	3,000	3×10^3	86	3,200	3,400	3,700	4,300
	35	3,000	10^3	86	3,200	3,300	3,600	3,800
	35	12,000	10^4	342	12,700	13,600	14,900	17,000

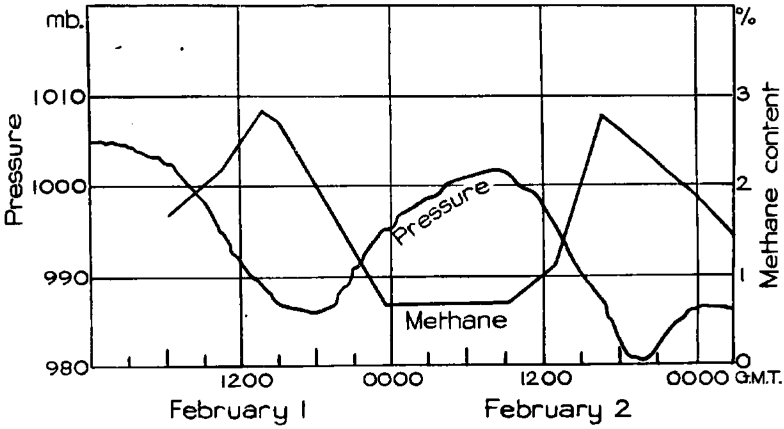
The bold figures indicate calculated emissions more than twice the emission under quiet conditions.

With greater rates of fall the excess over the values for quiet conditions would be proportionately increased, so that for example with a stopping which allowed a normal efflux of 3,000 cu.ft./hr. under a pressure of 15 mb. the efflux would be 6,600 cu.ft./hr. after a fall of 2 mb./hr. had lasted for 10 hr., provided the cavity was 10^7 cu.ft. ($a = 10^4$), but would only be 6,000 if the cavity were 3×10^6 cu.ft.

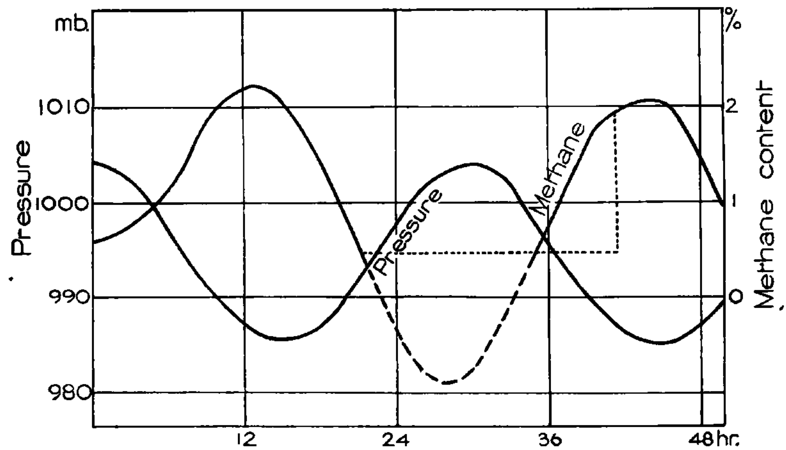
Application to a colliery worked on pillar-and-stall system.—At Colliery A 48 occasions were examined when sharp falls of pressure produced high values of methane content (they are set out in the Appendix). The peak values of methane were correlated with the maximum rate of pressure fall m_{max} and the duration of the fall t, and the following regression equation was obtained

$$x_{max} = 1 \cdot 64 + 0 \cdot 035\,(t - 7) + 0 \cdot 196\,(m_{max} - 5),$$

where x_{max} is the maximum percentage content of methane, t is in hours and m_{max} in millibars per three hours. The probable discrepancy in the maximum percentage of methane obtained from this equation is 0·25 per cent. and the percentage of methane when there is no pressure fall comes out at 0·42 per cent. (or $2 \cdot 5 \times 10^4$ cu.ft./hr.); this we may expect to be mainly due to the emission



Actual variation of pressure and methane content



Calculated methane content for a sinusoidal pressure variation

FIG. 5—COMPARISON OF THEORETICAL EFFLUX OF METHANE WITH THAT ACTUALLY OBSERVED AT COLLIERY A, FEBRUARY 1-2, 1950

c' from the operating part of the mine. If the total methane production is $3 \cdot 5 \times 10^4$ cu.ft./hr. we can suppose c to be about 10^4 cu.ft./hr. In the lower half of Fig. 5 a curve is drawn of the variation of methane content on the assumption that a is 5×10^4, b is 10^4, c is 10^4 and c' is $2 \cdot 5 \times 10^4$ with a pressure variation of $P_2 = \{1000 + 10 \cos (t\pi/15)\}$.

The curve is similar to that obtained from the actual values of methane observed during the period February 1–2, 1950, when pressures followed a similar course to that assumed for P_2. The observed values are reproduced in the upper half of Fig. 5.

In the calculated curve of methane content it is seen that the value falls below 0·4 per cent. between 23 and 35 hr. after the pressure variation begins. This means that during that time the pressure gradient across the stopping is reversed and air from the galleries is flowing back into the cavity. When pressure falls again the air will be extruded and delays the reappearance of the methane. Possibly this accounts for the very sharp rise at 1500 on February 2, 1950. It is tempting to surmise that the actual methane curve would follow the dotted line in the lower part of Fig. 5.

It would seem then that for this mine the gas reservoir is about 5×10^7 cu.ft. and the "make" of gas in the old workings is about 10^4 cu.ft./hr. (170 cu.ft./

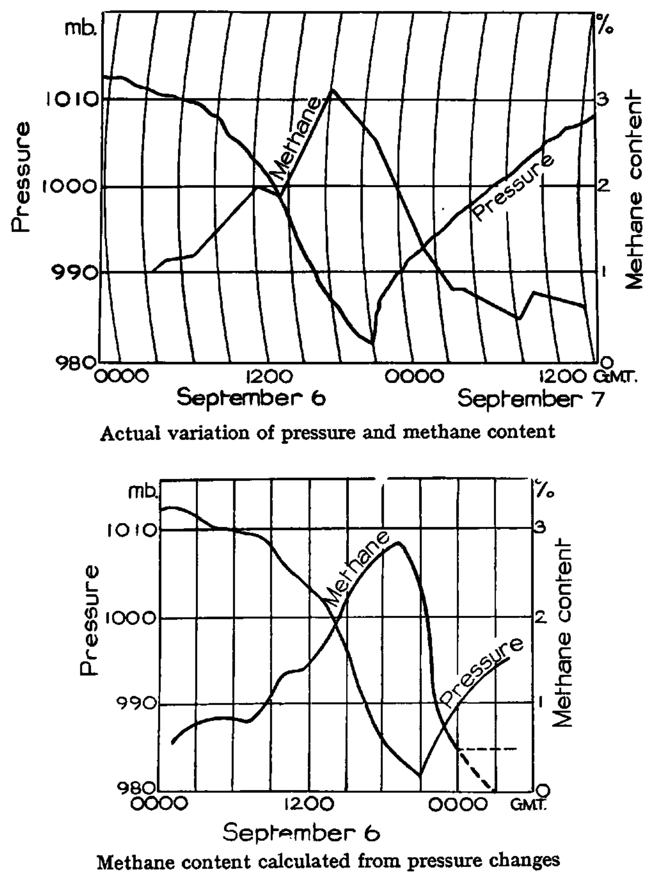


FIG. 6—COMPARISON OF THEORETICAL EFFLUX OF METHANE WITH THAT ACTUALLY OBSERVED AT COLLIERY A, SEPTEMBER 6–7, 1950

min.) with a pressure gradient across the stoppings of about 1 mb. Using these values the expected methane content has been calculated by step-by-step integration from equation (10) for the pressure variations which took place on September 6–7, 1950, and on the assumption that pressure had been steady before that date. The result is shown in Fig. 6 in comparison with the actual measurements.

Application to collieries worked by long-wall-face system.—What has been said so far is applicable to a mine in which there is an extensive area of worked-out waste stopped off by more or less tight stoppings from the rest of the mine. In the case of a long-wall face the roof is allowed to cave in behind the workings and the effects of changes in atmospheric pressure are somewhat different. Turning to the model of such a mine as shown in Fig. 2, back from the long-wall face there is a large area of waste filled with broken stone from the subsided roof (goaf); this packs very closely at some distance back from the face (say 120 ft. or so) and away from the retaining walls of the approach galleries, but on the whole it may contain a volume of gas (and air) of the order of 300,000 cu.ft. for a face 600 ft. long and 6 ft. high, and through fissures may have access to much more methane than this. Methane collects in this volume and the ventilation system passing along the face carries away a certain amount of gas by turbulence and at the same time a certain amount of air penetrates into the waste. Thus under quiet conditions the concentration decreases from 100 per cent. methane in the back part of the waste down to perhaps 0·6–1·0 per cent. in the gallery in some mines; there the control of the ventilation system keeps it at that level under quiet conditions. It is notable that a higher concentration of gas is usually found some distance back along the return road than at the face itself. This is probably because a certain amount of the ventilation finds its way through the retaining walls and then back into the return current.

We can form a picture of an outflow of methane content of c cu.ft./hr. into the back of the waste and an outflow of a similar amount into the ventilation system. Owing to eddying and seepage of air through the forward part of the waste the concentration of methane increases from the forward edge back to the interior where the goaf becomes packed solid. The gas and air in the goaf is constantly moving outwards at a very slow speed and under quiet conditions there will be a steady gradient of methane concentration from the forward edge into the goaf.

If then the pressure in the atmosphere falls, the air and gas in the goaf expands under Boyle's Law, and as the fall proceeds the concentration of methane exuding out of the forward edge of the goaf becomes greater and greater. To take some figures: if we say the volume of gas and air in the goaf is V cu.ft. and that under quiet conditions the percentage of gas increases steadily from, say, 15 per cent. in the forward edge of the goaf to 80 per cent. at a distance of 20 ft. from the forward edge, then if pressure falls m mb. in an hour there will be $mV/1000$ cu.ft. of gas and air exuded and the amount of gas will be $rmV \times 10^{-5}$ cu.ft., where r is the percentage concentration. If the ventilation rate is 10,000 cu.ft./min. (6×10^5 cu.ft./hr.) and the gas content is 0·6 per cent. under quiet conditions there must be exuded 3,600 cu.ft./hr. of gas under normal conditions. This is increased by $rmV \times 10^{-5}$ if there is a fall of m mb./hr. If V is 3×10^5 cu.ft., m is 2 mb./hr. and r is 20 this increment is 120 cu.ft./hr. only, and even when r is 100 it only becomes 600 cu.ft./hr. In order that the methane exuded under a pressure fall should be sufficient to double the percentage it would be necessary for the volume of the goaf to be six times greater.

In some mines worked on the long-wall-face system the goaf is thought to be of the order of 3×10^5 cu. ft., but there are sometimes connexions running back into former workings; this is probably the case in Colliery B where the observations of methane content shown in Fig. 7 were made. In this district the face was being worked alongside an incompletely consolidated goaf. The peaks which occur at about 1800 are attributed to partial blockage of the road by the stone brought down by shot firing and to the consequent deflexion of air through the old workings. The point which is of interest in the diagram is the effect of the rather protracted pressure falls which, it is surmised, brought richer and richer mixtures to the forward edge of the goaf.

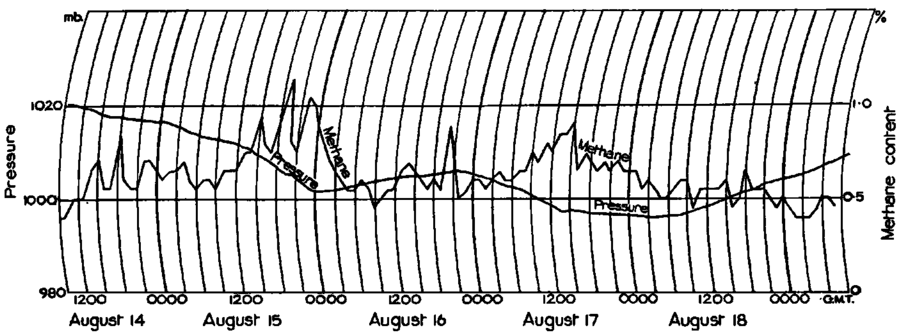


FIG. 7—METHANE CONTENT AT COLLIERY B AND PRESSURE AT WATNALL, AUGUST 14–18, 1950

Long-wall-face working

Conclusions.—It is confirmed that one cause of the efflux of gas from old mine workings is variation in atmospheric pressure; given careful observations it is possible to obtain the values of the constants with sufficient accuracy to calculate the variation in methane which will occur in a particular mine or district of a mine as the atmospheric pressure changes.

It is moreover possible to give forecasts of sharp pressure changes with a reasonable degree of accuracy so that the forecasting of high emission of methane can be achieved for those mines where there are large areas of waste. It is notable that the mines for which effective forecasts can be made are those that have been in operation for long periods and from which great masses of coal have been removed.

It must be remembered that by no means a large proportion of the mines in Great Britain show such marked effects as are discussed in this paper. This is largely because the " make " of gas is low, or the precautions against gas have been effective, or the mine's system of working is one which does not leave large areas of goaf.

Other causes than pressure changes, such as ground movements, will give large emissions, and the methane content of the air in galleries may be greatly affected by the mining operations in progress.

Acknowledgement.—My thanks are due to Mr. W. H. N. Carter, of the Ministry of Fuel and Power, for his guidance in the technicalities of mining and to many Inspectors of Mines and Colliery Managers who have aided Mr. Carter in obtaining the data with which I have worked.

Appendix

PRESSURE FALLS AND METHANE CONTENT DURING WARNING PERIODS
Colliery A, February 1950–January 1952

Time of origin of warning		Mid time of pressure fall		Maximum rate of pressure fall	End of pressure fall		Maximum methane content		
Date	Time	Date	Time		Date	Time	Date	Time	Amount
	G.M.T.		G.M.T.	mb./3 hr.		G.M.T.		G.M.T.	%
1. 2.50	0700	1st	1100	7½	1st	1800	1st	1400	2·8
2. 2.50	0855	2nd	1600	9	2nd	1900	2nd	1745	2·8
4. 2.50	1135	4th	2100	4	5th	0100	4th	2230	1·2
5. 2.50	1700	5th	1600	4½	5th	2300	5th	2300*	1·5
6. 2.50	1945	7th	1200	4½	7th	1500	7th	1300	1·1
12. 2.50	0450	12th	1700	6	12th	2300	12th	2000	1·8
19. 2.50	1215	19th	2100	4	20th	0700	20th	0100	1·8
17. 3.50	2200	18th	1500	2	19th	0100	no increase in methane		
19. 3.50	1915	20th	0300	3½	20th	0600	20th	0720	1·8
1. 4.50	1715	1st	2300	6½	2nd	0900	2nd	0130	1·9
17. 4.50	0538	17th	1200	3	17th	1600	17th	1215	1·7
23. 4.50	1425	23rd	2000	4	24th	0001	23rd	2235	1·6
6. 9.50	0345	6th	1500	9	6th	2100	6th	1815	3·1
13. 9.50	1135	13th	1600	3	13th	2100	13th	2200	1·3
16. 9.50	0445	16th	1600	6½	17th	0100	16th	2300	2·0
9.10.50	1515	9th	1900	3	9th	2300	10th	0100	1·0
12.11.50	1440	12th	1500	5½	12th	1800	12th	1500	1·6
28.11.50	1455	28th	1800	3½	28th	2200	28th	1930	1·3
13.12.50	0715	13th	1400	4	13th	2000	13th	1540	1·5
18.12.50	0330	18th	1000	3	18th	1400	18th	1000	0·9
10. 1.51	1510	11th	0001	6	11th	0600	11th	0600	1·9
16. 1.51	2050	16th	2000	4	17th	0500	17th	0600	0·9
3. 2.51	1500	4th	0300	8†	4th	1800	4th	1300	3·5
7. 2.51	1050	8th	0100	5½	8th	0400	8th	0330	1·3
20. 2.51	0330	20th	0500	7	20th	1200	20th	0600	2·1
6. 3.51	0345	6th	1200	3	6th	2200	6th	1800	1·4
7. 3.51	0500	7th	0800	3½	7th	1200	7th	1200	1·7
13. 3.51	1300	13th	1600	5	13th	2200	13th	2200	1·9
28. 3.51	1445	28th	2300	3	29th	0600	29th	0515	1·3
31. 3.51	0335	31st	0700	4	31st	1300	31st	1200	1·2
8. 4.51	1020	8th	1600	2½	9th	0400	8th	2230	1·0
12. 4.51	0230	12th	0100	3½	12th	1400	12th	0700	1·1
18. 8.51	1045	18th	1200	3½	19th	0130	18th	2330	1·4
23. 8.51	1130	23rd	1800	2½	24th	0500	24th	0130	1·1
12. 9.51	2220	13th	{0400 {1100	6 } 6½ }	13th	1500	13th	1345	2·1
3.11.51	1510	4th	0300	4½	4th	0900	4th	0615	2·0
14.11.51	1600	15th	0100	4	15th	0600	15th	0530	1·6
17.11.51	2010	18th	0100	5	18th	0200	18th	0430	1·4
8.12.51	0315	8th	1200	6	8th	1400	8th	1530	1·9
23.12.51	0910	23rd	2300	6½	24th	2100	24th	1315	2·7
26.12.51	1250	26th	2300	12	27th	1200	27th	0600	2·4‡
28.12.51	0425	28th	1600	3½	28th	1800	28th	1900	0·8
1. 1.52	1450	1st	2200	7	1st	2300	1st	2300	1·3
2. 1.52	1100	2nd	1400	2½	2nd	1700	2nd	1500	1·1
4. 1.52	0340	4th	1400	5	4th	1800	4th	1700	1·1
8. 1.52	0445	8th	1200	8	8th	1700	8th	1515	1·8
13. 1.52	0420	13th	1500	5½	13th	2000	13th	2030	1·3
14. 1.52	1535	14th	2200	3½	15th	0300	15th	0420	1·0
16. 1.52	1618	17th	0001	9	17th	1200	17th	0240	1·9

* No measurement of methane was possible between 1500 and 2300 G.M.T. during which time maximum probably occurred.

† Pressure fell 42 mb. in 18 hr. between 1800 on the 3rd and 1200 on the 4th.

‡ Measurement of methane began at 0600 when methane content was falling. Content probably exceeded 2·5 per cent. some hours earlier.

BIBLIOGRAPHY

1. SHAW, SIR NAPIER; Forecasting weather. 3rd edn, London, 1940.

2. HARRIES, H.; On the relation between barometric pressure and gas pressure in mines. *Mon. Not. R. astr. Soc. geophys. Suppl., London,* **1**, No. 7, 1926, p. 307.

3. CARTER, W. H. N. and DURST, C. S.; The influence of barometric changes on the emission of fire-damp. *Trans. Instn Min. Engrs., London,* **115**, Pt. 1, 1955-56.

4. CHAMPION, F. C. and DAVY, N.; Properties of matter. London, 1936, p. 244.

5. PATTEISKY, K.; Einfluss der Luftdruckschwankungen auf die Gas abgabe von Steinkohlengruben. *Glückauf, Essen,* **80**, 1950, p. 357.

(3457) Wt. 3191/BM4165 K.6 1/56 Hw.

Printed and published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London W.C.2
423 Oxford Street, London W.1
P.O. Box 569, London S.E.1
13A Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
Tower Lane, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast
or through any bookseller

Price 9*d.* net

Printed in Great Britain

S.O. Code No. 40-57-10-17