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REPORT No. 51.

**A Study of Absenteeism in
a Group of Ten Collieries.**

By H. M. VERNON, M.D., and T. BEDFORD, Ph.D.
(assisted by C. G. WARNER, B.Sc.)

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PREFACE.

An investigation was recently conducted for the Industrial Fatigue Research Board,* the results of which indicated, in conformity with expectation on physiological grounds, that both the working capacity and the accident rate of miners were affected by the atmospheric conditions in which they worked. With the concurrence of the Health Advisory Committee of the Mines Department and with a financial contribution from the Miners' Welfare Committee, this work has since been extended with the primary object of exploring further the effects of the physical environment of the miner.

This second investigation, the results of which are embodied in the present report, is based mainly on the records of absenteeism relating to about 23,000 miners working at a group of ten collieries in the same district, covering periods of twenty-one months to six years. These data, after classification according to the presumed cause of absenteeism, have been examined with the object of measuring the relation of different kinds of absenteeism to various operative factors, and more particularly to depth of working and atmospheric conditions. The principal conclusions are given on page 54, and need not be here repeated, but the Board think it desirable to direct attention to the caution with which, as the authors themselves admit, these conclusions must be accepted. Caution is imposed both by the nature of the subject and by that of the methods applied.

The question of the causes of absenteeism is clearly one of great complexity, involving not only the more physiological factors with which the present report is mainly concerned, but also a number of social factors, such as the "degree of settlement" of the working population, the distance between home and colliery, and the availability of other work for women. In the present instance, the effects of these disturbing causes have been lessened by the fact that the group of collieries studied were in the same neighbourhood and apparently subject to the same social conditions, but the possibility of their affecting to some extent the conclusions reached as to the other causes studied must not be disregarded.

Then again, the investigation from its very nature is inevitably subject to the limitations imposed on all statistical experiences. Correlation between one variable and another, which was the principal test applied in the report, implies association but not causation, for although, for two variable factors standing in the relation of cause and effect, the statistical correlation between their measures must be significant (in the case of direct causation approximating to unity under most conditions), yet the converse proposition is not true, and it cannot be inferred merely from the

* Vernon, H. M., Bedford, T., and Warner, C. G. (1927).—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rate of Miners.—*I.F.R.B. Report No. 39.*

fact that two variables are highly correlated, that one is the "cause" of the other; independent evidence is usually called for before this can be regarded as established.

Subject to these necessary limitations, the Board are of opinion that the results of the present inquiry are well worthy of the attention of the industry and of others interested, as disclosing various factors possibly influencing absenteeism which call for further study.

Finally, it is perhaps hardly necessary to point out that the investigation, having been confined to a limited number of collieries, the absolute figures relating to absenteeism given in the report must not be regarded as representative of the country as a whole.

The Board would acknowledge their indebtedness to the members of the Special Committee of Reference, containing representatives of the Mining Industry, for the critical consideration of the results of the inquiry, and to Sir Richard Redmayne, K.C.B., for many valuable suggestions received from him during the preparation of the report for publication.

July, 1928.

A STUDY OF ABSENTEEISM IN A GROUP OF TEN COLLIERIES.

BY

H. M. VERNON, M.D., and T. BEDFORD, Ph.D., Investigators
to the Board, assisted by C. G. WARNER, B.Sc.

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1. Introduction.

Absenteeism amongst coal miners, whether due to avoidable or to unavoidable causes, is an important economic factor in the industry. As was pointed out by the Coal Commission (1926), the average time lost by absenteeism in the whole of the coal fields of Great Britain amounted in 1924 to the equivalent of about four weeks per year, or 8·5 per cent. of the possible working time. In different districts it varied between the extremes of 11 days and 39 days per year. It has gradually fallen of recent years, but it still involves a serious loss of efficiency and especially so because of the irregularity of its incidence. It is nearly always greater on Mondays than on other weekdays, and the coal hewers are more prone to absenteeism than the haulage men and other underground men who are dependent on them, whilst the surface workers show the least absenteeism of all. The Coal Commissioners concluded that on an average over half the absenteeism is due to unavoidable causes, such as sickness and accidents, but the relative amounts of avoidable and unavoidable absenteeism appear to vary a great deal in different districts, so that it is important to estimate them as accurately as possible with a view to determining their causation. The problem of absenteeism is an extremely complex one, and the more exact our knowledge of it, the more chance is there of reducing absenteeism by the application of appropriate remedial measures.

The information to be described was obtained at a group of ten collieries, all of which were situated within ten miles of one another, and within a few miles of two large towns. In all of the collieries one or other of two seams (D and E) was being worked, whilst in two of the pits both were being worked. The D seam was 4 to 6 ft. in thickness, and the E seam, $3\frac{1}{2}$ to 6 ft. Four other seams of similar thickness were worked to a much more limited extent, as can be gathered from Table I. Counting a seam separately for each colliery at which it was tested, the total number of seams or localities investigated came to 17. Three of the pits, namely, A (1), A (2) and B, and three of the seams (C, D and F), recorded in this Table were examined by us in the course of a previous investigation (1927), but only two pits were then referred to, as collieries A (1) and A (2) are connected underground, and were then referred to as "Colliery A."

It will be seen that the average depth of the various pits at the coal face varied from 616 to 2,269 ft., and the number of men employed varied from 428 to 3,036, the total coming to 18,455 (or 22,911, including the surface men). Pit A (1) is entered twice in the Table, as we were able to get separate absenteeism statistics for each of the two seams worked. At four other pits the statistics likewise relate to one seam only, but at the remaining five pits they relate to the combined data of two or three seams.

The average ages of the men in the various pits are given in the last column of the Table. It will be seen that they do not show any regular relationship to the depth of the pit.

TABLE I.—*The collieries and seams investigated.*

Collieries. (10)	Seams. (17)			Depth in feet at coal face.	No. of men under- ground. (18,455)	Average age in years of	
	D.	E.	Others.			Coal face Workers.	Other Underground Workers.
A (1) ..	—	—	C	616	624	40·8	30·0
N ..	—	E	G, H	990	1,742	33·0	27·5
A (1) ..	D	—	—	1,359	428	41·8	32·2
Q ..	D	E	—	1,537	1,758	38·0	32·9
J ..	—	E	—	1,608	1,722	39·1	28·8
M ..	D	E	—	1,777	2,890	34·9	31·4
A (2) ..	D	—	—	1,778	537	39·2	31·2
P ..	—	E	—	1,850	1,831	34·1	28·8
K ..	D	—	F	1,886	2,263	31·5	27·9
B ..	D	—	F	1,969	1,624	37·9	26·2
L ..	—	E	—	2,269	3,036	39·5	32·5

Although our data relate to a body of nearly 23,000 men, it will be realised that these form only a small sample of the whole coal-mining industry. In addition, the investigation was confined to one locality in one coalfield. Because of these limiting factors it should be understood that our conclusions can only be regarded as provisional until they are tested and confirmed by investigation in other areas.

2. Absenteeism due to all Causes combined.

An accurate record of the weekly absenteeism is kept at each mine, such absenteeism indicating the number of shifts missed out of the total number possible. These records extend back for a number of years, but we thought it useless to go earlier than 1920, owing to the upsetting effect of war and post-war conditions. We obtained the weekly records of absenteeism for a 6½ year period (1920–26) at all the collieries enumerated in Table I, except J and M. As will be mentioned in the next section, we obtained another series of records lasting over a shorter period at these two collieries, but we thought it best not to mix them up with those under discussion.

We classified the men according as they were (a) workers at the coal face, including trammers, and (b) haulage men and others working underground. They were then split into four groups, according to the average depth of the workings. In order to determine if any seasonal variation of absenteeism existed, we averaged the results obtained in the four winter months (December to March), the four summer months (June to September), and the two two-month intermediate periods. These results are recorded in Table II, and are plotted in Fig. 1. It will be seen that the absenteeism varied to a marked extent with the depth of the workings, for the coal face men working at a depth of over 2,000 ft. lost 17·0 per cent. of working time, as compared with the 13·8 per cent. shown by those working at a depth of less than 1,000 ft. ;

i.e., an excess of 23 per cent. Men working at intermediate depths showed an intermediate amount of absenteeism, though it was not in close proportion to the depth. The other underground workers showed less than two-thirds the absenteeism of the coal face workers, but the men working at over 2,000 ft. had 46 per cent. more absenteeism than those working at under 1,000 ft.

As can be gathered from the data on the right side of Table II, the variation of absenteeism with depth of workings was not due to any distinct differences in the ages of the men composing the different groups.

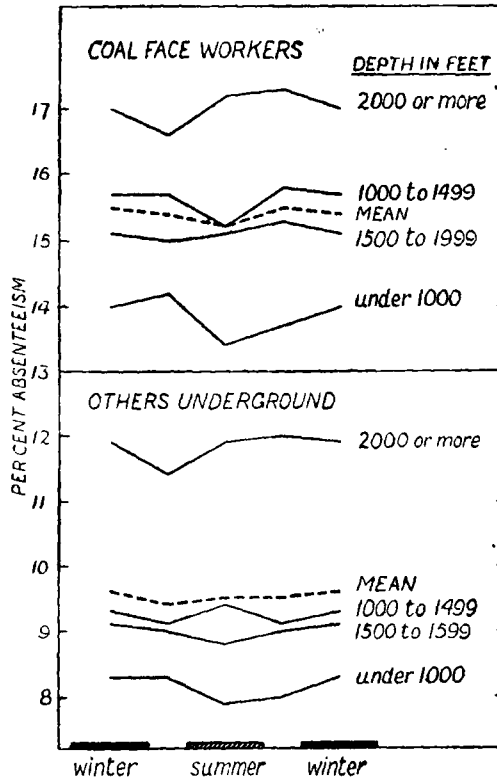


FIG. 1. Absenteeism in relation to depth of workings and to season.

TABLE II.—Absenteeism in relation to depth and to season.

No. of seams.	Range of depth.	Mean depth in feet.	Coal face workers.					Other underground workers.					Average age in years of	
			Dec.-Mar.	Apr.-May.	June-Sept.	Oct.-Nov.	Mean.	Dec.-Mar.	Apr.-May.	June-Sept.	Oct.-Nov.	Mean.	Coal face men.	others underground
3	Under 1,000 ft.	651	14.0	14.2	13.4	13.7	13.8	8.3	8.3	7.9	8.0	8.1	34.3	28.5
3	1,000 to 1,499	1,335	15.7	15.7	15.2	15.8	15.6	9.3	9.1	9.4	9.1	9.2	38.5	30.5
5	1,500 to 1,999	1,848	15.1	15.0	15.1	15.3	15.1	9.1	9.0	8.8	9.0	9.0	36.1	29.4
3	2,000 and over	2,160	17.0	16.6	17.2	17.3	17.0	11.9	11.4	11.9	12.0	11.8	36.3	28.9
			15.5	15.4	15.2	15.5	15.4	9.6	9.4	9.5	9.5	9.5	—	—

The individual curves in Fig. 1 show that there was no consistent seasonal variation in the absenteeism, but the mean results for all depths show a slight diminution in the warmer months of the year.

The absenteeism observed by us is considerably greater than that recorded by the Coal Commission. Their statistics show that absenteeism for the whole of Great Britain averaged 8·5 per cent. the extremes ranging from 4·2 to 14·7 per cent. Their data include surface men, who have a better record than underground men, and if our own surface men data—which are described hereafter—are included with the rest, the mean absenteeism comes to 12·5 per cent. Hence it is desirable that, for comparison purposes, an investigation similar to ours should be made in a district showing an absenteeism rate lower than the average.

We shall see (§3(a)) that the considerable influence of depth of workings upon the total absenteeism of the coal face workers was due almost entirely to its affecting the time lost through sickness and accidents, but amongst the other underground workers atmospheric conditions appeared to exert a distinct influence on voluntary absenteeism as well as upon sickness and accidents.

3. Absenteeism due to Sickness.

Since August, 1924, the collieries investigated by us have made monthly returns of the time lost by sickness, accidents and other causes to a local association, and we were able to obtain access to most of these records at the individual collieries. The mere fact that a record of this sort is made does not prove that it is reliable, for sickness records are notoriously uncertain. In many industrial establishments the plea of sickness as a cause of absenteeism is accepted only if it is substantiated by a doctor's certificate, but even then it is not very reliable, as it may be difficult for a busy doctor to discover if the sickness is genuine, and some doctors grant certificates more readily than others. At the collieries where we worked, no demand for a doctor's certificate was made, and dependence was placed on the word of the individual miner, who had to account for any absence of more than one shift, coupled with the judgment of the timekeeper, who is usually a shrewd man with a considerable knowledge of personalities. As the result of careful inquiries, we concluded that the sickness data were reliable at seven of the ten collieries investigated, but the data obtained at the remaining three in respect of sickness were unreliable, though our information was reliable in respect of total absenteeism and of time lost through accidents. Owing to the advent of the prolonged coal dispute in May, 1926, we were able to obtain the data for a 21-month period only.

In order to ascertain more closely the association of sickness and other causes of absenteeism with temperature and other atmospheric conditions underground, we made a fairly extensive survey at each of the ten pits. Between October, 1925, and April, 1927, we made altogether 471 sets of observations, or at the rate

of 47 per colliery. Of these observations, 280 were made at the coal face, 104 in the lesser haulage roads, 69 in the main haulage roads, and 18 at the pit bottom. Each set of observations consisted in the determination of the dry and wet bulb temperatures (by means of an Edney sling hygrometer), and of the dry and wet kata-thermometer cooling powers. From the dry kata cooling power the air velocity was calculated, but in some of the haulage roads, where the air had a velocity of several hundred feet a minute, the velocity was determined directly by means of a vane anemometer. The observations were distributed, so far as possible, in rough proportion to the numbers of men working at various places underground, except that the coal face observations, taken as a whole, were rather in excess of those made elsewhere. In some instances, where the observations were not distributed in sufficiently close relationship to the numbers of workers, the mean atmospheric conditions were calculated by weighting the observations so as to rectify the lack of proportion. In any case, owing to the wide variations in temperature and velocity which are found between the bottom of the downcast shaft and the coal face, it is very difficult to obtain a reliable figure for the average atmospheric conditions experienced by the underground men other than the coal face workers, though that for the coal face workers can be ascertained with fair accuracy.

The mean results are recorded in Table III. In the observations at colliery A (1), which are given separately for the C and the D seams, the total absenteeism recorded does not correspond exactly with the sum of the figures given for the individual causes of absence, as the sickness figures were unobtainable for five months out of the 21 investigated.

It will be seen that the atmospheric conditions observed at the coal face differed considerably from those observed elsewhere underground. Owing to the greater depth and to other factors, the temperature was usually about 5° F. higher, whilst the air velocity was much less. In consequence, the cooling power of the air at the coal face was a good deal lower.

In the lowest line of the Table is shown the average percentage of time lost from sickness and other causes at the seven pits where reliable data were obtained. The total absenteeism of the coal face workers and of the other underground workers was almost the same as that recorded in Table II, and of this total rather less than half was due to sickness and accidents. The various collieries are arranged in the Table according to their depth, and it appears that, on the whole, men working in the deeper pits suffered more sickness and accidents than those working in the shallower pits. In order to estimate the correlation between the two variables, we have treated each monthly percentage at a colliery as a separate item, though the temperature and other measurements were taken to be the same throughout. We thereby obtained from 155 to 228 pairs of observations from which to calculate the correlation coefficients.*

* The validity of these coefficients is discussed in the Appendix.

TABLE III.—*Mean atmospheric conditions and absenteeism at various collieries.*

Colliery.	Mean depth at coal face in feet.	Coal face workers.										Other underground workers.									
		Temperature.		Cooling power.		Air velocity.	Percentage of absenteeism.				Men employed.	Temperature.		Cooling power.		Air velocity.	Percentage of absenteeism.				Men employed.
		Dry bulb.	Wet bulb.	Dry.	Wet.		Sick-ness.	Acci-dents.	Volun-tary.	Total.		Dry bulb.	Wet bulb.	Dry.	Wet.		Sick-ness.	Acci-dents.	Volun-tary.	Total.	
A (1), C. . .	616	64.6	62.2	5.7	15.2	18	3.3	1.7	8.2	13.5	362	61.9	58.3	10.3	24.4	128	2.5	1.0	3.6	7.5	262
N ..	990	69.0	65.4	6.2	16.4	51	3.0	2.5	11.7	17.2	911	68.1	63.1	7.8	20.5	102	2.3	1.8	6.3	10.4	831
A (1), D. . .	1,359	77.3	71.6	3.4	11.3	20	5.5	4.5	8.9	18.8	228	72.3	65.8	7.7	21.8	158	4.3	1.4	3.2	8.8	200
Q ..	1,537	79.2	69.7	3.8	14.8	48	—	2.0	—	14.7	854	71.0	61.3	8.9	23.3	206	—	1.0	—	9.9	904
J ..	1,808	76.8	68.8	5.0	17.4	80	4.2	2.0	3.9	10.1	716	75.1	65.3	5.4	16.9	79	3.1	1.2	3.0	7.3	1,006
M ..	1,777	80.3	71.7	3.7	14.0	55	5.4	2.7	6.8	14.9	1,284	76.6	67.1	6.0	19.0	136	3.1	1.5	4.6	9.2	1,806
A (2) ..	1,778	81.4	76.2	2.7	10.2	21	3.9	2.2	7.0	13.1	251	72.4	62.7	8.3	23.8	196	3.3	1.2	2.8	7.3	286
P ..	1,850	77.9	72.7	7.4	22.2	276	—	1.6	—	19.4	1,049	72.6	65.4	8.5	22.4	211	—	1.7	—	14.0	782
K ..	1,886	80.1	74.5	3.1	11.8	26	3.4	2.5	11.3	17.2	1,305	73.2	65.3	7.5	20.1	163	3.1	1.8	6.0	10.9	958
B ..	1,909	83.6	75.0	2.7	11.6	41	—	3.2	—	18.8	774	79.8	66.7	4.7	16.8	111	—	1.3	—	8.4	848
L ..	2,269	82.2	74.0	3.5	13.7	71	6.1	3.3	12.5	21.9	1,217	77.1	68.1	7.6	21.2	264	5.0	2.2	8.8	16.0	1,819
Means of complete sets of data							4.3	2.7	8.8	15.8							3.3	1.5	4.8	9.7	

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(a) *Temperature.*

The correlation of absenteeism with the air temperature is recorded in Table IV. It will be seen that there was a positive correlation coefficient of $\cdot34$ to $\cdot51$ between wet or dry bulb temperature and absenteeism from sickness, whilst that between temperature and absenteeism from accidents was smaller, and ranged from $\cdot17$ to $\cdot31$. The correlation of temperature with absenteeism from voluntary causes was practically *nil* in the coal face workers, but showed a moderate figure in other underground workers, while the correlation of temperature with total absenteeism was similar in both groups of workers.

TABLE IV.—*Correlation of absenteeism with temperature of air.*

Cause of absenteeism.	No. of observations.	Coal face workers.		Other underground workers.	
		Dry bulb.	Wet bulb.	Dry bulb.	Wet bulb.
Sickness	155	$+\cdot466 \pm \cdot042$	$+\cdot342 \pm \cdot048$	$+\cdot473 \pm \cdot042$	$+\cdot513 \pm \cdot040$
Accidents	228	$+\cdot240 \pm \cdot042$	$+\cdot242 \pm \cdot042$	$+\cdot174 \pm \cdot043$	$+\cdot308 \pm \cdot040$
Voluntary causes	155	$-\cdot030 \pm \cdot054$	$+\cdot062 \pm \cdot054$	$+\cdot225 \pm \cdot051$	$+\cdot393 \pm \cdot046$
All causes... ..	228	$+\cdot248 \pm \cdot042$	$+\cdot307 \pm \cdot040$	$+\cdot213 \pm \cdot043$	$+\cdot343 \pm \cdot039$

In order to be able to appreciate fully the significance of the correlation coefficients, it is desirable to indicate the inter-relationships of the individual data on which they are based by means of regression diagrams. As the frequent introduction of such diagrams tends to break the continuity of the argument, they have been relegated to the Appendix.

Another method of demonstrating the relationship of sickness to underground temperature is to take the whole of the miners, irrespective of the pit in which they happened to be working, and group them according to the average temperature conditions experienced. It will be seen from Table V that 1,273 coal face men (who worked in two of the pits) experienced a mean dry bulb temperature of less than 70 deg., and they lost 3 per cent. of their shifts from sickness. There were no pits where the average temperature for the coal face men was 70 deg. to 74·9 deg., but those working at 75 deg. to 79·9 deg. suffered 50 per cent. more sickness than the low temperature workers, and the large group of men working at 80 deg. and upwards suffered 63 per cent. more. The other underground workers showed corresponding increments of sickness with rise of temperature, though they were working under somewhat cooler conditions. The sickness appeared to increase rather more rapidly with rise of wet bulb temperature than with rise of dry bulb, as can be gathered by comparing the curves in Fig. 2.

TABLE V.—*Absenteeism from sickness in relation to temperature.*

Range of temperature.	Coal face workers.			Other underground workers.			
	Mean temperature.	No. of men.	Percentage of time lost.	Mean temperature.	No. of men.	Percentage of time lost.	
	0			0			
Dry bulb	Under 70° ..	67.9	1,273	3.0	66.7	1,093	2.3
	70° to 74.9°	—	0	—	72.9	1,444	3.2
	75° to 79.9°	76.9	944	4.5	76.5	4,431	4.0
	80° or more..	80.9	2,773	4.9	—	0	—
Wet bulb	Under 62° ..	—	0	—	58.3	262	2.5
	62° to 65.9°	64.6	1,273	3.0	64.5	3,281	3.0
	66° to 69.9°	68.8	716	4.2	67.7	3,425	4.2
	70° to 73.9°	71.7	1,512	5.4	—	0	—
	74° or more..	74.4	2,773	4.7	—	0	—

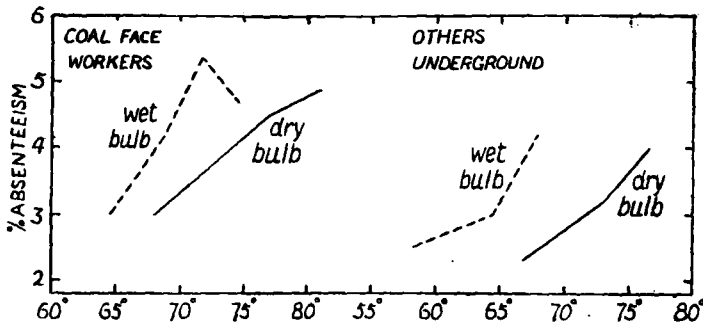


FIG. 2. Relationship of sickness to temperature at all collieries combined.

Surprise may be felt at the very marked effect of underground temperatures on sickness, for many dwellers in warm climates habitually experience higher temperatures than those investigated by us, without ill effects. Presumably the causation of the sickness depends, not on the high temperatures at which the miners perform their work, but on the sudden changes experienced when coming to the surface. Sometimes the surface air temperature is 50 deg. lower than that underground, near the coal face, and an over-heated and freely perspiring man, on emergence into such cold air, would be very liable to catch a chill.

(b) *Cooling Power of Air.*

The correlation of sickness absenteeism with the dry and the wet kata cooling power of the air is recorded in Table VI. The coefficients were almost always negative in sign, for the absenteeism tended to increase as the cooling power of the air diminished. By comparing the coefficients with those recorded in Table IV, it will be seen that the correlation of sickness with cooling power was smaller than its correlation with temperature. The reason is that the cooling power depends on air movement as well as on temperature, and as is indicated below, increased air movement appears to increase sickness rather than diminish it. Hence a given reduction of cooling power would tend to

increase sickness, in so far as the reduction was due to an increase of temperature, but would tend to decrease sickness, in so far as it was due to increase of air movement.

TABLE VI.—*Correlation of absenteeism with cooling power of air.*

Cause of absenteeism.	No. of observations.	Coal face workers.		Other underground workers.	
		Dry kata cooling power.	Wet kata cooling power.	Dry kata cooling power.	Wet kata cooling power.
Sickness	155	-·371 ± ·047	-·156 ± ·053	-·109 ± ·054	+·020 ± ·054
Accidents	228	-·398 ± ·038	-·424 ± ·037	-·070 ± ·044	-·101 ± ·044
Voluntary causes	155	-·007 ± ·054	-·155 ± ·053	+·015 ± ·054	-·078 ± ·054
All causes	228	-·029 ± ·045	-·007 ± ·045	+·117 ± ·044	+·085 ± ·044

Our previous investigation on the working capacity of coal miners (1927) showed that the wet kata cooling power was a better index of the suitability of atmospheric conditions for work than the dry kata cooling power, but the present observations show that sickness is correlated more closely with dry kata cooling power than with wet. Perhaps this may be due to the disturbing influence of the air velocity factor. The same factor may be responsible for the lack of correlation between cooling power and total absenteeism.

The coefficients recorded on the right side of Table VI show that there was no definite relationship between the absenteeism of other underground workers and the cooling power of the air.

(c) *Air Velocity.*

The correlation of absenteeism with air velocity is recorded in Table VII. It will be seen that for "other underground workers" the coefficient between sickness and air velocity attained the high positive value of ·59, whilst for coal face workers it was only ·28. The correlation of absenteeism from voluntary causes with velocity was likewise rather high in "other underground workers," but the significance of this coefficient is doubtful, owing to the possible inclusion of some absenteeism due to sickness. It will be noted that whilst the other underground workers showed a positive correlation between absenteeism from accidents and air velocity, the coal face workers showed a substantial negative correlation. This discrepancy, which is referred to again later on, probably depends on the fact that the air velocities experienced by the coal face workers were much lower than those to which the other miners were subjected.

TABLE VII.—*Correlation of absenteeism with air velocity.*

Cause of absenteeism.	No. of observations.	Coal face workers.	Other underground workers.
Sickness	155	+·278 ± ·050	+·586 ± ·036
Accidents	228	-·293 ± ·041	+·207 ± ·043
Voluntary causes	155	-·092 ± ·054	+·453 ± ·043
All causes	228	+·230 ± ·042	+·610 ± ·028

TABLE VIII.—*Absenteeism from sickness in relation to air velocity.*

Coal face workers.					Other underground workers.				
Range of air velocity. (ft. per min.)	Mean velocity.	No. of men.	Mean age in years.	Per-centage of time lost.	Range of air velocity. (ft. per min.)	Mean velocity.	No. of men.	Mean age in years.	Per-centage of time lost.
Under 30 ..	24	2,146	34.6	3.7	Under 120	90	1,837	28.2	2.7
30 to 59 ..	53	2,195	34.1	4.3	120 to 159	137	2,068	31.3	3.1
60 or more..	74	1,933	39.4	5.5	160 to 199	171	1,244	28.7	3.1
					200 or more	264	1,819	32.5	5.0

On classifying the sickness data obtained at the various collieries according to the air velocity, the mean results recorded in Table VIII were obtained. They are plotted in Fig. 3, and it will be seen that as the air velocity increased, the sickness showed a slow rise at first, followed by a more rapid one. Thus, in the "other underground workers" an increase of velocity from 90 ft. to 171 ft. per minute was associated with a rise of only 15 per cent. in sickness, whilst the further increase of velocity to 264 ft. was associated with an additional rise of 70 per cent.

The marked rise of sickness observed in coal face workers at velocities of 60 ft. or more is probably due in part to the fact that the men in this group were 5 years older than those in the other groups. (Cf. Table VIII.)

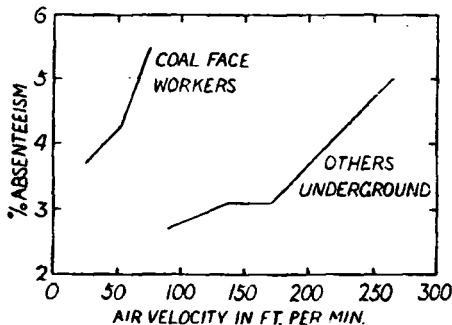


FIG. 3. Relationship of sickness to air velocity at all collieries combined.

The air velocities recorded in Table III, and the other velocities subsequently recorded in Tables XI and XII, are the means of individual values possessing a fair degree of divergence. The range and frequency of the velocities observed at collieries A (i.e., A (1) and A (2) combined) and B have been already recorded by us (1927), and as those observed at other collieries were similar, it seemed unnecessary to record them in addition. It should be stated that of the coal face observations made at the collieries other than A and B, nine-tenths were at long wall faces, and only one-tenth at headings and pillars.

The seemingly adverse effect of the comparatively small increments of air velocity on the sickness of coal face workers might be thought to contradict every-day experience obtained in factories and other buildings above ground. As the result of numerous observations made in ten factories (1926), we found that in summer time, at a temperature of 75 deg., the air velocity in the work-rooms averaged 51 ft. per minute, and we recommended that when possible it should be increased to 100 ft. In the present observations, made at a mean temperature of 76.5 deg. (dry bulb), the air velocity in the various pits ranged from 18 ft. to 80 ft., and averaged 43 ft. As the miners were engaged in severe physical work, it might be thought that they would need a much higher air velocity than the above-mentioned factory operatives, whose work was for the most part of a light character. Doubtless a higher air velocity would have been better for the physical efficiency of the men, but it may induce sickness from chills. We showed (Reports 39 and 41, 1927) that coal face men are frequently held up by lack of tubs and from other causes, these involuntary rests sometimes lasting over 20 minutes. It is evident that a miner, streaming with perspiration and wearing nothing but breeches, would under such circumstances be very sensitive to air currents, unless he took the precaution of temporarily donning some extra clothes.

Having regard to the possible effect of age of the men on the result observed, and of other unknown factors such as the presence of impurities in the air of the mines, it is better to suspend judgment about the effects of air velocity on sickness until further information is obtained.

(d) *Age of Men.*

It is well known that sickness tends to increase with increase of age, and the sickness absenteeism of the miners conformed to the general rule. Our data were not altogether satisfactory, as we were unable to obtain information about the sickness of individual men of known age, but only about the average sickness of all the underground men at each colliery after separation into the two groups of face workers and others. We obtained the frequency distributions of the ages of all the men who signed on after the coal disputes of 1921 and 1926, and from these figures, which agreed well with one another, we calculated the average ages during the 1924-26 period for which the absenteeism data were available. The average ages of the coal face workers varied a good deal at the different collieries, the extremes ranging from 31.5 to 41.8 years; but those of the other underground men were more steady, and ranged only from 27.2 to 32.9 years. On correlating the monthly absenteeism data with the average ages of the men at the eight pits, we found that the coal face workers gave a coefficient of $+0.328 \pm 0.048$ in respect of sickness absenteeism, and the other underground workers, one of $+0.569 \pm 0.037$. The other coefficients were small and irregular, so they are not worth quoting.

On classifying the men according as the average age at a colliery fell in one or other of three groups, the following results were obtained :

TABLE IX.—*Absenteeism from sickness in relation to average age of men at the collieries.*

Average age of men at colliery.	Coal face workers.			Other underground workers.		
	Mean age.	No. of men.	Percentage of time lost.	Mean age.	No. of men.	Percentage of time lost.
Under 28 years ..	—	—	—	27·7	1,789	2·7
28 to 31·9 years ..	31·5	1,305	3·5	30·4	3,160	3·1
32 to 35·9 years ..	34·1	2,195	4·3	32·5	2,019	5·0
36 or more ..	39·7	2,774	5·1	—	—	—

(e) *Sickness in Relation to Season.*

In order to determine if there were any seasonal variation in the absenteeism from sickness, we classified the sickness data obtained at the eight pits on the same plan as that described above for the total absenteeism data. The results showed that in every pit the sickness was least during the summer months (June to September), both for the coal face workers and for the others ; but the incidence of the maximum sickness was irregular, for it came in October to November as frequently as in winter (December to March), and sometimes fell in April to May.

A better way of testing the seasonal variation was to classify the data according to the temperature and irrespective of the pit. On comparing the sickness experienced in the four winter months and the four summer months, the results plotted in Fig. 4 were obtained. It will be seen that though the sickness increased fairly steadily with the dry bulb temperature, it was always, with one slight exception, rather greater in winter than in summer.

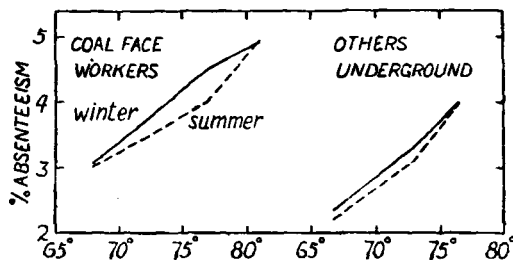


FIG. 4. Sickness in relation to season and to temperature.

The sickness data hitherto described did not distinguish the various causes of sickness, but we were able to obtain some information on this subject from an entirely different source. At the request of the Mines Department, the Medical Research

Council instituted a preliminary enquiry into the causes of sickness in coal miners, and the results obtained were placed at our disposal. Details concerning the sickness of 3,208 coal face workers in the year 1922 were obtained from the National Health Insurance cards kept by a large Friendly Society in Scotland. They related to the men in 17 pits, situated for the most part in Fifeshire, Lanarkshire and Ayrshire. Only a portion of the men in these pits belonged to the Friendly Society in question, and as the coal face workers form only about half of all the underground men, the average number of men investigated amounted only to 30 per cent. of the total underground workers in the 17 pits. Nevertheless, it is probable that they were a fair sample of the whole.

We classified the sickness under several headings, but owing to the small mass of data available, we decided to reduce them to two, consisting of (a) sickness due to respiratory diseases (bronchitis, pneumonia, pleurisy, pharyngitis, pleurodynia, asthma), and to influenza; (b) sickness due to all other causes (accidents excluded). The reason why we grouped influenza with respiratory diseases was because of doubts about diagnosis. For instance, at one pit scarcely any sickness was attributed to respiratory diseases, whilst that assigned to "influenza" was extremely large. At an adjoining pit nearly equal amounts of sickness were assigned to the two causes. Such a marked difference could scarcely have been genuine.

In order to determine if the sickness was dependent on temperature, we separated the pits into three nearly equal groups, according to their depth. We made no direct observations of temperature in the workings, but the Mines Department supplied us with information about the average depth of the workings at each pit, and as we shall see hereafter, temperature is very closely correlated with depth, the coefficient observed by us being $+0.952 \pm 0.015$. We also divided the sickness records according as they occurred in the six winter months (November to April), or the six summer months. The 53 men on disablement benefit (which is incurred after the receipt of 26 weeks' full pay) were excluded altogether from our analysis, as the inclusion of chronic cases may lead to erroneous conclusions when the volume of data is inconsiderable. Hence the recorded data relate to 3,155 men, and not the 3,208 men above mentioned.

TABLE X.—*Effect of depth of pit and of season on sickness.*

	Mean depth in feet.	No. of men.	Days lost from respiratory illness in			Days lost from all causes,		
			Winter.	Summer.	Percentage excess in winter.	Winter.	Summer.	Percentage excess in winter.
8 shallow pits	881	999	2.24	0.72	211	4.8	3.3	45
4 medium pits	1,412	988	2.83	1.19	138	5.5	4.2	31
5 deep pits	1,970	1,168	1.83	0.80	129	4.0	2.7	48
	—	—	2.30	0.90	159	4.8	3.4	41

The mean results recorded in Table X show the number of working days lost from sickness in each six-month period, the initial three days' sickness—for which benefit is not paid—being included. It will be seen that the sickness from all causes was considerably greater in the winter than in the summer, the average excess amounting to 41 per cent. It seemed to be due entirely to the additional respiratory illness experienced in the winter, for this averaged 1·4 days more than in the summer, or exactly the same amount as that by which the winter sickness from all causes exceeded the summer sickness. The total sickness per year, namely, 8·2 days, was 3·1 per cent. of the possible shifts which could be worked, if we accept the shift figure given by the Coal Commission for the whole of Scotland in 1924. Hence it was slightly greater than the average time observed by us, which amounted to 2·7 per cent.

The present results differ from those previously described in showing no increase of sickness with increasing depth of pit ; i.e., with increasing temperature. Judging from our own results, the dry bulb temperature of the air in the shallow pits was probably about 67 deg., and in the deep ones about 84 deg. The rather smaller rise of temperature than this which was recorded in the previous results (Table V), was accompanied by an increase in sickness of 63 per cent.

Another unexpected result relates to the respiratory illness. We see that in winter time the men working in shallow pits suffered three times as much illness of this character as they did in summer time, whilst the men working in deep pits suffered only twice as much. One would have expected that men working at a temperature of 84 deg. would get more overheated than those working at 67 deg., and would consequently be more liable to catch a chill when they came to the surface.

Evidently it is necessary to obtain more extensive information about sickness before definite conclusions can be arrived at. Our own data are more reliable than these Scottish data, as they relate to a larger group of men and they were obtained for a longer period. Moreover, they relate to the whole of the men working in a small number of somewhat similar pits in the same district, instead of a portion of the men working in a wide area, with very different types of pit, and very different atmospheric conditions above ground.

4. Absenteeism due to Accidents.

Accurate information concerning absenteeism from accidents is obtainable from the records of compensation cases. Previous to 1924 compensation was paid on all accidents involving an absence from work of over seven days, whilst from 1924 onwards the minimum time was reduced to an absence of over three days. We classified separately the accident records for the years 1924 and 1925 of all the ten collieries and 17 seams previously referred to. We calculated the accident frequency rate per 100,000

man-shifts worked, and the accident severity rate in terms of days lost per 1,000 hours worked. A shift, inclusive of the winding times, was assumed to be of $7\frac{1}{2}$ hours' duration. In calculating severity rates, it is sometimes assumed that a fatal accident corresponds to the loss of 20 years of working life, or of 6,000 days of working time. Their inclusion on this basis causes the severity rates to be extremely irregular, for fatal accidents occurred, in our experience, at the rate of about two per pit per year, but in some cases there were none at all, and in others as many as six. Hence we found it best to calculate severity rates on the system previously adopted by us (1927), and assume that no accident, fatal or otherwise, caused a loss of more than 150 days (six months) of working time.

In order to determine whether there was a substantial relationship between accident frequency and the natural conditions at the coal face, we arranged the seams of the various collieries in order according to their degree of danger from falls of roof and side. In making this ranking, we chiefly relied on the opinion of the managers and others who had an intimate knowledge of the various collieries. We also arranged the seams in order according to their accident rate (see below), and obtained the following correlation coefficients between rankings of accidents and of natural conditions:—

Accident frequency from falls of ground, with natural conditions	.. ..	$r = + \cdot 18 \pm \cdot 16$
Accident severity from falls of ground, with natural conditions	.. ..	$r = + \cdot 22 \pm \cdot 16$

These coefficients suggest that there is a slight tendency to increase of accidents with increasing danger of natural conditions, but they are statistically insignificant. It is, of course, well known that a bad roof is very often easily controlled, and scrupulous care is taken to see that it is properly supported. Under a good roof men are very liable to take liberties. It has been pointed out by the Safety in Mines Research Board (Paper No. 6, 1926) that indifference to the timbering of good roofs is responsible for many accidents that could be prevented, with the result that good roofs prove to be as dangerous as bad roofs, if not more so.

(a) *Atmospheric Conditions.*

The accident frequency rate and severity rate of the coal face workers in 1924 and 1925 at each of the 17 seams are recorded in Table XI, together with the average atmospheric conditions experienced. The data are arranged according to the mean depth of the workings, and it will be seen that, on the whole, the accident rates tended to increase with depth. In Table XII the corresponding data for the other underground workers are similarly recorded, with the exception that the figures for the D and E seams at pit Q are given in combination instead of separately. It will be seen that the accident rates are considerably smaller than those observed in the coal face workers.

TABLE XI.—*Accident rates of coal face workers.*

Colliery and seam.	Mean depth at coal face (ft.).	Mean atmospheric conditions.					Accident frequency.					Accident severity.					No. of men employed.
		Temperature.		Cooling power.		Air velocity in feet per min.	Falls of ground.	Other causes.	All causes.			Falls of ground.	Other causes.	All causes.			
		Dry bulb.	Wet bulb.	Dry.	Wet.				1924.	1925.	Mean.			1924.	1925.	Mean.	
N, H ..	546	61.5	60.0	7.1	16.4	31	28	75	99	108	103	1.2	2.6	4.7	2.9	3.8	170
A (1), C ..	616	64.6	62.2	5.7	15.2	18	25	38	52	74	63	1.5	2.0	2.6	4.5	3.5	370
N, G ..	791	65.6	62.3	7.1	18.5	54	41	42	97	69	83	1.7	1.6	3.9	2.6	3.3	340
Q, E ..	1,260	75.9	69.5	4.7	16.4	56	48	49	93	101	97	1.8	1.4	2.9	3.5	3.2	479
A (1), D ..	1,359	77.3	71.6	3.4	11.3	20	50	47	73	122	97	3.0	1.9	4.3	5.5	4.9	234
N, E ..	1,386	75.8	70.9	5.0	14.7	68	52	59	115	107	111	2.3	1.5	4.1	3.5	3.8	381
M, E ..	1,420	78.1	71.2	3.7	12.8	34	39	57	85	107	96	1.2	1.6	2.9	2.6	2.8	391
J, E ..	1,608	76.8	68.8	5.0	17.4	80	61	67	130	126	128	2.0	2.1	4.0	4.3	4.1	691
K, D ..	1,715	78.7	74.4	3.3	10.8	24	50	102	158	146	152	1.7	2.6	4.5	4.1	4.3	587
A (2), D ..	1,778	81.4	76.2	2.7	10.2	21	46	45	80	101	91	2.0	2.1	3.8	4.5	4.1	245
P, E ..	1,850	77.9	72.7	7.4	22.2	276	33	39	75	69	72	1.3	1.1	2.7	2.1	2.4	1,036
Q, D ..	1,920	83.8	69.9	2.5	11.4	33	34	45	74	84	79	1.0	1.4	2.2	2.5	2.4	380
M, D ..	1,930	81.3	71.9	3.7	14.5	70	93	66	168	151	159	2.3	1.5	4.1	3.5	3.8	910
B, D ..	1,942	83.4	74.8	2.6	11.1	33	66	73	141	137	139	2.9	2.3	4.5	6.0	5.2	423
K, F ..	2,042	81.3	74.6	3.0	12.8	33	45	74	116	121	119	1.5	1.8	2.9	3.7	3.3	654
B, F ..	2,168	85.4	75.7	2.6	12.5	59	72	59	134	127	131	2.5	2.0	4.6	4.4	4.5	274
L, E ..	2,269	82.2	74.0	3.5	13.7	71	79	82	153	169	161	2.6	2.4	4.9	5.1	5.0	1,212

TABLE XII.—*Accident rates of other underground workers.*

Colliery and seam.	Mean atmospheric conditions.					Accident frequency.					Accident severity.					No. of men employed.
	Temperature.		Cooling power.		Air velocity in feet per min.	Falls of ground.	Other causes.	All causes.			Falls of ground.	Other causes.	All causes.			
	Dry bulb.	Wet bulb.	Dry.	Wet.				1924.	1925.	Mean.			1924.	1925.	Mean.	
N, H ..	59.4	56.0	9.2	22.3	69	7	35	45	39	42	0.3	1.4	1.4	2.0	1.7	111
A (1), C ..	61.9	58.3	10.3	24.4	128	4	33	44	31	37	0.1	1.5	2.0	1.3	1.6	260
N, G ..	64.6	60.1	8.5	21.4	90	13	36	57	41	49	0.6	1.5	2.4	1.7	2.1	273
Q, D + E ..	71.0	61.3	8.9	23.3	206	10	40	52	49	50	0.3	1.4	1.6	1.8	1.7	918
A (1), D ..	72.3	65.8	7.7	21.8	158	8	30	46	30	38	0.5	1.2	1.6	1.8	1.7	215
N, E ..	72.4	66.6	7.1	19.5	126	10	51	66	56	61	0.6	1.7	2.2	2.3	2.3	447
M, E ..	75.0	66.0	5.8	17.9	97	12	38	54	47	50	0.4	1.4	1.7	1.9	1.8	611
J, E ..	75.1	65.3	5.4	16.9	79	12	39	47	56	51	0.3	1.4	1.6	1.9	1.7	985
K, D ..	73.0	64.6	6.7	18.7	115	12	64	88	64	76	0.4	2.1	3.0	2.1	2.5	567
A (2), D ..	72.4	62.7	8.3	23.8	196	5	38	44	43	43	0.1	1.7	1.7	1.9	1.8	280
P, E ..	72.6	65.4	8.5	22.4	211	10	43	51	54	53	0.6	1.6	2.1	2.3	2.2	801
M, D ..	77.6	67.7	6.2	19.6	170	21	58	79	79	79	0.8	1.6	2.3	2.4	2.4	993
B, D ..	80.0	68.6	4.4	15.8	94	9	55	68	60	64	0.2	1.7	1.8	2.1	1.9	531
K, F ..	73.5	66.2	8.5	22.0	230	21	83	114	95	104	0.6	2.8	3.8	3.0	3.4	457
B, F ..	81.9	69.6	4.6	18.2	148	20	78	95	100	98	0.6	2.3	2.9	2.9	2.9	196
L, E ..	77.1	68.1	7.6	21.2	264	31	59	96	83	90	1.0	1.7	2.8	2.5	2.7	1,793

For the calculation of the correlations of accidents with atmospheric conditions the two yearly accident rates for each seam were regarded as separate observations, so there were 34 observations of frequency and of severity for the coal face workers, and 32 for the other underground men. The coefficients are recorded in Table XIII. It will be seen that the correlation of accident frequency with dry bulb and wet bulb temperatures was fairly high for coal face workers, and quite high for other underground workers. The accident severity rates show lower coefficients than the frequency rates, for a reason mentioned further on. The correlation of accidents with dry and wet kata cooling powers is, on the whole, lower than the correlation with temperatures because of the disturbing effect of the air velocity factor. Air velocity appears—for a reason previously mentioned and referred to again below—to have very little influence on accidents to coal face workers, though it showed a considerable positive correlation with accidents to other underground workers. In their case, therefore, an increase of accidents was associated with a rise of air velocity and also with a rise of air temperature; but as these rises act in opposite directions on the kata-thermometer, one increasing its rate of cooling and the other diminishing it, it follows that the correlation of accidents with cooling power was small.

TABLE XIII.—*Correlation of accident rates with atmospheric conditions.*

	Coal face workers.		Other underground workers.	
	Frequency.	Severity.	Frequency.	Severity.
Dry bulb temperature ..	+·452 ± ·092	+·214 ± ·110	+·593 ± ·077	+·401 ± ·100
Wet bulb temperature ..	+·461 ± ·091	+·299 ± ·105	+·623 ± ·073	+·478 ± ·092
Dry kata cooling power ..	-·436 ± ·094	-·357 ± ·101	-·381 ± ·102	-·172 ± ·116
Wet kata cooling power ..	-·321 ± ·104	-·398 ± ·097	-·312 ± ·108	-·125 ± ·117
Air velocity	-·147 ± ·113	-·299 ± ·105	+·418 ± ·098	+·491 ± ·097

The reason why the accident rates of coal face workers showed a small negative correlation coefficient with air velocity instead of the fairly substantial positive coefficient shown by other underground workers was entirely due to the very abnormal air velocity observed at one colliery (P). Here the velocity at the coal face was 276 ft. per min., and was greater than that observed in the airways, whilst no velocity higher than 80 ft. per min. was observed at any of the other seams. If this value is ignored, and the remaining accident rates are classified in four groups according to the air velocity, the mean results shown in Table XIV are obtained.

It will be seen that whilst the accident frequency was practically constant at all velocities under 60 ft. per min., it showed a considerable increase at a mean velocity of 72 ft. The accident severity was high at very low velocities,

but fell to a minimum at one of 30 to 59 ft. per min. Then it rose rapidly like the accident frequency. There can be no doubt that a certain amount of air movement is necessary for the attainment of maximum working capacity, and presumably the same condition holds for the attainment of minimum accident liability. Arguing from the small amount of evidence here adduced, it seems probable that accidents reach their minimum when the air currents have a comparatively low velocity, such as 30 to 60 ft. per min. As has already been suggested in connection with the causation of sickness, their increase at higher velocities may be due to the men tending to get rather chilled when they are temporarily resting from work. They would, in consequence, become stiffer and clumsier in their movements.

It will be noted that the highest velocity group were at the greatest depth, and this fact may in part account for the higher accident rates then observed.

TABLE XIV.—*Accident rates in relation to air velocity.*

Range of air velocity.		Mean velocity.	Mean accident		Mean depth in feet.
			frequency.	severity.	
Coal face workers	Under 30 ft. per min.	21	101	4.22	1367
	30 to 39 ft. per min.	33	107	3.41	1574
	40 to 59 ft. per min.	56	104	3.65	1406
	60 to 80 ft. per min.	72	140	4.19	1809

All other conditions being equal, we might expect that the thinner the seam the greater would be the air velocity, and the increase of accidents associated with high velocities might therefore be attributable to the thinness of the seams. As a matter of fact, the results recorded later on show that the reverse relationship holds between thinness of seam and accident rate. In any case, the present observations indicate that there is no consistent relationship between thickness of seam and air velocity, as can be gathered from Table XV.

Table XV.—*Air velocity in relation to thickness of seam.*

Range of thickness of seam, in inches.	Mean thickness in inches.	Number of seams.	Mean air velocity in feet per min.
72	72	2	57
66 to 63	65	5	48
60	60	3	28
54	54	3	38
50 to 48	49	2	51
47 or less	40	2	165

TABLE XVI.—Correlations of accident rates from various causes with atmospheric conditions.

Atmospheric conditions.			Accident frequency.			Accident severity.		
			Falls of ground.	Other causes.	All causes.	Falls of ground.	Other causes.	All causes.
Coal face workers	Dry bulb temperature	+	569 ± 078	+ 188 ± 112	+ 452 ± 092	+ 323 ± 104	- 097 ± 115	+ 214 ± 110
	Wet bulb temperature	+	515 ± 085	+ 257 ± 108	+ 461 ± 091	+ 378 ± 099	- 007 ± 116	+ 299 ± 105
	Dry kata cooling power	-	454 ± 092	- 275 ± 107	- 436 ± 094	- 332 ± 103	- 177 ± 112	- 357 ± 101
	Wet kata cooling power	-	227 ± 110	- 308 ± 105	- 321 ± 104	- 274 ± 107	- 362 ± 101	- 398 ± 097
	Air velocity	+	013 ± 116	+ 067 ± 115	- 147 ± 113	- 116 ± 114	- 421 ± 095	- 299 ± 105
Other underground workers	Dry bulb temperature	+	491 ± 091	+ 563 ± 081	+ 593 ± 077	+ 340 ± 105	+ 308 ± 108	+ 401 ± 100
	Wet bulb temperature	+	537 ± 085	+ 583 ± 079	+ 623 ± 073	+ 466 ± 093	+ 332 ± 106	+ 478 ± 092
	Dry kata cooling power	-	277 ± 110	- 387 ± 101	- 381 ± 102	- 136 ± 117	- 138 ± 117	- 172 ± 116
	Wet kata cooling power	-	214 ± 114	- 317 ± 107	- 312 ± 108	- 101 ± 118	- 101 ± 118	- 125 ± 117
	Air velocity	+	470 ± 093	+ 341 ± 105	+ 418 ± 098	+ 432 ± 097	+ 292 ± 109	+ 431 ± 097

Our results suggest that atmospheric conditions influence different types of accident to different degrees, and in order to obtain further light on the subject, we classified all our data separately under two headings: (a) accidents due to falls of roof, coal and side, and (b) accidents due to all other causes combined. Such accidents consist largely of strains incurred when lifting tubs, rails, etc.; the crushing of fingers or arms between tubs and props; the trapping of fingers between haulage ropes and pulleys; the cutting of fingers against the iron on the edge of the tubs, or on loose strands of haulage rope; injuries from picks and other tools, and from kicks of ponies.

As can be seen from Table XI, the accidents incurred by coal face workers from these two causes—for the years 1924 and 1925 combined—were, on the whole, nearly equal in number, though they varied a great deal in different pits. From Table XII it will be seen that the other underground men differed greatly from the coal face men as they incurred only about a fourth as many accidents from falls of ground as from other causes.

The correlation coefficients of accident rates from the two specified causes with atmospheric conditions are recorded in Table XVI. It will be seen that amongst coal face workers the correlations of accidents due to falls of ground were, on the whole, considerably greater than the correlations of accidents due to other causes. The correlation with dry bulb and with wet bulb temperature was particularly high: but amongst the other underground men the accidents due to falls of ground showed a lower correlation—in respect of frequency—than the accidents due to other causes, though a slightly higher one in respect of severity.

It is not worth while to give further details of the relationships between accidents to coal face workers and atmospheric conditions, because of the more satisfactory information adduced further on, but some of the details may be given for the other underground workers. When the data were grouped according to air velocity, the results recorded in Table XVII and plotted in Fig. 5 were obtained. It will be seen that the association between accidents

TABLE XVII.—*Accident rates of other underground workers in relation to air velocity.*

Range of velocity.	Mean velocity.	Accident frequency.			Accident severity.			Total shifts worked.
		Falls of ground.	Other causes.	All causes.	Falls of ground.	Other causes.	All causes.	
Under 100 ft. per min...	87	11	42	53	0.35	1.49	1.84	1,233,694
100 to 149 ft. per min...	125	11	56	67	0.44	1.89	2.33	780,872
150 to 199 ft. per min...	174	16	49	65	0.62	1.51	2.13	734,507
200 to 249 ft. per min...	213	12	51	63	0.51	1.77	2.28	1,064,427
250 ft. or more ..	264	31	58	89	0.94	1.71	2.65	852,448

from falls of ground and velocity was considerable, for the accidents were nearly three times more frequent at the highest velocities than at the lowest velocities, whilst the severity rate varied in similar proportion. Accidents from other causes were, however, comparatively little affected.

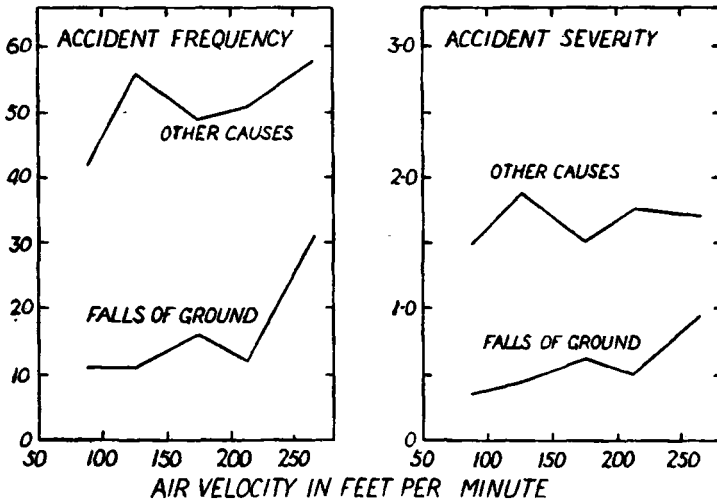


FIG. 5. Accidents to other underground workers in relation to air velocity.

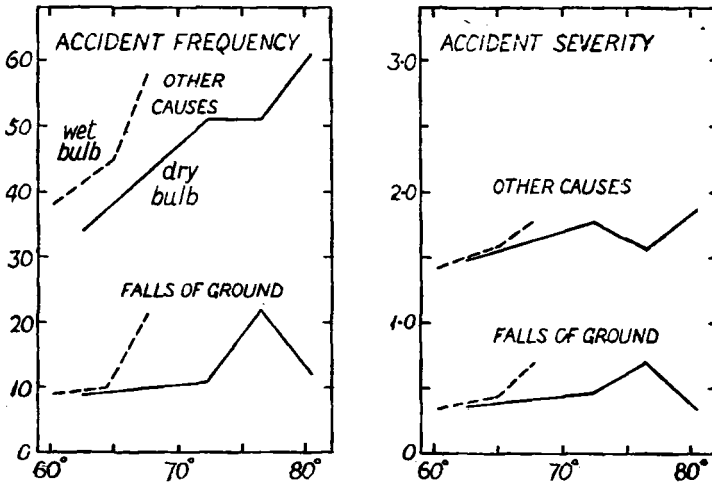


FIG. 6. Accidents to other underground workers in relation to temperature.

When the data were grouped according to the dry bulb and the wet bulb temperature, the mean results plotted in Fig. 6 were obtained. It will be seen that the frequency of accidents from both causes increased rapidly with rise of temperature, being nearly double as great at the highest dry bulb temperature

experienced as at the lowest. The variations in accident severity were considerably smaller, or in other words, at high temperatures the number of minor accidents increased rather than the number of major ones. This differential effect of temperature on minor and major accidents was observed in relation to other conditions as well. It is a fact of such great importance as to dominate the interpretation placed by us upon most of our absenteeism data, whether they relate to absenteeism from accidents, sickness, or from voluntary causes. Before we describe the differential effects in detail, it is desirable that we should adduce some abutting evidence relating to the differential action of certain economic circumstances upon the apparent number of accidents of various degrees of severity.

Our first piece of evidence is drawn from the Annual Report of the Secretary for Mines (1926) concerning accident frequency in relation to the earnings of miners. The data recorded on the left side of Table XVIII, which were extracted from this report, show that between the years 1920 and 1925 the number of severe accidents (fractures, dislocations, and other severe personal injuries; also accidents due to explosions and to overwinding) incurred by British miners was very steady. Reckoned per 1,000 persons employed, it varied only from 3·5 to 4·3 (after correcting the 1921 figure for the three months lost by a coal dispute). On the other hand, the number of minor accidents varied considerably, for they were 26 times more numerous than the major accidents in 1920, but rose rapidly in later years till they were 40 times more numerous in 1925. Accompanying this rise in the relative proportion of minor accidents, the earnings of the miners underwent a rapid fall, and in 1925 they averaged only three-fifths their 1920 figure. However, this was partly compensated for by the fall in the cost of living, which in 1922 to 1925 ranged from 76 per cent. to 73 per cent. of its 1920 figure.

TABLE XVIII.—*Accident frequency in relation to earnings.*

Year.	Great Britain (all coal miners).			Accident frequency to coal face workers at colliery.		Relative earnings per shift at colliery.		
	Severe accidents incurred.	Minor accidents for each major accident.	Yearly earnings in £.	A.	B.	A.	B.	
Basis of over 7 days {	1920	3·5	26	223	46	84	85	100
	1921	3·6*	27	192*	53	73	87	98
	1922	4·1	38	125	82	95	64	70
	1923	4·3	39	134	86	104	59	64
Basis of over 3 days {	1924	4·0	39	138	68	137	65	72
	1925	3·9	40	132	99	132	60	64

* Corrected for time lost by coal dispute.

On the right side of Table XVIII, we record the relative earnings of the coal face workers at two of the collieries investigated by us, and they show a similar fall between the years 1920 and 1925. We did not attempt to split up the accidents on the scheme employed by the Mines Department, but the frequencies recorded in the Table show a rapid rise at each colliery from 1920 onwards, and there can be no doubt that the rise related to minor accidents rather than major ones.

The explanation of the variations in the frequency of accidents is suggested by the Coal Commission (1926). The Commissioners point out, with reference to the increase of accidents, that "there is some, though not conclusive ground, for connecting their number with the state of employment: the prospect of low and irregular earnings tends to keep the men on compensation longer than they would be if employment was plentiful and wages high." That is to say, the decision of the miner to remain on compensation or go back to work is influenced by considerations other than those dependent on the plain question of recovery from an injury. In fact, it appears to be influenced not only by economic considerations, but by many other considerations such as the conditions under which the miner is working and his environment in general. Such conditions have an influence, not only on the question of return to work, but even more on the question of claiming compensation at all. Few if any conditions are more important in this respect than the atmospheric conditions experienced underground.

Support of this statement was obtained by analysing the frequency of occurrence of accidents causing various durations of absence. Accidents were classified according as they provoked an absence of less than 10 working days, of 10 to 19 days, 20 to 59 days, or of 60 days (10 weeks) or more. We see from Table XIX that coal face workers, when working at a mean dry bulb temperature of 64.4 deg., incurred 3.6 accidents of less than 10 days' duration, owing to falls of ground. At a temperature of 77.3 deg., however, the number of such accidents rose to 9.5, and at 82.1 deg., to 18.2. Taking the number of accidents incurred at the lowest temperature as 100, it rose to 264 and 506 respectively at the higher temperatures. But when we consider the accidents causing a disability of 10 to 19 days, we find less than half as much increase at the higher temperatures, and when we consider major accidents causing a disability of 60 days or more, we find that the frequency was entirely unaffected by temperature. Accidents due to causes other than falls of ground were similarly affected, except that the major accidents incurred at high temperatures were less numerous than those incurred at low temperatures. When the accident disabilities were calculated in relation to wet bulb temperature instead of in relation to dry bulb temperature, a similar effect was observed, both as regards accidents from falls of ground and from other causes. All these results are plotted out in Fig. 7, where the differential effect of increasing temperature on minor and on major accidents is clearly revealed.

TABLE XIX.—*Accident disability of coal face workers in relation to temperature.*

Duration of absence.				Dry bulb temperature.						Wet bulb temperature.							
				Accident frequency at			Relative frequency at			Accident frequency at				Relative frequency at			
				under 70°	70° to 79°	80° or more.	under 70°	70° to 79°	80° or more.	under 66°	66° to 69°	70° to 73°	74° or more.	under 66°	66° to 69°	70° to 73°	74° or more.
(Mean temperature)				64.4°	77.3°	82.1°	—	—	—	61.8°	69.3°	71.9°	74.6°	—	—	—	—
Falls of ground	Under 10 days	3.6	9.5	18.2	100	264	506	3.7	13.0	13.1	15.2	100	351	354	411		
	10 to 19 days	11.3	17.4	23.0	100	154	204	11.3	17.7	21.9	20.1	100	157	194	178		
	20 to 59 days	11.5	14.4	22.2	100	125	193	11.5	15.8	15.7	22.0	100	137	137	191		
	60 or more days	5.4	5.0	4.9	100	93	91	5.2	3.8	5.0	5.4	100	73	96	104		
Other causes	Under 10 days	6.8	13.9	21.2	100	204	312	6.8	13.6	14.8	22.0	100	200	218	324		
	10 to 19 days	14.7	23.7	23.8	100	161	162	14.7	20.2	20.9	27.9	100	137	142	190		
	20 to 59 days	18.6	18.3	20.4	100	98	110	18.6	18.0	15.8	24.2	100	97	85	130		
	60 or more days	6.3	2.8	3.2	100	44	51	6.3	3.5	2.0	3.6	100	56	32	57		

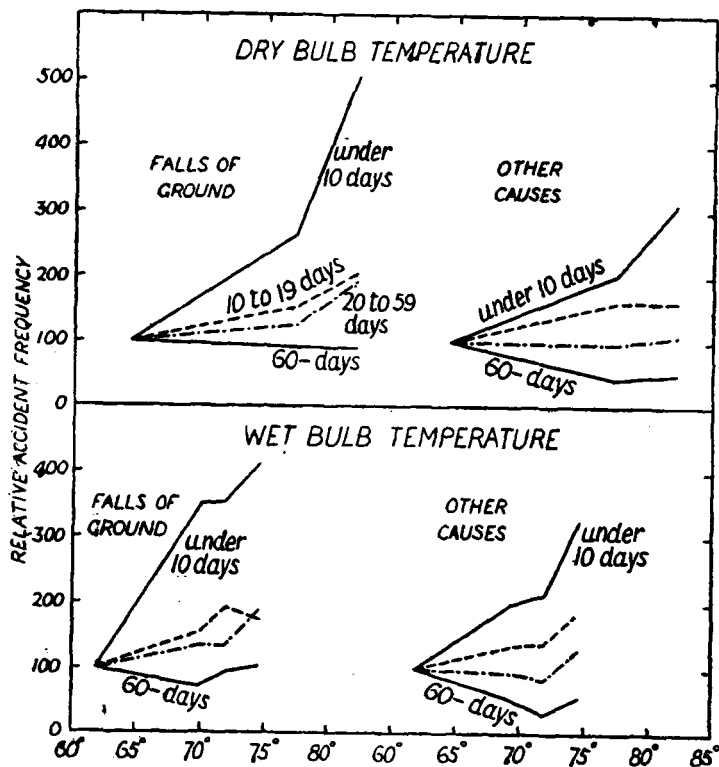


FIG. 7. Accident disability of coal face workers in relation to temperature.

When the accidents to other underground workers were classified on the same principle, the results recorded in Table XX were obtained. It will be seen that they show a similar differential effect of high temperature upon minor and major accidents. The effects of the highest mean temperatures observed upon the relative frequency of various minor and major accidents, both to coal face workers and to others were as follow :—

	<i>Relative frequency, that at low temperatures being 100.</i>	<i>Mean.</i>
Minor accidents (less than 10 days' disablement)	506, 312, 411, 324, 611, 438, 509, 361	434
Major accidents (60 days or more of disablement)	91, 51, 104, 57, 108, 103, 117, 146	97

On an average, therefore, the major accidents were almost exactly as numerous at the highest underground temperatures observed as at the lowest, whilst minor accidents were more than four times as numerous. This huge excess of minor accidents, together with the smaller excess shown by accidents causing intermediate degrees of disability, was presumably due to the injured men who worked at high temperatures claiming compensation more frequently than those working at low temperatures. Some idea of the extra time lost by these additional compensation

TABLE XX.— *Accident disability of other underground workers in relation to temperature.*

Duration of absence.	Dry bulb temperature.						Wet bulb temperature.						
	Accident frequency at			Relative frequency at			Accident frequency at			Relative frequency at			
	under 70°	70° to 74°	75° or more.	under 70°	70° to 74°	75° or more.	under 62°	62° to 65°	66° or more.	under 62°	62° to 65°	66° or more.	
(Mean temperature)	62·6°	72·3°	77·0°	—	—	—	60·2°	65·0°	67·6°	—	—	—	
Falls of ground	Under 10 days ..	0·9	2·4	5·5	100	267	611	1·1	2·7	5·6	100	245	509
	10 to 19 days ..	2·1	4·0	7·5	100	190	357	3·9	3·3	7·7	100	85	197
	20 to 59 days ..	4·4	3·2	6·0	100	73	136	3·0	3·1	6·3	100	103	210
	60 or more days ..	1·2	1·4	1·3	100	117	108	1·2	1·2	1·4	100	100	117
Other causes	Under 10 days ..	2·9	8·3	12·7	100	286	438	3·8	7·8	13·7	100	205	361
	10 to 19 days ..	12·7	18·2	20·0	100	143	157	14·9	14·6	22·4	100	98	150
	20 to 59 days ..	15·7	20·7	16·6	100	132	106	16·7	18·7	18·3	100	112	110
	60 or more days ..	3·3	3·6	3·4	100	109	103	2·6	3·4	3·8	100	131	146

claims was obtained by assuming that the men working at the lowest temperatures went on to compensation no more and no less than their injuries warranted, and calculating the extra time taken at higher temperatures. As an average of the results obtained with the coal face workers and others underground, it was found that accidents of less than 10 days' duration involved a mean absence of 6 days. The number of these minor accidents (of all kinds) incurred by the men at low dry bulb temperatures totalled 14·2, but at intermediate temperatures they came to 34·1, or 19·9 extra, and at high temperatures they came to 57·6, or 43·4 extra. It can be calculated that these extra claims involved the loss of 379·8 extra days, and it will be seen from Table XXI that similar calculations applied to accidents of 10 to 19 days' duration involved the loss of 806·4 extra days. Altogether 1,852 extra days were taken, as compared with the 4,306 days taken on the minimum basis observed at low temperatures. In calculating this minimum, it was assumed that the frequency of accidents of 60 or more days' duration was 13·9 (i.e., the mean of the frequencies observed at all temperatures), whilst the average duration (149·1 days) was calculated by ignoring fatal accidents altogether, but counting the full time of absence from work, even if it lasted a year. It follows, from the figures quoted, that nearly one-third of the total accident absenteeism was due to additional compensation claims over and above the minimum made on the low temperature basis, or in other words, it failed to earn the customary title of "unavoidable."

Why is it that the men working at high temperatures felt so powerful an inclination to go on to compensation when they incurred an injury? Probably the adverse atmospheric conditions induced a feeling of additional fatigue, from which they desired a temporary relief. It seems likely that sickness absenteeism is subject to the same qualification as accident absenteeism, if not a greater one, though we did not obtain any evidence on the subject.

In our previous investigation (1926) we found that the accident severity rate of the coal face men at Colliery A showed as great an increase at high temperatures as the frequency rate did, though the other underground men responded differently in respect of severity and of frequency. However, it is obvious that the present results, applying as they do to ten times the number of coal face workers then tested, and distributed over ten collieries, are much more reliable. At the same time, there can be no doubt that at very high temperatures the number of major accidents must tend to increase, as well as the minor ones. At the Morro Velho gold mine in Brazil, for instance, the number of fatal accidents incurred in the 16 months previous to the introduction of a cooling plant was 20, as contrasted with 6 in the succeeding 16 months. The plant cooled the intake air to 43 deg., and thereby reduced the temperature in the lowest workings from 89 deg. (wet bulb) to 80 deg. (Davies, 1922).

TABLE XXI.—*Time lost by accident disablement at various temperatures.*

Duration of absence.	Mean duration of absence.	Frequency of accidents incurred at			Minimum days lost.	Additional days lost.
		Low temperatures.	Intermediate temperatures.	High temperatures.		
Under 10 days ..	6.0	14.2	34.1	57.6	$6.0 \times 14.2 = 85.2$	$6.0 \times (19.9 + 43.4) = 379.8$
10 to 19 days ..	14.4	40.8	63.3	74.3	$14.4 \times 40.8 = 587.5$	$14.4 \times (22.5 + 33.5) = 806.4$
20 to 59 days ..	31.1	50.2	56.6	65.2	$31.1 \times 50.2 = 1561.2$	$31.1 \times (6.4 + 15.0) = 665.5$
60 or more days ..	149.1	16.2	12.8	12.8	$149.1 \times 13.9 = 2072.5$	
Total ..	—	—	—	—	4306.4	1851.7

(b) *Depth of Workings and Thickness of Seam.*

It can be seen from Table XI that there is a close correspondence between temperature and depth of workings. The correlation coefficients were extremely high, especially that for dry bulb temperature :—

Between depth and dry bulb temperature $r = +\cdot952 \pm \cdot015$
 " " " wet " " " $r = +\cdot898 \pm \cdot032$

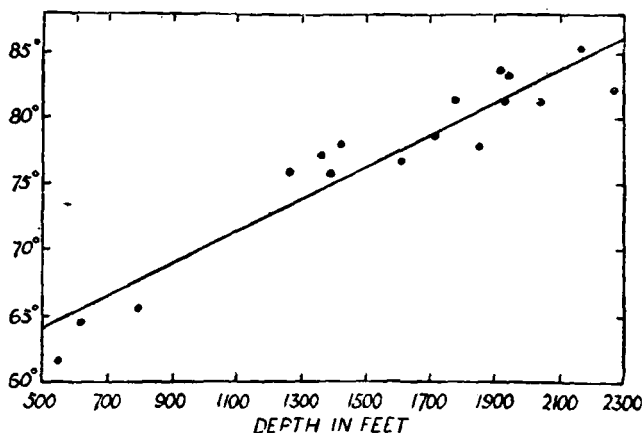


FIG. 8. Dry bulb temperature in relation to depth of workings.

The results obtained at the 17 seams are plotted in Fig. 8, where it will be seen that the individual values correspond closely with the regression line of temperature on depth. The regression equations of temperature on depth indicated that for each 1,000 ft. increase of depth there was an average rise of $12\cdot7^\circ$ F. in dry bulb temperature, and of $8\cdot4^\circ$ F. in wet bulb temperature, whilst the regression equations of depth on temperature indicated that for each rise of 1° F. in dry and wet bulb temperatures there was an average increase in depth of 71·6 and 96·1 ft. respectively. The following relationships between dry bulb temperature and depth were deduced from the equation :—

<i>Depth of workings.</i>				<i>Dry bulb temperature.</i>
500 ft.	..	..	..	63·6° F.
1,000 ft.	..	..	..	70·0° F.
1,500 ft.	..	..	..	76·3° F.
2,000 ft.	..	..	..	82·6° F.
2,500 ft.	..	..	..	89·0° F.

It has been calculated that the standard error of estimation of temperature on depth is $2\cdot06^\circ$ F. That is to say, if the depth of the workings in any seam of the ten pits investigated is known, the dry bulb temperature of the air can be predicted with an *average* error of only 2 deg.

TABLE XXII.—*Correlation of accident rates of coal face workers with depth.*

Cause of accidents.	Accident frequency.	Accident severity.
Falls of ground.. ..	+·614 ± ·072	+·305 ± ·105
Other causes	+·286 ± ·106	-·046 ± ·115
All causes	+·538 ± ·082	+·225 ± ·110

The correlations of the accident rates of coal face workers with depth are recorded in Table XXII. It will be seen that accidents from falls of ground are highly correlated in respect of frequency, and to a much less extent in respect of severity. On the other hand, accidents from other causes, if considered in relation to severity as well as frequency, cannot be said to have any significant correlation with depth. The corresponding correlations for other underground workers are not recorded, as it was impossible to determine the average depth at which the men were working with sufficient exactness.

The relationships observed at the individual seams between the frequency of accidents from falls of ground and the depth are plotted in Fig. 9. It will be seen that there is a fairly good correspondence with the regression line. Assuming that this line correctly represents the relationship between accidents from falls of ground and depth, we calculated from the regression equation that the mean accident frequency at a depth of 500 ft. was 27, whilst that at a depth of 2,300 ft. was 67, or $2\frac{1}{2}$ times as much.

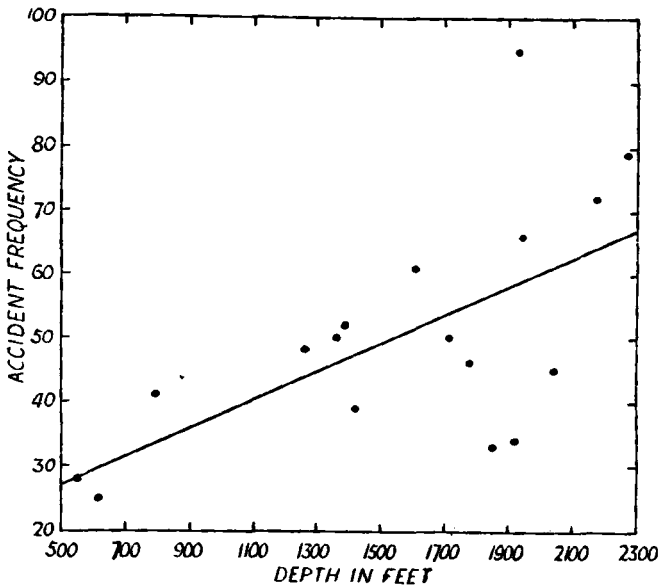


FIG. 9. Frequency of accidents from falls of ground in relation to depth of workings.

TABLE XXIII.— *Accident rates of coal face workers in relation to depth.*

Range of depth.	Mean depth (feet).	Accident frequency.			Accident severity.			Total shifts worked.
		Falls of ground.	Other causes.	All causes.	Falls of ground.	Other causes.	All causes.	
Under 1,000 ft. ..	670	32	46	78	1.5	1.9	3.4	381,169
1,000 to 1,499 ft. ..	1,352	47	53	100	1.9	1.5	3.4	673,440
1,500 to 1,999 ft. ..	1,822	57	61	118	1.9	1.7	3.6	1,895,563
2,000 ft. or more ..	2,183	67	76	143	2.3	2.1	4.4	942,503

On classifying the data according to the depth and irrespective of the pit, the mean results recorded in Table XXIII were obtained. They are plotted in Fig. 10, and it will be seen that the frequency of accidents from "other causes" increased fairly regularly with depth, though not so rapidly and regularly as those from falls of ground. However, the severity rate of accidents from other causes showed no consistent relationship to depth.

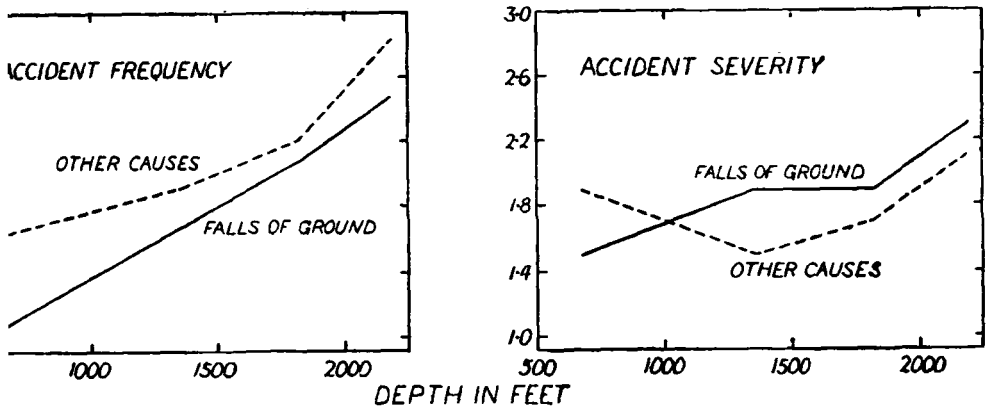


FIG. 10. Accidents of coal face workers in relation to depth of workings.

As depth and temperature are so highly correlated, it follows that the association of depth with accidents involving various durations of absence is similar to that observed for temperature. In Table XXIV the frequencies of accidents from falls of ground and from other causes are recorded in relation to depth. From the relative numbers given on the right side of the Table, it will be seen that at an average depth of 2,183 ft. minor accidents, lasting less than 10 days, were more than four times as numerous as at a depth of 670 ft. Major accidents from falls of ground, lasting 60 days or more, were uninfluenced by depth, whilst those due to other causes were considerably less frequent in deep pits than in shallow ones. The reason of this is unknown. Accidents involving an intermediate degree of disability showed an intermediate response to depth, as can be gathered from the curves plotted in Fig. 11.

TABLE XXIV.—*Accident disability of coal face workers in relation to depth.*

Duration of absence.	Accident frequency at depth of				Relative frequency at depth of				
	under 1,000 ft.	1,000 to 1,499 ft.	1,500 to 1,999 ft.	2,000 ft. or more.	under 1,000 ft.	1,000 to 1,499 ft.	1,500 to 1,999 ft.	2,000 ft. or more.	
(Mean depth)	670	1,352	1,822	2,183	—	—	—	—	
Falls of ground {	Under 10 days	3.7	7.1	14.4	18.0	100	192	389	486
	10 to 19 days	11.3	18.4	20.1	22.0	100	163	178	195
	20 to 59 days	11.5	15.2	18.0	21.8	100	132	157	190
	60 days or more	5.2	6.1	4.3	5.4	100	117	83	104
Other causes {	Under 10 days	6.8	11.6	16.5	24.4	100	171	243	359
	10 to 19 days	14.7	20.9	23.5	26.4	100	142	160	180
	20 to 59 days	18.6	18.4	18.3	22.3	100	99	98	120
	60 days or more	6.3	2.4	3.1	3.2	100	38	49	51

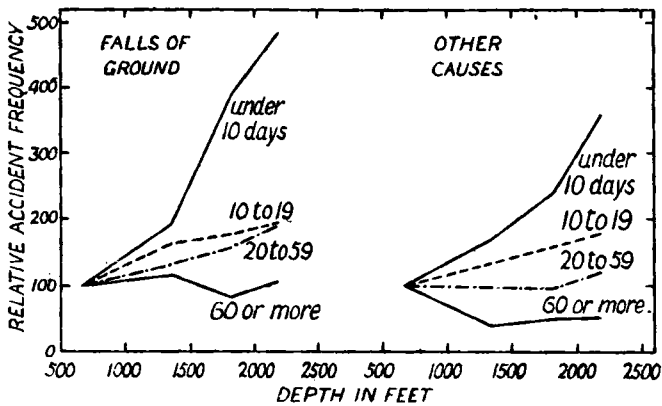


FIG. 11. Accident disability of coal face workers in relation to depth of workings.

The accident rate is greatly influenced by the thickness of the coal seam, the greater the thickness the greater being the frequency in the falls of coal and of side. We ascertained the average thickness of the seams at the 17 localities recorded in Table XI, and found that it varied between 36 and 72 inches. The correlation coefficients were:—

For accident frequency from falls of coal with thickness of seam $r = +.707 \pm .058$
 For accident severity from falls of coal with thickness of seam $r = +.665 \pm .065$
 For accident frequency from falls of roof with thickness of seam $r = -.149 \pm .113$

It will be seen that there was no significant correlation between accident frequency from falls of roof and thickness of seam.

A more satisfactory method of demonstrating the relationship between accident rate and thickness of seam is to keep to the same seam throughout. The E seam, which we investigated at six collieries, varied in average thickness from 44 to 72 in., and it will be seen from the data adduced in Table XXV that the accident rate from falls of coal and side (which formed 40 per cent. of all accidents from falls of ground) varied in close correspondence

with the thickness. Frequency and severity were affected almost equally, the rate of each of them being more than four times greater when the seam was at its thickest than when at its thinnest.

TABLE XXV.—*Accidents through falls of coal and side in relation to thickness of seam.*

Colliery.		Depth of workings.	Thickness of seam.	Accident frequency.	Accident severity.
		Ft.	In.		
P	.. ..	1,850	44	9.0	0.32
N	.. ..	1,386	50	12.7	0.45
L	.. ..	2,269	66	27.8	0.97
Q	.. ..	1,260	66	32.0	1.01
M	.. ..	1,420	72	32.4	1.04
J	.. ..	1,608	72	41.6	1.56
				29.9	0.99
				37.0	1.30

It follows from this correspondence between frequency and severity rates that the influence of thickness of seam was as great on major accidents as on minor accidents. This deduction is supported by the disability figures recorded in Table XXVI. They are rather irregular, owing to the fact that there were only 17 sets of data altogether (i.e., one for each of the 17 seams investigated), but it will be seen that accidents of all durations were about four times more numerous when 72-in. seams were being worked than with 36- to 48-in. seams. This similarity of effect on accidents involving all degrees of disability is what one would expect, for there was no correspondence between thickness of seam and depth. That is to say, the atmospheric conditions at thick seams were neither better nor worse than those at thin seams, so there was no greater inducement for the men who incurred minor accidents to go on compensation more frequently if they worked at thick seams than at thin ones.

Since there was no correspondence between atmospheric conditions and thickness of seam, it follows that the association between accident rates and atmospheric conditions cannot have been influenced by the thickness of the seams.

TABLE XXVI.—*Accident disability from falls of coal in relation to thickness of seam.*

Duration of absence.	Accident frequency at seams of					Relative frequency at seams of				
	36" to 48".	50" to 54".	60" to 63".	66".	72".	36" to 48".	50" to 54".	60" to 63".	66".	72".
Under 10 days ..	2.6	2.7	1.9	9.2	11.4	100	104	73	354	498
10 to 19 days ..	3.8	5.8	4.8	10.4	12.1	100	153	126	274	318
20 to 59 days ..	2.5	5.1	7.1	10.1	10.8	100	204	284	404	432
60 days or more	0.8	0.8	2.0	1.7	3.9	100	100	250	213	487

The results recorded in Table XXVI, in spite of their irregularity, afford a valuable support to the correctness of the explanation given for the excess of minor accidents experienced under adverse atmospheric conditions in the pits.

It is interesting to note that in 1909 the Committee on Accidents of the Royal Commission on Mines found that the death-rate from falls of ground of persons employed underground in South Staffordshire was much higher in thick seams than in thin ones. In the very thick seams (over 15 feet) the death-rate was 2·3 per 1,000, and in the thin seams, 0·8.

(c) *Output per Man.*

The output of the miners at the various pits differed considerably, and at most of the collieries we were able to obtain information concerning the average output per man (at the coal face) per shift. This information is recorded in Table XXVII in a relative form for the years 1924 and 1925. It will be seen that the means of the two years' results vary between the extremes of 68 and 137, or as 1 to 2. The accident frequency data are likewise recorded, and it is evident that there is a rough correspondence between the two. The correlation coefficient of output with accident frequency was, in fact, rather high.

For output with accidents from falls of ground $r = +\cdot615 \pm \cdot079$
 " " " " " other causes $r = +\cdot340 \pm \cdot113$
 " " " " " all causes $r = +\cdot580 \pm \cdot084$

TABLE XXVII.—*Accident frequency of coal face workers in relation to output.*

Colliery and seam.	Depth in feet.	Thickness of seam worked, in inches.	Relative output.			Accident frequency from		
			1924.	1925.	Mean.	Falls of ground.	Other causes.	All causes.
N, H	546	54	65	71	68	28	75	103
A (1), C	616	60	93	98	96	25	38	63
N, G	791	36	85	90	87	41	42	83
N, E	1,386	50	88	86	87	52	59	111
M, E	1,420	72	102	115	108	39	57	96
A, D	1,581	63	81	78	79	48	46	94
J, E	1,608	72	140	133	137	61	67	128
K, D	1,715	54	114	109	112	50	102	152
P, E	1,850	44	95	84	89	33	39	72
M, D	1,930	66	133	133	133	93	66	159
B, D	1,942	60	121	107	114	66	73	139
K, F	2,042	48	84	82	83	45	74	119
B, F	2,168	54	85	90	87	72	59	131
L, E	2,269	66	121	119	120	79	82	161

The relationships observed for the individual seams between output and accidents from falls of ground are plotted in Fig. 12,

and it will be seen that the values agree fairly well with the regression line.

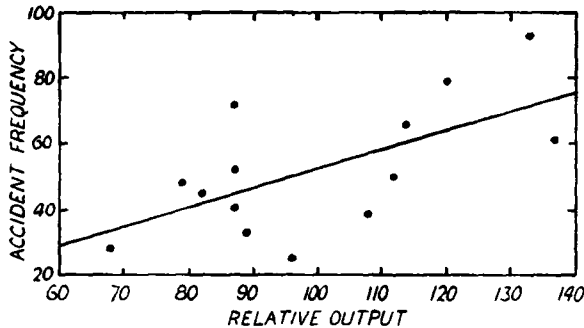


FIG. 12. Frequency of accidents from falls of ground in relation to output.

Other correlation coefficients calculated from the observations recorded in Table XXVII were the following :—

For depth with accidents from falls of ground $r = +.702 \pm .065$
 For output with depth $r = +.410 \pm .106$
 For output with thickness $r = +.624 \pm .078$

It might be thought that the positive correlation of output with depth is opposed to our previous observations (1927), in which we found that the working capacity of the miners is considerably reduced at high temperatures. The explanation of the apparent contradiction depends on the fact that the coal of the deepest seam investigated, the D seam, is softer and more easily extracted than that of the E seam lying above it, whilst that of the shallow C seam is hard steam coal, difficult to extract.

The high positive correlation between output and thickness suggests that much of the increase of accidents associated with higher output should really be ascribed to the influence of the thick seams.

When the accidents were classified according to their duration, it was found that the effect of rate of output on frequency was practically confined to minor accidents. From Table XXVIII, which shows the accident frequency from all causes at seams where various outputs were attained, it will be seen that at pits where the output was 120 or more, the minor accidents—causing less than 10 days' disablement—were three times more numerous than at pits where the output was 80 or less. Accidents causing 10 to 19 days' disability showed a moderate increase with increasing rate of output, whilst accidents causing 20 days or more of disability were practically independent of output. This relationship held equally for accidents from falls of ground and from other causes, but we thought it unnecessary to record the separate sets of data. This increase of minor accidents with increase of output may be dependent on the above-mentioned correlation of output with depth. We saw previously that minor accidents increased with increase of depth, and consequently they likewise increase with increase of output.

TABLE XXVIII.— *Accident disability in relation to output per man.*

Duration of absence.	Accident frequency when output was					Relative frequency when output was				
	Under 80.	80 to 89.	90 to 109.	110 to 119.	120 or more.	Under 80.	80 to 89.	90 to 109.	110 to 119.	120 or more.
Under 10 days ..	15	21	18	45	46	100	140	120	300	307
10 to 19 days ..	31	39	34	53	51	100	126	110	171	165
20 to 59 days ..	50	32	34	47	41	100	64	68	94	82
60 days or more	12	7	10	9	9	100	58	83	75	75

Related to the subject of rate of output is the rate of advance of the coal face. It is stated by the Safety in Mines Research Board (1926) that risks at the working face usually diminish as the rate of advance increases. We were able to obtain information about the rate of advance of the coal face at all the collieries investigated except one, and we found that it showed great variations. In the E seam it ranged from 70 to 140 yds. per year, in the D seam, from 80 to 150 yds., and in the F seam, from 120 to 380 yds. The correlation between rate of advance of coal face and accident frequency was insignificant, as the following coefficients show:—

For rate of advance of face on accidents from all falls of ground $r = -.147 \pm .129$

For rate of advance of face on accidents from falls of roof only $r = +.020 \pm .132$

When, however, all the available data from the various pits were grouped together, and classified according to the average rate of advance, the accidents (from all falls of ground) showed a distinct diminution of frequency with increasing rate of advance. As can be gathered from the data recorded in Table XXIX, the rate diminished less in respect of minor accidents than in respect of major ones.

TABLE XXIX.— *Accident frequency in relation to rate of advance of coal face.*

Duration of absence.	Frequency when rate of advance was					Relative frequency when rate of advance was				
	80 yds. or less.	101 to 120 yds.	121 to 140 yds.	141 to 160 yds.	380 yds.	80 yds. or less.	101 to 120 yds.	121 to 140 yds.	141 to 160 yds.	380 yds.
Under 20 days ..	34	39	39	27	28	100	115	115	79	82
20 to 59 days ..	21	21	15	14	13	100	100	71	67	62
60 days or more	6.2	5.2	4.8	3.7	3.6	100	84	77	60	58

Another matter indirectly related to rate of output is labour turnover. As will be shown hereafter, the labour turnover at the various pits investigated varied between the extremes of 9.6 per cent. and 33.6 per cent. per annum, and it seems reasonable to assume that if the labour turnover is large (in respect both of men leaving and of new men taken on), the men are less contented with the conditions of work than if it is small. When we

classified the accidents of the coal face workers according to the labour turnover at the pit at which they were incurred, we obtained the results recorded in Table XXX. We see that minor accidents causing less than 20 days' disability were three times more numerous at pits where there was a labour turnover of 20 per cent. or more than at those where it was less than 10 per cent. Accidents causing 20 days or more of disability were, however, unaffected by the labour turnover of the pit.

TABLE XXX.— *Accident disability of coal face workers in relation to labour turnover.*

Duration of absence.	Accident frequency when labour turnover was				
	Under 10 per cent.	10 to 19 per cent.	20 to 29 per cent.	30 to 39 per cent.	40 per cent. or more.
Under 20 days	26	49	84	78	81
20 to 59 days	40	30	43	28	42
60 days or more	14	8	9	6	8

(d) *The Age of the Men.*

It is well known that the accident rate tends to decrease as the experience and age of the workers increase. For instance, Chaney and Hanña (1918) found that the accidents suffered by the men employed at a large steel works fell steadily with length of service, till it reached zero with men of over 15 years' service. Kitson and Campbell (1923), who obtained information relating to 29,000 accidents incurred in the manufacture of motor cars, railway cars, cutlery, and coke and gas, found that the accident rate varied synchronously with the number of new men employed. No attempt was made in either of these investigations to distinguish between the effects of experience and of the age of the workers, but Miss E. M. Newbold (1926), in her statistical study of the accidents incurred in a number of industrial occupations, such as the manufacture of machinery, motor cars, soap, and confectionery, came to the conclusion that age is a more important factor than experience. The accidents certainly diminished with experience, but when allowance was made for age there was no independent association between experience and accidents. However, her data did not include many absolutely new workers. In a few instances the accident rate reached a minimum at an age of 47 to 65, and rose at greater ages, but as Miss Newbold points out, the numbers of accidents at the higher ages are too few for the rise to be of any significance when considered alone, though its agreement with a similar rise of the accident mortality rates among older workers is suggestive.

As previously stated, we were able to calculate the age distributions of the men at all the collieries in 1924 and 1925 from our information about the ages of the men signing on after the coal disputes of 1921 and 1926. As the age of every man coming under compensation is recorded at the time of his accident, we were able to calculate the accident rates at various ages with considerable accuracy. The mean results are recorded in Table XXXI, and are plotted in Fig. 13. It will be seen that

TABLE XXXI.—*Accidents in relation to the age of the men.*

		Age group.					
		Under 20.	20 to 29.	30 to 39.	40 to 49.	50 to 59.	60 and over.
Coal face workers	Number employed	263	2,838	2,626	1,921	934	189
	Frequency ..	312	264	232	268	283	327
	Relative frequency	134	114	100	116	122	141
	Severity	6·06	5·45	5·31	7·26	8·37	10·60
	Relative severity	114	103	100	137	158	200
Others underground	Number employed	3,363	2,496	1,297	1,132	849	397
	Frequency ..	199	139	140	157	145	157
	Relative frequency	142	99	100	112	104	112
	Severity	4·67	3·10	3·67	4·24	4·64	5·48
	Relative severity	127	84	100	116	126	149

both with the coal face workers and the other underground workers the accidents reached a minimum at an age of about 30, and rapidly increased at higher ages. At an age of 60 or more coal face workers suffered 41 per cent. more accidents than at 30-39, and as their accident severity rate was 100 per cent. greater, it follows that for each accident incurred by the older men there was, on an average, a much greater loss of working time. Owing to the large number of men concerned and to the fact that they were all employed on work of the same character, whatever their age, it follows that considerable reliance can be placed on the correctness of this variable relationship between accident rate and age. The same claim cannot be made for the accident rates of the other underground workers, as the occupations of these men varied greatly with age. The younger men were mostly occupied on haulage work of various kinds, and the older ones, upon light repairing jobs on the roads, and on overseeing the other men. Men engaged in drifting (driving new roads) and ripping (removing ground from the roof) were usually of intermediate age. We do not know to what extent the accident risks of these men varied with occupation, but from the results recorded in Table XXXI it is clear that, taken as a whole, their risks were much less than those of the coal face workers.

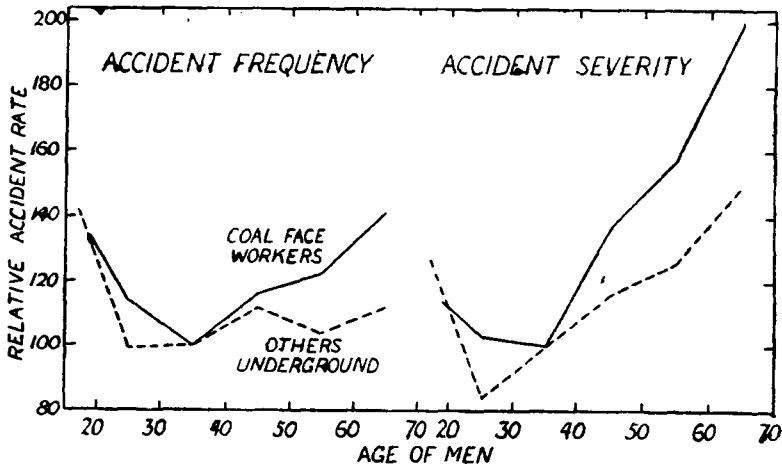


FIG. 13. Accident rates in relation to the age of the men.

It may be wondered why the relationship of accident rate to age in coal miners differs so considerably from that observed in other industrial workers. Probably it is due to the arduousness of the coal miners' work. Accidents tend to diminish with age, because the older men are usually more skilful and more careful than the younger men; but on the other hand they are more easily fatigued, and fatigue may lead to accidents.

Another method of showing that, the older the men, the longer the duration of their accident disability, was to classify the accidents incurred at various ages according as they led to a disability of less than 20 days, of 20 to 59 days, and of 60 days or more. It will be seen from Table XXXII that whilst 67 per cent. of the accidents incurred by the youngest men (coal face workers) lasted under 20 days, only 48 per cent. of those incurred by men of 50 and upwards had a similar duration. On the other hand, accidents causing a disability of 60 days or more formed but 5 per cent. of the accidents to the youngest men, as against 11 per cent. of those to the oldest men.

TABLE XXXII.—*Accident disability in relation to age of men (coal face workers).*

Age of men.	Percentage of accidents causing absence of			Number of accidents		
	under 20 days.	20 to 59 days.	60 days or more.	under 20 days.	20 to 59 days.	60 days or more.
Under 30 years ..	67	28	5	1,108	476	77
30 to 39 years ..	65	28	7	793	346	77
40 to 49 years ..	56	35	9	580	354	97
50 or more years ..	48	41	11	314	269	68

(e) *Hour of Shift.*

The influence of fatigue in the causation of accidents is suggested by the frequency with which accidents occur during the progress of the shift. The time at which an accident happened was always recorded, and from these records we determined the frequency from hour to hour of the 7-hour shift. We split up our data according to the air temperature (under 70°, 70° to 79° or 80° and over), and the accidents per hour per 100,000 man-shifts are plotted in Fig. 14. It will be seen that amongst coal face workers they reached a maximum in the sixth

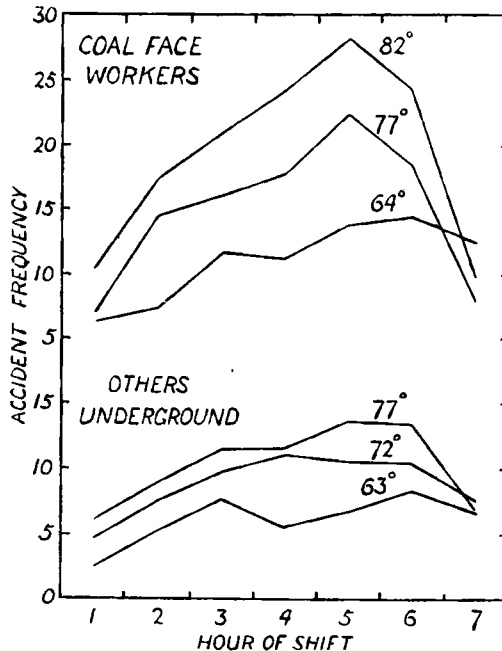


FIG. 14. Accident frequency in relation to hours of shift.

hour of the shift when the temperature was low, and in the fifth hour when it was medium or high. As the miners work for only a portion of the last hour of the shift, their accident frequency during this hour may be ignored. Consequently it follows that at low temperatures the coal face workers attained their maximum accident frequency in the last hour of full work, whilst at high temperatures they attained it in the last hour but one. The other underground workers, whilst attaining maximum accident frequency in the last hour of full work at low temperatures, attained it one to two hours earlier when working at higher temperatures.

When the accidents were separated into those due to falls of ground and those due to other causes, they were found to give closely similar distributions in frequency during the course of the shift.

It should be stated that our data include the men working on all the shifts, whether morning, afternoon or night. When split up according to shifts, the distribution was very similar in all three. The morning and afternoon shifts were approximately equal in size, but the night shift was very much smaller.

5. Absenteeism due to "Voluntary" Causes.

The term "voluntary," as applied to absenteeism, is taken to imply all absenteeism which is not definitely attributed to accidents or to sickness. It is impossible to say how exact a measure it is of genuine voluntary absenteeism, because it suffers from an over-estimate in some directions, and an under-estimate in others. For instance, a man may suffer a minor injury which incapacitates him for two or three days, but if it does not prevent work for the minimum legal period of four days, he is not entitled to accident compensation. Again, a man may catch a cold and feel too ill to work for two or three days, but as he is not entitled to claim sickness benefit for the first three days of an illness, it is useless for him to obtain a doctor's certificate, and at collieries where such a certificate is demanded as a proof of sickness, his absenteeism counts as "voluntary." As already stated, this particular cause of error did not arise in the present observations, as the word of the individual miners was relied on, if considered satisfactory by the time keeper, but the judgment of time keepers is not infallible. Again, if a miner arrives late at the pit head for any cause whatsoever, e.g., some breakdown in the transport from his home, he is not allowed to go underground, and loses his whole day's work. Amongst factory workers, however, late arrival is often condoned, and especially so if the lateness is not due to the worker's own fault.

On the other hand, we have seen that under adverse working conditions, such as high temperature, and even under adverse economic conditions, the men claim compensation for minor injuries far more frequently than when the conditions are more favourable, so in these instances a considerable fraction of the time ascribed to accident absenteeism should really have been classified as voluntary absenteeism.

The Coal Commission (1926) concluded that, taking all the coal areas of the country together, rather less time was lost voluntarily than by sickness and accidents combined. Our own data show that in the area tested by us the coal face workers lost 8·8 per cent. of their time from voluntary causes and 7 per cent. from sickness and accidents, whilst the other underground workers lost the same amount of time from both sets of causes, namely, 4·8 per cent. We shall see that the surface workers lost slightly less time voluntarily than from sickness and accidents, but as they formed only a fifth of the total number of men employed, it follows that the whole body of miners in the area investigated by us lost rather more time from voluntary causes than from involuntary ones. Hence it is a matter of great

practical importance to discover what we can about the conditions which tend to influence voluntary absenteeism, with a view to its reduction.

(a) *Atmospheric Conditions.*

The correlation tables previously recorded (pp. 8 and 10) indicate that there was little if any correlation between atmospheric conditions such as temperature, cooling power and air velocity, and the voluntary absenteeism of the coal face workers. On the other hand, the other underground men showed a substantial correlation in respect of temperature and air velocity. The correlation coefficient of voluntary absenteeism with wet bulb temperature was $+0.39$, and on classifying the combined data obtained at all the pits according to the wet bulb temperature, it was found—as can be gathered from Table XXXIII—that a rise of 10 deg. in temperature was associated with nearly a doubling of the voluntary absenteeism. Air velocity appeared to have just as much influence as wet bulb temperature. The correlation coefficient of voluntary absenteeism with air velocity was $+0.45$, and on combining and classifying the data it was found that the absenteeism was doubled when the air velocity rose from 137 ft. per minute to 264 ft. (*cf.* Table XXXIII).

The Table also indicates the proportions of the men living near to large towns. As will be shown later on, such proximity tends to augment their absenteeism, and the fact that the great majority of the men working at high air velocities lived near towns, whilst those working at low velocities did not, may be partly the cause of the increased absenteeism recorded. However, it will be seen that the adverse effect of high wet bulb temperature on absenteeism cannot be ascribed to this cause.

TABLE XXXIII.—*Voluntary absenteeism of other underground workers in relation to temperature and air velocity.*

Wet bulb temperature.		No. of men.	Percent living near large towns.	Per-centage of time lost.	Air velocity in feet per min.		No. of men.	Percent living near large towns.	Per-centage of time lost.
Range.	Mean.				Range.	Mean.			
Under 62° ..	58.3	262	91	3.6	Under 120 ..	90	1,837	32	4.6
62° to 65.9° ..	64.5	3,281	66	4.8	120 to 159 ..	137	2,068	21	4.4
66° or more ..	67.7	3,451	52	7.0	160 to 199 ..	171	1,244	94	5.2
					200 or more	264	1,819	97	8.8

The fact that coal face workers and other underground workers reacted so differently to atmospheric conditions may appear to discredit the reliability of the results. So far as concerns air velocity there is no contradiction, for we saw that, except at one pit, the air velocity to which the coal face workers were exposed never exceeded 80 ft. per minute; whilst with one exception, that to which the other underground men were exposed was always over 100 ft. The high air velocities appeared to induce sickness, for we saw that men exposed to a 264 ft. velocity lost twice as much time from this cause as those exposed to a 90 ft. velocity.

(b) *Distance of Workings from Pit Bottom.*

According to evidence furnished to the Royal Commission by the Mining Association,* the miners take on an average 23 minutes to get from pit bottom to coal face, but the time varies from 17 to 38 minutes in different districts, and in one pit it was over 60 minutes. When the distance from pit bottom to coal face is considerable, the men are frequently "ridden in" for part of the way, but admittedly they may sometimes have to walk over two miles. A long time spent in transit means a reduced time in which to get coal and a diminution of earnings, so it might be expected to cause discontent. We certainly found that it tended to increase the voluntary absenteeism of the men. We were able to determine the approximate distance which the men had to walk from pit bottom to coal face in seven of the pits, and it will be seen from Table XXXIV that it varied from 1,000 yds. to 2,860 yds. The average times lost from voluntary absenteeism appear to vary more or less in relationship with the distance walked, the correlation coefficient of absenteeism on distance walked being $+0.383 \pm 0.046$. When the results were split into three groups according to the distance walked, and averaged, it was found that an addition of 1,482 yds. to the distance was associated with a 58 per cent. increase in the time lost by voluntary absenteeism.

TABLE XXXIV.—*Relationship between voluntary absenteeism and distance walked underground.*

Colliery.	Distance walked in yards.	Percentage of time lost.
A (1), C	1,000	8.2
A (2)	1,500	7.0
M	1,500	6.8
A (1), D	2,000	8.9
L	2,420	12.5
J	2,500	3.9
K	2,770	11.3
N	2,860	11.7
	1,333	7.3
	2,307	8.4
	2,815	11.5

(c) *Labour Turnover.*

The extent of the labour turnover at a colliery affords some measure of the conditions under which the work is carried on. If the turnover is low the conditions are presumably satisfactory, and contented men are less likely to lose time by voluntary absenteeism than discontented men. If the turnover is high, it may be due to some extent to the age of the collieries, for the population takes time to settle down in a newly developed colliery

* Vol. 3, 314.

district. For the same reason absenteeism would be affected by the age of the collieries. Again, newer pits tend to be deeper than older ones, so the greater absenteeism observed at deep pits might be due to some extent to the more unsettled character of the miners, and not to the higher temperature. We obtained information about the age of the collieries investigated by us, and this information is recorded in Table XXXV. It will be clear that there was no close relationship between labour turnover and the age of the collieries investigated.

In order to test the relationship between labour turnover and absenteeism, we obtained information (a) in regard to the number of underground men who left, reckoned as a percentage of the average number of men on the books; and (b) in regard to the number of new men signed on, reckoned as a similar percentage. We obtained these data for each of the years 1924 and 1925, and for purposes of comparison with the absenteeism data we took a mean of the turnover data for the two years.

TABLE XXXV.—*Labour turnover and voluntary absenteeism.*

Colliery.	Age of Colliery in years.	Percentage of men.			Percentage of time lost voluntarily.	
		Leaving.	Taken on.	Mean.	Coal face workers.	Others underground
A (2) ..	60	4.9	10.0	7.5	7.0	2.8
A (1), D		17.9	5.6	11.8	8.9	3.2
A (1), C		11.0	8.1	9.6	8.2	3.6
J ..	10	18.0	23.3	20.7	3.9	3.0
L ..	22	19.4	22.6	21.0	12.5	8.8
M ..	55	26.2	25.8	26.0	6.8	4.6
B ..	32	24.8	28.7	26.8	—	—
N ..	47	25.8	28.0	26.9	11.7	6.3
K ..	100	28.6	28.3	28.4	11.3	6.0
P ..	11	33.0	34.2	33.6	—	—

The turnover at the various collieries—except at colliery Q, where data were not obtainable—is recorded in Table XXXV. It relates to all the underground workers put together, as it was not possible to separate them, and it will be seen that the percentages of men leaving and of new men taken on corresponded well at all the collieries except two. As the two collieries in question (A (2) and A (1), D) were connected underground and were working on the same seam, their turnover may be averaged. The means come to 11.4 per cent. of men leaving and 7.8 per cent. of new men. Hence it may be said that the correspondence between the numbers of men leaving and of new men taken on was fairly good at all the collieries, so a mean of the two values may be accepted as the best index of the turnover. It varied from a maximum of 33.6 per cent. to a minimum of 9.6 per cent.

The absenteeism of the coal face workers and of the other underground men had to be correlated with the labour turnover of the whole body of underground workers, and the coefficients obtained are recorded in Table XXXVI. It will be seen that there was little if any correlation between sickness and labour turnover, but that between voluntary absenteeism and labour turnover was quite distinct. The relationships between voluntary absenteeism at the individual collieries and turnover are recorded in Table XXXV. It will be seen that as the result of splitting the data into three groups and averaging, it appears that a trebling of the labour turnover was associated with almost a doubling of the voluntary absenteeism in "others underground," and with a 24 per cent. rise in the coal face workers. Apparently, therefore, dissatisfaction with the conditions of work, as indicated by the labour turnover, had a considerable influence on voluntary absenteeism.

TABLE XXXVI.—*Correlation of absenteeism with labour turnover.*

Absenteeism on account of	No. of observations used in each correlation.	Coal face workers.	Other underground men.
Sickness	155	- .071 ± .054	- .135 ± .053
Accidents	207	- .186 ± .045	+ .293 ± .043
Voluntary causes ..	155	+ .290 ± .050	+ .491 ± .041
All causes	207	+ .302 ± .043	+ .448 ± .037

(d) *Distance of Homes from Colliery.*

In order to determine if voluntary absenteeism was influenced by the distance of the miners' homes from the colliery, we obtained details at each colliery of the number of men living in various localities. By measuring the distances on a large scale map, we were able to ascertain the average distance between the pit and the men's homes. As can be gathered from Table XL, it ranged between the extremes of 1.4 and 3 miles. The correlation between the average distance (of all underground workers) and the absenteeism of the coal face workers and others is recorded in Table XXXVII. It will be seen that the coefficients of voluntary absenteeism with distance were fairly high, being + .61 and + .50 respectively, whilst those of distance with sickness were negative. That is to say, the further the men lived from the colliery the greater their voluntary absenteeism but the less their sickness. An explanation of this curious result is afforded by the correlation coefficients between the average age of the men and the average distance between homes and pit. For the eight collieries (or seams) where reliable sickness data were obtained, they were strongly negative, the coefficient between age and distance being - .700 ± .122 for coal face workers, and - .710 ± .118 for other underground workers. These values indicate that the older

men lived a good deal nearer to the colliery than the younger ones, and as they were more liable to sickness, it follows that the correlation of sickness absenteeism with distance of homes was negative.

TABLE XXXVII.—*Correlation of absenteeism with distance of homes from colliery.*

Absenteeism on account of	No. of observations used in each correlation.	Coal face workers.	Others underground.
Sickness	155	- .361 ± .047	- .206 ± .052
Accidents	228	- .042 ± .045	+ .355 ± .039
Voluntary causes	155	+ .610 ± .034	+ .496 ± .041
All causes	228	+ .282 ± .041	+ .362 ± .039

The relationship between age and distance is shown more directly in Table XXXVIII. It will be seen that the coal face workers living nearest to their respective collieries were nearly seven years older than those living furthest from them, whilst the other underground workers were two years older. That the older men were also the steadier men with a low labour turnover is indicated by the fact that there was a considerable negative correlation between age and labour turnover, the coefficient between age and labour turnover being $- .756 \pm .102$ for coal face workers, and $- .385 \pm .203$ for other underground workers. We see from Table XXIX that when the seams were classified according to the average age of the workers, the associated labour turnover ranged from 39 per cent. for the youngest coal face men to 10 per cent. for the oldest men, and from 32 per cent. for the youngest of the "others underground" to 18 per cent. for the oldest. Again, we see from Table XXXVIII that the labour turnover of the men living nearest to the collieries was not half as great as that of the men living furthest from them.

TABLE XXXVIII.—*Average age and labour turnover in relation to average distance of homes from colliery.*

Range of distance of homes from pit.	Average distance.	No. of seams.	Mean labour turnover of all underground men.	Average age in years.	
				Coal face workers.	Others underground.
1·60 miles or less ..	1·59	5	Percent. 19·3	37·9	29·7
1·61 to 2·10 miles ..	1·88	3	22·0	39·0	28·4
2·11 to 2·60 miles ..	2·29	3	23·6	36·4	29·2
2·61 to 3·10 miles ..	2·89	2	28·4	31·5	27·9
3·11 miles or more ..	3·39	2	42·9	31·1	27·8

TABLE XXIX.—*Labour turnover in relation to average age.*

Age group.	Coal face workers.			Others underground.		
	Average age.	No. of seams.	Mean labour turnover for all underground.	Average age.	No. of seams.	Mean labour turnover for all underground.
Under 28 ..	—	—	Per cent.	26·3	5	Per cent.
28 to 31·9 ..	30·9	3	39·3	29·6	8	31·7
32 to 35·9 ..	33·8	4	26·5	33·5	2	23·3
36 to 39·9 ..	38·6	5	23·1	—	—	18·4
40 or more ..	40·7	3	9·6	—	—	—

The relationship of voluntary absenteeism to distance of homes at the individual collieries is shown in Table XL. It will be seen that up to a distance of two miles the absenteeism was fairly steady, whilst at distances greater than two miles it was nearly double as much. The three distant pits which showed the large voluntary absenteeism were not situated in the same neighbourhood. In fact, they were several miles apart.

TABLE XL.—*Voluntary absenteeism in relation to distance of homes from colliery.*

Colliery.	Distance of homes from pit in miles.	Percentage of time lost voluntarily by		
		Coal face workers.	Others underground.	Mean.
A (2)	1·39	7·0	2·8	4·9
M	1·60	6·8	4·6	5·7
B	1·68	—	—	—
Q	1·78	—	—	—
J	1·80	3·9	3·0	3·5
A (1) D	1·81	8·9	3·2	6·1
A (1), C	1·94	8·2	3·6	5·9
L	2·13	12·5	8·8	10·7
P	2·16	—	—	—
K	2·89	11·3	6·0	8·7
N	3·00	11·7	6·3	9·0

(e) *The Proximity of Large Towns.*

It has been mentioned that the collieries investigated were situated within a few miles of two large towns. The Coal Mining Organisation Committee (1915) were informed that absenteeism

was always greater at collieries near to large towns than at those situated in rural areas. At the various collieries we ascertained the numbers of men living in different localities, and from these data we have calculated the percentages of men living in, or within easy reach of, these large towns. From Table XLI we see that the number varied from 0 to 99 per cent. of the men. The collieries with the smallest proportion of men residing in close proximity to towns were those which showed, on the whole, the least absenteeism, but the difference was not marked.

Table XLI.—*Absenteeism and labour turnover in relation to percentage of men living near large towns.*

Colliery.	Percentage of men living near large towns.	Per cent. of time lost voluntarily.		Per cent. of time lost from all causes.		Mean percentage labour turnover.
		Coal face workers.	others underground.	coal face workers.	others underground.	
B	99	—	—	18.8	8.4	26.8
L	97	12.5	8.8	21.9	16.0	21.0
A.2	96 } 95	7.0 } 9.8	2.8 } 5.3	13.1 } 16.9	7.3 } 10.0	7.5 } 18.7
K	93	11.3	6.0	17.2	10.9	28.4
A (1) C	91	8.2	3.6	13.5	7.5	9.6
A (1) D	85 } 77	8.9 } 10.3	3.2 } 4.8	18.8 } 18.0	8.8 } 9.6	11.8 } 19.4
N	68	11.7	6.3	17.2	10.4	26.9
P	25	—	—	19.4	14.0	33.6
J	2	3.9	3.0	10.1	7.3	20.7
M	1 } 7	6.8 } 5.4	4.6 } 3.8	14.9 } 14.8	9.2 } 10.1	26.0 } 26.8
Q	0	—	—	14.7	9.9	—

It has been suggested to us that one explanation of this influence of the proximity to large towns might be the opportunity for the employment of the female members of the colliers' families in the industries of the town. After careful enquiry we have found that in the towns in question there is little opportunity for such employment, and the families living in the towns would be but little better placed in this respect than those in the small mining villages in the neighbourhood. Another and more likely explanation is that in the larger towns there is more distraction to be found in the way of sporting events, excursions and other amusements.

There must be innumerable other causes affecting voluntary absenteeism which we were not able to investigate or obtain evidence about, but one powerful influence was briefly investigated, namely, wage payments. During the 21 months of our chief statistical period the wage rate varied between the extremes of 168.4 and 146.7, and on splitting up the data into three groups and averaging, we observed the following relationships between wages and total absenteeism in the coal face workers at all the collieries combined :—

<i>Mean wage rate.</i>	<i>Total absenteeism.</i>
163.1	17.3 per cent.
158.0	16.4 ..
147.5	16.0 ..

These figures suggest that the higher the scale of pay the more readily did the men absent themselves. This effect of wage scale is well known in other industries, and again it is illustrated in the present report by comparing the absenteeism of the well-paid coal face workers with that of the less well-paid other underground men, and of the least well-paid surface workers.

6. Absenteeism of Surface Workers.

We were able to obtain information concerning the absenteeism of the surface workers at all of the ten collieries investigated from August, 1924, to April, 1926. For collieries J and M, and again for A (1) and A (2), the information was combined, so the data recorded in Table XLII relate only to eight units. It will be seen that on an average the surface workers lost 7·7 per cent. of working time, as compared with the 17·1 per cent. shown by the coal face workers and the 10·7 per cent. shown by the other underground men. The smaller loss was due partly to the fact that the time lost from accidents was only a half to a quarter as great as that lost by the underground men, but chiefly to the smaller extent of the voluntary absenteeism. It can be seen from Table III that in the pits where complete data were obtained, the coal face men lost 8·8 per cent. of their time voluntarily, and the other underground men, 4·8 per cent., whilst Table XLII shows that the surface men lost only 3·7 per cent. of it. This lower voluntary absenteeism must have been due in part to economic causes, as already suggested.

TABLE XLII.—*Absenteeism of surface workers from various causes.*

Colliery.	No. of men.	Percentage of time lost from				Percentage of time lost from all causes by	
		Sick-ness.	Acci-dents.	Volun-tary causes.	All causes.	Coal face workers.	Others under-ground.
Q ..	462	2·1	0·9	2·8	5·8	14·7	9·9
A ..	360	3·7	0·5	2·0	6·2	14·8	7·8
B ..	312	1·9	0·3	4·1	6·3	18·8	8·4
J + M	1,278	3·7	0·9	2·9	7·5	12·5	8·2
K ..	608	3·3	0·7	3·7	7·7	17·2	10·9
P ..	378	4·4	0·6	3·2	8·2	19·4	14·0
N ..	428	3·6	1·1	5·0	9·7	17·2	10·4
L ..	630	4·0	0·9	5·6	10·5	21·9	16·0
Mean ..		3·3	0·7	3·7	7·7	17·1	10·7

The loss of time from sickness was almost as great for surface workers as for underground men, but it differed in that it showed a considerable seasonal fluctuation. Presumably this was due

to the greater exposure of the surface men to the weather. The percentages of time lost in the four summer months (June to September) and the four winter months (December to March) are recorded in Table XLIII, and it will be seen that at every colliery but one the winter sickness was considerably in excess. The average excess, after weighting, came to 30 per cent. Total absenteeism showed an excess of 6.6 per cent., and if due allowance is made for the time lost by sickness and accidents, it appears that distinctly less time was lost by voluntary absenteeism in winter than in summer, the percentages of shifts lost being 3.7 and 4.1 respectively.

TABLE XLIII.—*Seasonal variation in absenteeism of surface workers.*

Colliery.	Sickness.		Accidents.		All causes.	
	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.
Q ..	1.8	2.5	0.7	0.9	5.3	6.7
A ..	2.7	4.6	0.6	0.5	6.5	6.7
B ..	1.7	2.4	0.2	0.3	6.7	6.9
J + M	3.2	4.2	0.9	0.9	7.2	8.0
K ..	2.9	4.1	0.8	0.6	8.1	8.1
P ..	3.4	5.7	0.4	0.6	7.4	9.4
N ..	4.1	3.1	1.2	1.1	10.1	10.1
L ..	3.6	4.2	0.7	1.0	10.8	10.5
Weighted mean.	3.03	3.93	0.76	0.79	7.88	8.40

7. Practical Conclusions.

The value of our analysis of the causes of absenteeism depends on the extent to which it is able to suggest feasible remedial measures for the reduction of absenteeism. We do not claim to have investigated more than a fraction of the numerous causes which influence absenteeism, but we think that we have obtained sufficient information to indicate the most hopeful lines on which progress can be made. Our chief conclusions relate to the extraordinary sensitiveness of the miner to his conditions of work and his general environment. Any and every change of condition affects, not only his voluntary absenteeism, but in addition—as we have indicated at length in previous sections (pp. 5 to 42)—the time lost by sickness and accidents as well. Our results suggest that the most valuable method of reducing absenteeism is to improve the conditions of work. We have seen, for instance, that there is probably a certain narrow range of air movement underground which is associated with a minimum of accidents, and that at lower or higher velocities the accident frequency rises rapidly. Our conclusion that accident and sickness rates increase

when the air velocity rises above a moderate figure was unexpected, and it is important that further information on the subject should be obtained. Probably the adverse effect of too rapid air currents is due to their tendency to chill the over-heated and perspiring men, who usually are very scantily clad when at work. Almost unavoidable delays occur from time to time (e.g., in the provision of tubs), which necessitate the men standing idle for periods which sometimes exceed twenty minutes in duration. Hence they may easily catch a chill, and in addition such delays may cause them to become temporarily more stiff and clumsy in their movements, and thereby to run an increased chance of accident. Even if improved ventilation does cause a slight increase in sickness and accidents, it may be worth while to introduce it, for it tends to reduce the high temperature of the air, and we saw that temperature is associated to a marked extent with absenteeism from sickness and accidents. Also improved ventilation would reduce the risk of explosion in mines rich in gas. In any case, our data show that in many instances the air velocity was much too low, and in several pits it averaged only 18 to 21 feet per minute at the coal face.

In addition to atmospheric conditions, we saw that other conditions such as the distance walked by the men from pit bottom to working place appeared to influence absenteeism greatly, and it is obvious that this distance could be reduced in many cases by an extension of the system of mechanical transport. There are other underground conditions requiring improvement which we did not subject to statistical investigation, and probably the most important of these is illumination. Such improvements are bound to affect the absenteeism of the miner.

The effects of improving the conditions above ground may be equally important, for we saw that such conditions greatly influence the large amount of time lost by other causes than notified sickness and accidents. We found that miners living $2\frac{1}{2}$ miles from the colliery showed nearly double the voluntary absenteeism of those living $1\frac{1}{2}$ miles from it, and there can be little doubt that the introduction of an adequate system of housing in the neighbourhood of a colliery would do much to reduce absenteeism and labour turnover. We obtained no information about the effect of pithead baths, but it seems probable that their introduction would make for increased contentment, and would in consequence reduce absenteeism.

It should be realised that, though many of our correlations were highly significant, it is impossible to predict with any accuracy what the absenteeism would be in individual instances, under a given set of conditions. Our results are *average* results, applying to the large body of men working at a number of pits, and treated as a group. Nevertheless our evidence, if considered with reference to the reduction of the average absenteeism in a community by the improvement of working conditions, is just as valuable as if it applied with equal force to individual instances.

Again, it should be realised that the correlation of absenteeism from any cause with some condition such as temperature, though it proves a definite association of two variables with one another, does not necessarily imply *causation*. The increased or decreased absenteeism may not be due directly to the high or low temperature, but be related to it indirectly, in some way not yet identified. Hence, it is important that we should obtain further information.

8. Summary.

The absenteeism of nearly 23,000 miners, working at a group of ten collieries, was studied for periods of 21 months to six years (p. 3). It was found that the total absenteeism of the men varied with the depth of the workings. In coal face workers the time lost at a depth of 650 ft. averaged 13·8 per cent., whilst that at a depth of 2,160 ft. came to 17·0 per cent., or 23 per cent. more. The haulage men and others working underground showed less absenteeism, but a greater variation, for absenteeism in the deepest pits was 46 per cent. greater than in the shallowest pits (p. 4).

Absenteeism from sickness varies greatly with the underground temperature. A rise of 13 deg. F. in the dry bulb temperature was associated with a 63 per cent. increase of sickness in the coal face workers, whilst a rise of 10 deg. was associated with a 74 per cent. increase of sickness in the other underground men. Presumably this influence depends chiefly on the sudden change of temperature experienced by the men on coming to the surface (p. 9).

Absenteeism from sickness is associated with air velocity, for the average time lost by underground workers other than those at the coal face was 85 per cent. greater at a velocity of 260 ft. than at one of 90 ft. This effect of air currents is probably due to the liability of the very lightly clad men to catch chills (p. 11).

Absenteeism from accidents is likewise related to air velocity. Accidents to underground men other than those at the coal face increased steadily at all velocities from 70 ft. per minute upwards, and at a velocity of 264 ft. they were 68 per cent. more numerous than at one of 87 ft. (p. 22).

Accident frequency varies greatly with underground temperature, though accident severity shows but little response as the effect is confined to minor accidents. In comparison with the number of minor accidents (causing less than 10 days' disablement) which occurred at the lowest temperatures (64 deg. d.b. and 61 deg. w.b.), those occurring at the highest temperatures (80 deg. d.b. and 71 deg. w.b.) were 4·3 times more numerous. Accidents causing 10 to 19 days' disablement were, however, only 2·0 times more numerous at the highest temperatures, and those causing 20 to 59 days' disablement were 1·5 times more numerous. Major accidents, causing 60 days or more of disablement, were of almost exactly the same frequency at the highest temperatures as at the lowest ones. The probable explanation of this remarkable differential effect of temperature is discussed in detail (pp. 24 to 29).

There is a close correlation ($r = + \cdot 95$) between depth of workings and dry bulb temperature. At depths of 500, 1,500 and 2,500 ft. the mean temperature was 63·6 deg., 76·3 deg. and 89·0 deg. respectively. Hence it follows that the frequency of accidents is highly correlated with depth. Minor accidents (causing less than 10 days' disablement) were four times more numerous at a depth of 2,200 ft. than at one of 670 ft., whilst major accidents were unaffected (p. 34).

The accident rate is greatly affected by the thickness of the seam. One seam was found to vary in thickness from 44 to 72 in. at six collieries, and the accidents from falls of coal and side were four times more numerous when the seam was at its thickest than when at its thinnest. This effect was just as marked on major accidents as on minor ones (p. 35).

The average output of coal per man at the coal face varied in the proportion of 1 to 2 at different pits, and accident frequency varied with output. At pits where output was 50 per cent. greater than in other pits, the minor accidents (causing less than 10 days' disablement) were three times more numerous, but accidents causing 20 or more days of disablement showed no increase (p. 38).

Accident frequency is related to labour turnover, for minor accidents causing less than 20 days' disablement were three times more numerous at pits where the annual labour turnover was 20 per cent. or more, than at those where it was less than 10 per cent. However, accidents causing over 20 days' disablement were not affected (p. 39).

Accident rates vary considerably with the age of the men, and reach a minimum at the age of 30 to 39. In comparison with this minimum, coal face workers over 60 years of age showed a 41 per cent. excess in frequency rate, and a 100 per cent. excess in severity rate, whilst the other underground men showed smaller increments (p. 40).

Accident frequency varies greatly at different hours of the shift, and in coal face men working at high temperatures it reached a maximum in the last full hour of work but one. In those working at low temperatures it did not reach a maximum till the last full hour (p. 42).

The time lost by "voluntary" absenteeism (i.e., all absenteeism not definitely attributed to sickness and accidents) was found to vary with the distance walked by the men underground, for men who walked 2,800 yds. showed 58 per cent. more absenteeism than the men who walked 1,330 yds. (p. 45). It is related to labour turnover, the men at pits with an annual turnover of 27 per cent. showing 24 to 75 per cent. more voluntary absenteeism than those at pits with a turnover of 10 per cent. (p. 46). Again, it is related to the distance of the men's homes from the collieries, men living 2·6 miles away showing 80 per cent. more voluntary absenteeism than those living 1·6 miles away. It is likewise influenced by the proximity of large towns (p. 50).

Surface workers showed less absenteeism from voluntary causes than underground men, but greater seasonal fluctuations in absenteeism from sickness.

In conclusion, we wish to offer our warm thanks to the managements of the collieries visited by us for their kind assistance during our investigations, and for placing their records at our disposal so freely.

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9. Appendix.

We are indebted to Miss Newbold, of the Statistical Department of the Medical Research Council, for advice concerning the working out of our results, and for the following detailed criticism of the correlation coefficients recorded in Tables IV, etc.

"It was noted on page 6 that monthly observations were made of absenteeism from sickness, etc. ; but that though numerous observations of atmospheric conditions were made for different places in each pit, these were taken at a later date and could not be paired either with the monthly or yearly observations of absenteeism. Single mean values for each pit (separated in respect of coal face workers and others underground) had to be taken. To make the fullest use of the data, however, the monthly values of absenteeism were not grouped in calculating the correlation coefficients, but used singly, associating each with the single appropriate mean atmospheric value for the pit in question. This treatment raises two statistical points which make the estimation of the correlation difficult. The first is that with x the unit is a single observation, and with y the unit is the *mean* of a group (each mean being repeated several times). If the groups were random samples of the whole set of observations, then it is well known that the correlations of means would give the same value as the correlations of single observations. If, however, there is selection in choosing the groups (as there certainly was, judging by the distinct differences in atmospheric conditions in different pits), and if there exists any correlation between single observations, then the correlation between the *means* of groups will be larger than the correlation between the single observations. The correlations used here are between the means of groups in one variable, and single observations of the other variable, so that the values obtained are probably larger than they would be if separate monthly observations of atmospheric conditions could have been used, but smaller than they would be if the single mean values for each pit for the whole period had been used as units for absenteeism as well as for atmospheric conditions.

"The second point concerns the value to be attached to the probable error of these correlation coefficients. As the number of independent values of atmospheric conditions is smaller than the number of independent values of absenteeism (varying from 10 to 17 in different Tables, according to the number of seams or pits concerned), it follows that the probable error of r found by the ordinary formula, using the number of independent values of absenteeism as the number of observations, is too small. What it actually is cannot be ascertained, except in respect of limiting maximum and minimum values. The values given in the tables are the minimum values. The maximum values for the probable errors recorded in Tables IV, VI, VII, XXXVI and XXXVII can be found by multiplying them by $\sqrt{21}$, or 4.58 (21 being the number of occasions when the same mean value for the atmospheric conditions at each seam or pit was used). The true value of the probable error lies between the two extremes.* The maximum value of the probable errors of the correlation coefficients recorded in Tables XIII, XVI and XXIII, is 1.41 (i.e., $\sqrt{2}$) times those quoted.

"In spite of these defects, the correlation coefficients recorded in the various tables are of some utility. They indicate that in some instances there is little or no correlation ; but in many cases when they did show a substantial degree of correlation, further confirmatory evidence was adduced by analysing the data in sub-groups, and finding them to be consistent."

* It is not likely that the probable errors approach anywhere near to the maxima, for the mean underground atmospheric conditions are very steady from month to month, and show no seasonal variations. (Note by H. M. V. and T. B.)

Regression Diagrams.

Regression diagrams are useful in order to indicate the relationships of the results obtained at the individual collieries to one another. The straight regression lines drawn through them indicate the best fit, in which the squares of the distances of the observational points from the line reach a minimum value.

Absenteeism from Sickness.—In Fig. 15 the relationship between absenteeism from sickness and temperature is shown (*cf.* correlation coefficients in Table IV, p. 8). It will be seen that the correspondence with the regression lines is moderately good.

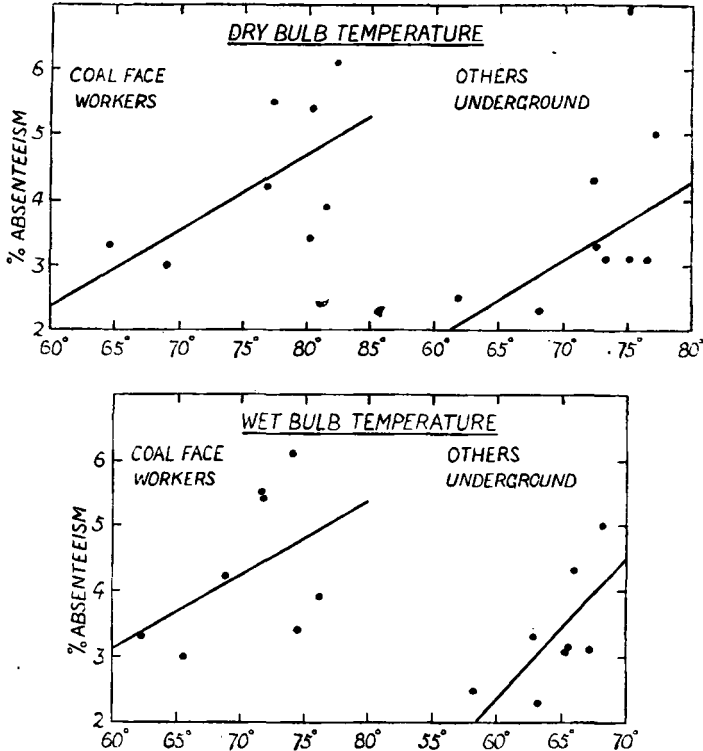


FIG. 15. Relationship between sickness and temperature at individual collieries.

In Fig. 16 is shown the relationship of sickness absenteeism of the coal face workers with the cooling power of the air (*cf.* correlation coefficients in Table VI, p. 10). It will be seen that the correspondence with the regression lines is not close.

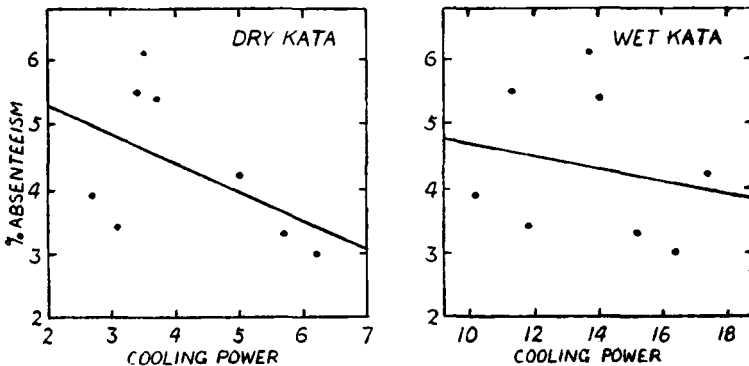


FIG 16. Relationship between sickness of coal face workers and cooling power of air at individual collieries.

In Fig. 17 is shown the relationship of sickness absenteeism to air velocity (*cf.* correlation coefficients in Table VII, p. 10). It will be seen that for "others underground" the values agree well with the regression line, and indicate that sickness increases rapidly with rise of air velocity.

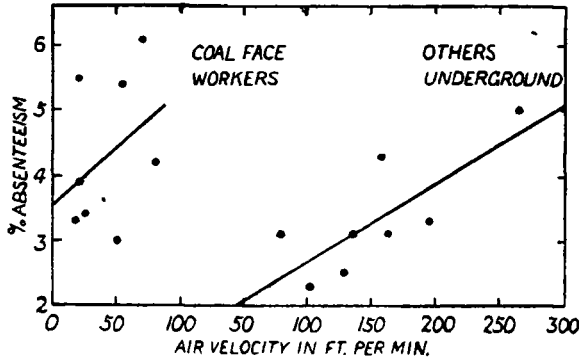


FIG. 17. Relationship between sickness and air velocity at individual collieries.

In Fig. 18 is shown the relationship between sickness absenteeism and the average age of the men at the individual collieries. The corresponding correlation coefficients were $+ .328 \pm .048$ for coal face workers, and $+ .569 \pm .037$ for other underground workers (*cf.* 3 (d)).

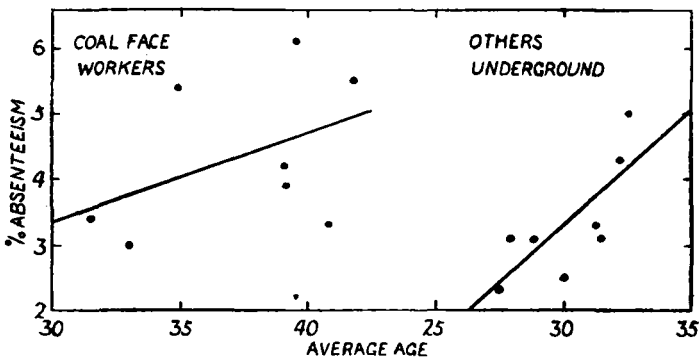


FIG. 18. Relationship between sickness and average age of men at individual collieries.

Absenteeism from Accidents.—The regression diagrams relating to accidents contain more observations than those relating to sickness, as the number of collieries and seams for which reliable results were obtained was larger. For the purpose of diagrammatic representation, each pair of mean values obtained for 1924 and 1925 was averaged. The means are plotted in Figs. 19 to 21. In Fig. 19 is shown the relationship of accident frequency to temperature, and in Fig. 20 the relationship of accident frequency to cooling power and to air velocity (*cf.* correlation coefficients in Table XIII, p. 19).

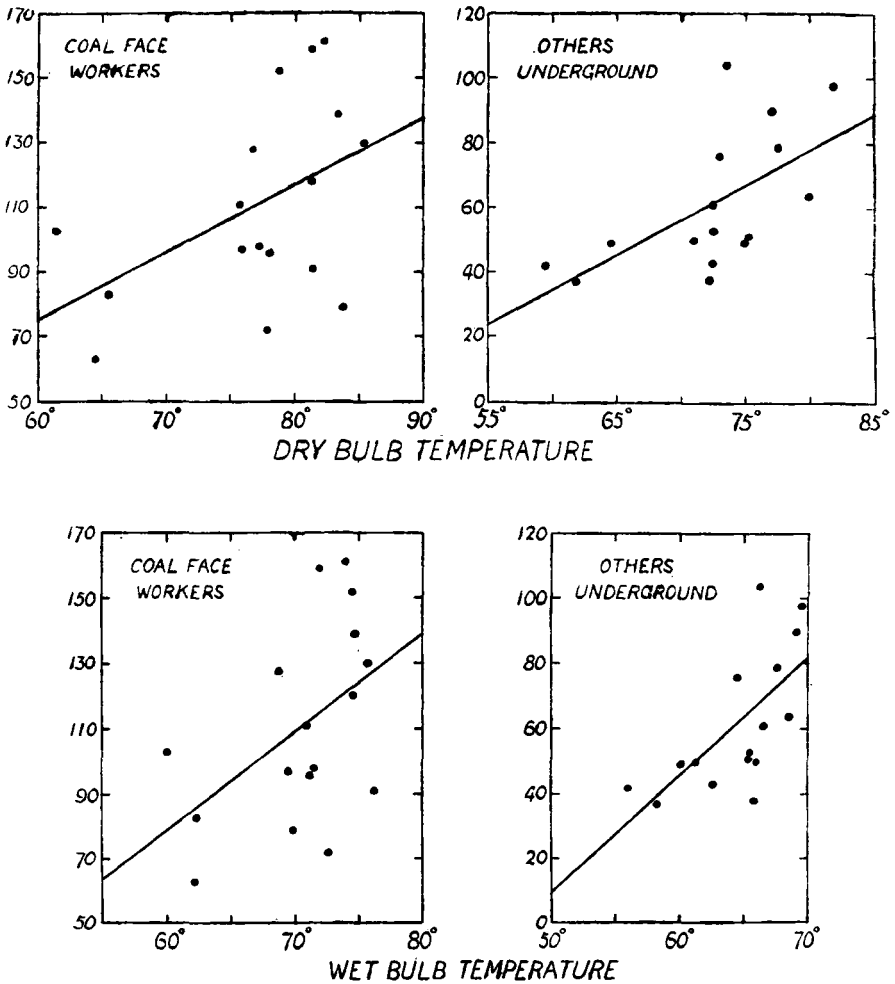


FIG. 19. Accident frequency in relation to temperature.

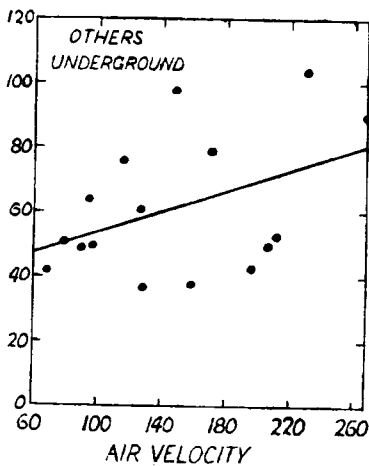
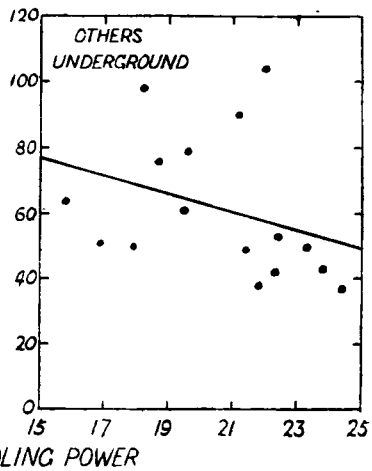
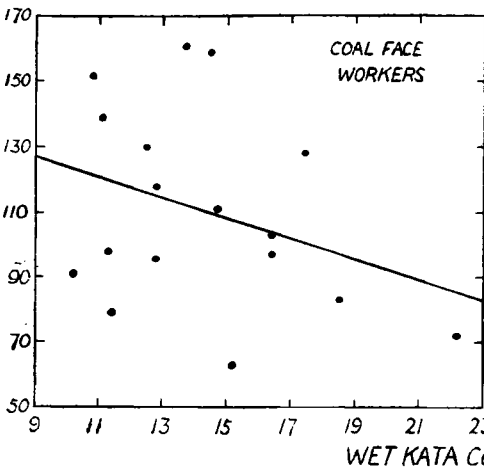
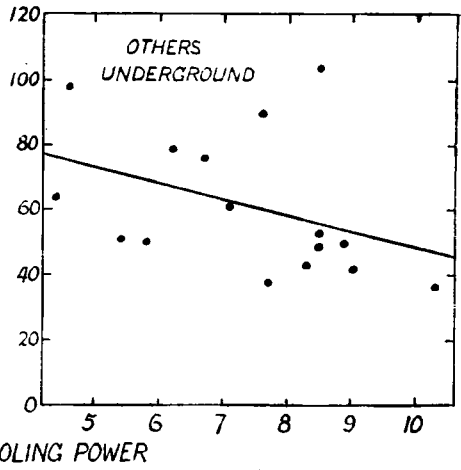
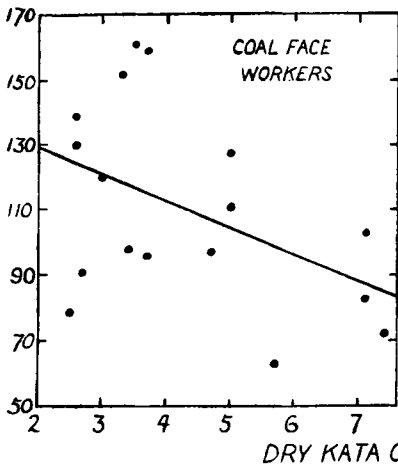


Fig. 20. Accident frequency in relation to various atmospheric conditions.

The relationships of accident severity rates to wet bulb temperature and to air velocity are shown in Fig. 21. It will be seen that, as regards the air velocity diagrams, the values for accident severity of "others underground" agree very well with the regression line, and indicate that the time lost increased rapidly as the velocity increased between the limits of 69 and 264 feet per minute. The coal face workers, on the other hand, appeared to suffer a diminishing loss of time as the air velocity increased, but this result is chiefly dependent on the low severity rate observed at pit P. If this result is ignored, the remaining data yield a result which does not disagree with the accident severity rates observed in "others underground," (cf. Table XIV, p. 20).

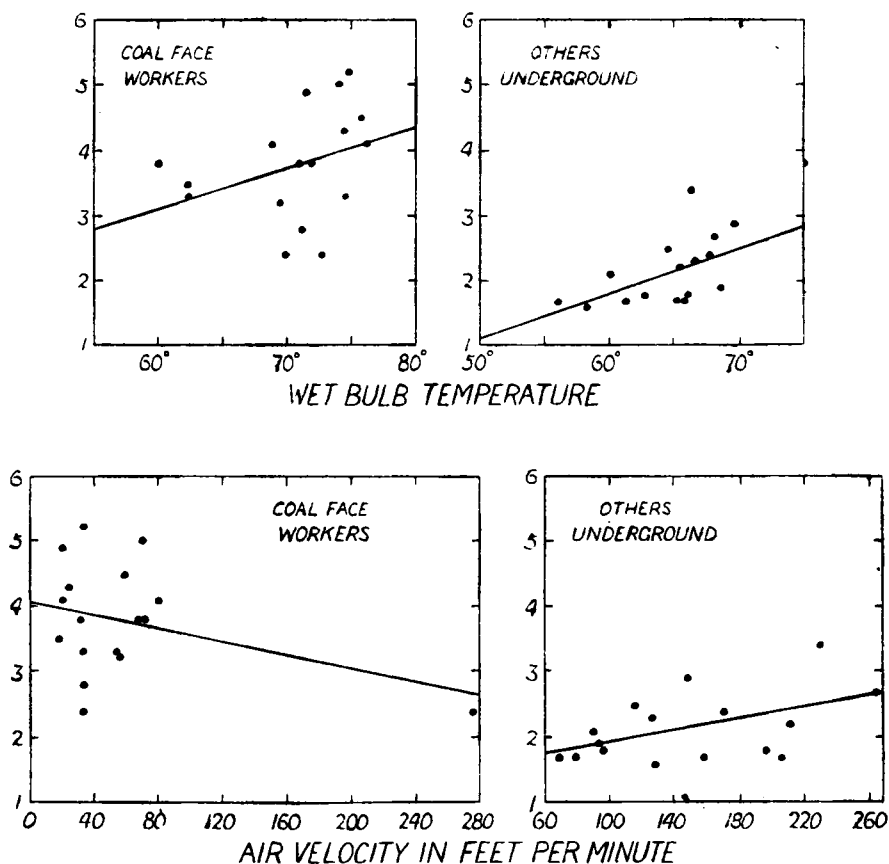


FIG. 21. Accidents severity in relation to atmospheric conditions.

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