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These reports of the Kansas State Mine Inspector mostly concern coal mining, though by 1929 the scope of the reports broadens to include metal mines. The content of individual reports will vary. The reports address mining laws and mining districts; industry production and earnings; fatal and non-fatal accidents; accident investigations and transcripts of oral interviews; labor strikes; mine locations; mining companies and operators; and proceedings of mining conventions. The reports document the political, economic, social, and environmental impacts of more than seventy years of mining in southeastern Kansas.

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COAL-DUST EXPLOSIONS IN COAL-MINES.

There has been a great deal of agitation among coal-miners on this subject in Kansas during the last eight years. The awakening cause of this interest was an explosion that occurred December 17, 1887, in No. 3 shaft of the Western Coal-Mining Company, located at Fleming, near Cherokee, Crawford county, by which three men (all that were in the mine at the time of the explosion) lost their lives and the shaft was utterly wrecked. No such explosion as this had ever taken place in Kansas, the mines of the state being comparatively free from carbureted-hydrogen gas (fire-damp), the only agent through which it was supposed such an explosion could be produced. This interest was increased and intensified beyond all conception by a similar explosion which occured at No. 2 shaft, owned by the Cherokee & Pittsburg Coal and Mining Company, located at Frontenac, about four miles northeast of Pittsburg, Crawford county, on the 9th day of November, 1888, by which 44 men and boys were killed. This catastrophe was made the subject of the most thorough and rigid investigation, by men of every kind and degree—men of scientific attainments, men of lifelong experience and acknowledged ability in all departments of mining, and practical working miners of all nationalities, age and experience. Men were exposed in the witness-box to the strongest search-lights of the legal fraternity, turned upside down and inside out, so to speak, for the purpose of discovering the cause of this disaster; and yet, in the opinion of those best able to judge, whose minds are free and unbiased, the whole matter is shrouded in densest uncertainty and doubt.

While interest in this matter is of comparatively recent date in our part of the globe, the subject is by no means new, and antedates the natal period of any miner now living. The dangerous, injurious and destructive character of coal-dust in connection with gas explosions in mines was described by Mr. Buddle, of England, in a report made by him on the investigation of an explosion at Walsend colliery, in the north of England, in 1803, by which 13 men and boys were killed and 20 seriously injured. The subject is again mentioned by the Rev. J. Hodgson, in describing an explosion at the Felling colliery, England, in 1812, by which 92 men and boys lost their

lives. But little interest seems to have been manifested, however, in the discovery of this dangerous element in connection with coal-mining, as we have no further allusion to it in any record for 12 years, when Mr. Ball, of England, again attempts to draw public attention to its dangerous properties. Probably the principal reason for this lack of interest in and paucity of investigation on the subject lies in the fact that knowledge of new discoveries was not as widely disseminated among the people half a century ago as it is to-day, and especially among the class who are most interested, viz., the miners, as it was the exception then for a workingman to ever see a public document, much less read one.

Nothing more is recorded regarding this matter until 1845, when those distinguished scientific authorities, Messrs. Faraday and Lyell, drew attention to the importance of coal-dust as a destructive factor in coal-mine explosions, in a report to the British home secretary of an investigation on the Haswell colliery explosion, which occurred in September, 1844, by which 95 men and boys lost their lives. In a discourse by Faraday to the Royal Institution, January 17, 1845, commenting on this report, he said, "The ignition and explosion of the fire-damp mixture would raise and then kindle the coal-dust which is always pervading the passages of coal-mines, and these effects must in a moment have made the part of the mine which was the scene of the calamity glow like a furnace."

M. du Souich, chief government mining engineer of the Saint Etinnie arrondissement, France, referring to an explosion at Firminy colliery in 1885, says: "The deposition of a light coke upon the props was due to dust, which was swept up and transported to a distance by the violent current produced by the explosion, and which, being in part inflamed, would carry on and prolong the effects of the fire-damp."

The fact that men near the pit's mouth received burns and other injuries, while others who were in the workings near the seat of the explosion but out of the main air current escaped unhurt, was ascribed by him to this ignition and carriage of flame by dust.

M. du Souich, referring to an explosion in the Freuil pits on 26th of May, 1861, says: "The small residue of dust in the shape of coke was not inconsistent with the serious effects of the explosion, as it merely shows that the combustion was more complete, and consequently the effects greater."

Another Frenchman, named M. Verpilleux, experimented on this subject in 1864-'67, and came to the conclusion that coal-dust enhanced the danger from and destructive force of fire-damp explosions.

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M. Burrat, engineer-in-chief of the mines of the Saone et Loire department, in a letter to M. Pititjean, chief engineer of the Blanzy mines, dated 21st of March, 1872, commenting on an explosion that occurred at these mines on the 5th of February, 1871, by which two men were injured, one of them dying afterwards, supposed to be caused by a blown-out shot, as no gas had been seen in the mine, says: "I consider it to be established that the rapidly shot-out, flaming and highly heated gases, such as those produced when a shot blows out its tamping, can inflame an atmosphere charged with fine particles of coal-dust." In the same letter, commenting on an explosion at the Cinq Sois pit, in 1867, by which 80 men lost their lives, he says: "We may ask if this fatal event was not a reproduction, on a large scale and in a disastrous manner, of the facts that were verified in regard to the recent accident of February 5?"

In 1875, M. Vital, mining engineer, after experimenting in connection with an investigation into the cause of an explosion at the Campagnac colliery, France, on the 2d of November, 1874, says: "The accident occurred in a part of the working where no trace of deleterious or explosive gas had ever been found; its unusual aspect and its serious issue gave rise to a minute inquiry into its nature, and the results of these researches permit us to attribute its origin to the instantaneous combustion of coal-dust under the influence of a blown-out shot. . . . Certain kinds of coal-dust, rich in gas, and in a state of very minute division, take fire when they are raised into the air by the explosion of a blasting shot; the coal is decomposed gradually, and gives rise to explosive mixtures which ignite at the flame of the powder and produce explosions. . . . Very fine coal-dust is a cause of danger in dry workings; it may of itself alone give rise to disastrous explosions."

It will be noticed that up to this period coal-dust in mines was only considered dangerous in connection with an explosive mixture of gas (fire-damp) and air; that it was not the cause of, but simply increased the destructive power of gas explosion after it had taken place. Now, however, the coal-dust theory assumed a very different phase, namely, Is the presence of coal-dust in large quantities alone accountable for some of the destructive catastrophes that have occurred in coal-mines?

From this time forward there has been no lack of interest manifested, no labor or money spared, in investigating and experimenting on this subject in order to find out exactly to what extent explosions in coal-mines are influenced by the presence of coal-dust. Scientific men of distinguished ability have devoted many hours to solve the problem. Mining engineers and mine managers have

spent thought, time and money in inventing, building and perfecting appliances to experiment with in a practical manner.

Mining institutes and miners' unions have spent session after session comparing notes, discussing experiments and experiences, debating, expounding and illustrating the various opinions held by the different members on the question. Nearly every government in Europe—Great Britain, France, Belgium, Prussia, and Austria—have appointed commissions composed of skilful men, with almost unlimited power, to visit mines, make experiments, summon witnesses and report with a view to remedial legislation, if found necessary. Private individuals, separate and in company, have labored incessantly to throw light on this matter, and still, the diversity of opinion is only circumscribed by the number of men who have given the question any thought.

Mr. William Galloway, an English mining engineer and ex-mine inspector, made some very elaborate experiments, extending over a number of years. He says: "After considerable study, prior to experimenting, I had come to the conclusion that air mixed with certain proportions of fire-damp and dry coal-dust would be explosive at ordinary pressure and temperature." After having experimented to some extent, he says: "The result of these experiments seems to indicate that a mixture of air and coal-dust is not inflammable at ordinary pressure and temperature." Afterward he finds that "When air contains a very small quantity of fire-damp, 0.892 per cent. of its volume, it is capable of forming an inflammable mixture with coal-dust."

Later, in 1879, after further experiment, and experience with actual explosions in mines, he withdraws his former statements, and says: "The assertion that a mixture of air and coal-dust is not inflammable at ordinary pressure and temperature without the presence of a small proportion of fire-damp has not been borne out by my further experiments, as I consider that I have now conclusively shown that fire-damp is altogether unnecessary for the propagation of flame with explosive effects by a mixture of coal-dust and air."

The same conclusions had been reached some time before this, after careful and comprehensive investigation, by Prof. A. Freire Mareco and D. P. Morrison, and so stated in a paper to the North of England Institute of Mechanical and Mining Engineers in November, 1878. Their conclusions are, in effect, that "Coal-dust acted upon by the inflamed gases of the shot, liberate inflammable gas, which mixes with the air, and it is fired, the non-volatile part of the coal being in part consumed and in part deposited as a feeble coke."

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In 1875 Mr. Henry Hall, British inspector of mines for the seventh (Liverpool) district, and Mr. George Clark, acting under instructions from the British home secretary, made some experiments with a view to demonstrating whether coal-dust alone would produce a destructive explosion by the agency of a blown-out shot. An open drift, 45 yards long, 35 feet in sectional area, arched over with brick, dipping toward the inside and ventilated by a vertical shaft, was placed at their disposal. The apparatus used for blasting was a strong iron tube two feet long and 2½ inches in diameter. The results of the experiments may be summed up briefly, as follows: With a charge of 2½ pounds of powder loosely tamped with debris, the drift free from dust, the flame did not expand beyond 10 feet. With the same charge of powder tamped hard, and fired under the same conditions, the iron tube burst, and the shock was quite perceptible at the mouth of the drift, but no flame went beyond a distance of 10 or 15 feet. Another tube similar to the one destroyed was procured, a similar charge of powder introduced, and tamped with fine coal and dust; coal-dust was obtained from the screens and scattered on the floor and sides of the drift for a distance of 24 feet back from the face; on the shot being fired, "flames extended a distance of 60 feet, and the blast at the mouth of the slope or drift was very strong and fierce, lifting an iron pipe weighing nearly 60 pounds, hurling it a distance of 45 feet, and moving a mine-car on the pit bank 75 yards." Another charge of 2½ pounds of powder was fired, and this time—the drift being wet—the floor was covered with boards and coal-dust scattered along its entire length. In this instance "flames issued from the mouth of the slope, having traveled 45 yards; the blast was very strong, and would certainly have killed any one standing in its course." Conclusion: "If coal-dust be present even in a comparatively damp mine, the flame of a blown-out shot may travel 150 feet, but in a dry mine of high temperature this distance would be greatly exceeded."

In a paper read before the North of England Institute of Mining and Mechanical Engineers in June, 1876, describing the result of his experiment the year previous, Mr. Hall says: "On any partial vacuum being formed in an underground coal workings, fire-damp will instantly issue in large quantities; and there are fair grounds for assuming that a shot blowing out in the face of a narrow heading (entry) and setting coal-dust on fire in its course, would, by its exhaustive action, produce such a vacuum, and might cause a serious explosion in a mine practically free from gas."

Again he says: "In Lancashire they had an unfortunate practice of blasting without any nicking (mining) or side preparation, that

is, shooting practically in the fast, and then, when it occurs that the coal bears the strain of the powder longer than the stemming (tamping) in the hole, the result is a blown-out shot. He thought that these experiments almost proved the fact that, whenever there was a body of flame, caused either by lighting a small body of gas or a blown-out shot, there might be a serious explosion through its lighting any small coal-dust that might be in the way.

Mr. A. C. Greenwell, in a paper on the use of powder read before the Manchester Geological Society, May 31, 1870, says: "Where a shot is not strong enough to blow down the coal, and acts simply like a cannon, projecting the tamping and in all probability much blazing powder, it may be, as it in all probability has been, the cause of very serious consequences, in addition to powder burns occasioned. I am of the opinion that accidents, unsatisfactorily accounted for hitherto, may be attributed to the action of such shots. Cases have occurred in which the theories of the inflammation of coal-dust have been advanced as a cause of explosion very similar to that of fire-damp; and the chief argument advanced in the favor of these theories consisted in the proved absence of fire-damp, both before and after the explosions, and in the usual contemporaneousness of the accident with an exploded shot such as above referred to, the effect of which would be to cause the ignition of inflammable dust." Again: "In 1877, at a meeting of the North of England Institute, while discussing a paper read to that body by Mr. Henry Hall on this subject in 1876, he says, 'dust would become distilled by the heat which would be produced by a blown-out shot, and the gases distilled from the dust would become explosive matter.'"

Prof. A. S. Herschel, while discussing this same paper at the same meeting, said: "It appears that the importance to be attached to the vacuum, said to be produced by a blown-out shot, depends on the possibility of its extracting additional fire-damp from the area affected by the shot, and that this additional fire-damp may produce a more explosive and readily inflammable condition of the air in the track of the wave or concussion that proceeds from the shot."

In April, 1879, the Chesterfield and Derbyshire Institute of Civil, Mining and Mechanical Engineers appointed a committee to experiment on the effects of coal-dust in colliery explosions. The apparatus they constructed to experiment with was an air-tight wooden box 82 feet long, 16 inches wide, and 18 inches deep. This box was made to represent a gallery in a mine; a small Gunther fan was placed at one end, to circulate air through the box. A dust-hopper, with small fans, to be worked by hand to scatter the dust in the air;

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a steam coil, to heat the air; a thermometer; a hygrometer, and a gas-pipe, to introduce gas into the air, when experimenting with a mixture of gas, air, and dust, were all attached to and connected with this box. Small panes of glass were fitted into the sides of the box to enable the experimenters to observe the result. Two hundred and eleven experiments were made. The first 20 were made to familiarize the observers with the work, and no account was taken of them; No. 164 missed fire; 10 were made in a clean box without dust, to aid the observers in discriminating as to the effects; this left 180 to be analyzed, of which 134 were made with a mixture of air and dust only, and 46 with a mixture of dust, gas, and air.

In giving the result of this comprehensive test, the committee thought it necessary to define the words "explosion" and "inflammation":

An explosion is anything which causes a sudden increase of pressure in the surrounding air or gases, from the sudden and violent expansion of any substance (gas, liquid, or solid) in their neighborhood. Inflammation is the quiet production of flame, unaccompanied by any sudden or violent change of pressure in the surrounding gases (air).

The committee unanimously agreed that no explosion took place when gas was not present; but that inflammation or ignition of the dust did occur.

Upon the introduction of gas, it was of course much more likely that there would be an explosion; but no noise or violence was observed beyond what might be ascribed to concussion from the shots, except perhaps in the following instances: No. 184—Top of box lifted and splintered, from dust-hopper to firing place. Gas 1.00 per cent.; shot 90 grammes across air current; length of dust flame, 17 feet from hopper; force indicated, .0114 pound per square inch. No. 185—Same effect as 184. Gas 1.09 per cent.; shot 90 grammes across air current; length of dust flame, 10 feet 6 inches; force, .0036 pound per square inch. No. 188—Door opposite No. 3 window blown open. Gas 1.12 per cent.; shot 60 grammes across air current; no flame; force indicator, nil. No. 189—Tube considerably shaken; gas 2.22 per cent.; shot 90 grammes, with air current; no flame; force indicated, .0036 pound per square inch.

Flame issued through the joints of the box in the following experiments: With gas, Nos. 203, 207, 209, 210; without gas, Nos. 53, 120, 151, 154, 155.

The force and recoil indications generally bear out and confirm the observations that the ignited dust traveled along the tube at a rate certainly not greater, if at all, exceeding the velocity of the air current, etc.

Some dusts are more inflammable than others; but the experiments seemed to point to the practicability of igniting almost any coal-dust under especially arranged conditions, such as may never occur in any mine. [This refers to dust heated to a high temperature.]

The same dust is certainly more inclined to inflame under some conditions than others. Thus, the finest and dryest dust is that most likely to ignite, especially in a dry atmosphere.

The greater and sharper the initial flame, the more readily it ignited the dust.

Heavy charges were more efficacious than light charges, and an explosive

mixture of two parts hydrogen and one part oxygen was of all methods the most certain, showing that, the more suddenly generated as well as the greater the flame and heat, the more certain is ignition of the dust.

The extra pressure due to the depth of the mine would probably increase rather than decrease the liability of mixtures of coal-dust, gas and air to inflammation.

Dry, cold weather may be considered the most favorable for the inflammation of dust, because the air entering the downcast shaft at, say a little over 32 degrees, and rushing into the mine meets with air of a higher temperature, gradually increasing to a temperature of about 70 degrees. Under these circustances, the air most readily absorbs the humidity of the workings and renders the dust dry, mobile, and easily raised into a cloud. [Both of the explosions in our state occurred in winter.] It would appear that a dust flame, per se, would never be of an explosive character.

In a non-gaseous but dusty mine, ignition of the dust could, at the worst, only burn without an explosive shock.

The result of those experiments had a decidedly cooling effect on the growing enthusiasm of those who were converted to the idea that coal-dust alone was the sole cause of many destructive explosions. Nevertheless investigations went steadily on.

An explosion occurred at Zwickau, near Dresden. The following verdict appeared in the official "Dresden Journal" on the 11th of January, 1880: "Neither overman, underviewer, manager, nor anyone else is to blame. It is impossible to determine whether the explosion was due to gas, or to a mixture of gas and coal-dust, with which the air of the mine was largely charged; the latter seems more probable."

An explosion occurred at the Seaham colliery, Durham, England, on the 8th of September, 1880, by which 164 men and boys lost their lives. The circumstances under which this catastrophe had taken place were such as to accentuate the opinion then formed and forming in the minds of a great many men, that coal-dust was the sole cause of many disastrous explosions in coal-mines. The initial point of the explosion was at a place near the commencement of the work on the intake airway. The air had not circulated through any old work, nor had it passed over any freshly cut face, so that it was practically free from gas. There was 61,000 cubic feet of air passing the point at the time the explosion occurred, and the heat of the explosion only passed over such parts of the underground workings and roadways as were thickly covered with dust. The return air-course, which was practically free from dust, was undisturbed, and the explosion was contemporaneous with the firing of a blown-out shot. At the inquest held over the bodies of the men killed, a representative of the miners' union arose and made the following request: "That the coroner be requested to inform the home

office that it is the desire of the miners' association that experiments be made by an experimental chemist with the coal-dust in the Seaham colliery, with a view to ascertain how far it may produce an explosion, or increase or intensify an explosion."

The result of this application was the appointment of Prof. F. A. Abel, C. B., F. R. S., president of the Institute of Chemistry, chemist to the war department, etc., by the home secretary, with instructions to experiment with the dust of Seaham and other collieries, and report the result to the government. The experiments made by him were very comprehensive, including the ignition of small heaps of gunpowder and quantities of guncotton by electricity, to resemble flashes of flame from gas explosions, and the firing of cannon, to correspond to the effects of a blown-out shot.

The points made were as follows: "Cannons fired in a mixture of 2.5 per cent. of fire-damp, passing at velocities of 100 and 200 feet per minute, in an atmosphere containing 3.75 per cent., traveling with a velocity of 300 feet per minute, have no effect on the atmosphere. With only 1.75 per cent. of gas, and 100 feet velocity, coal-dust being abundantly suspended in the air, the portion of the gallery immediately in front of the flash produced by the shot was filled with flame, which did not, however, travel further; corresponding results were obtained by firing the shot against and with the current. With a slight increase in the proportion of gas (2 per cent. and 2.25 per cent.), the dust being freely passed, the gas mixture was inflamed throughout, with explosive effect. On one occasion air containing 2 per cent. of gas was passed at a velocity of 100 feet per second through the gallery, in which there was only a very small quantity of coal-dust deposited upon the bottom and sides; when a shot was fired in the direction of the current a reddish flame was produced, which extended to a distance of four feet, and which rolled along the floor of the gallery a further distance of three feet. This result illustrated the influence of a few dust particles in promoting the ignition and propagation of flame by a gas mixture which otherwise would not have inflamed. It may be admitted as possible that, with the large volume of flame and the great disturbing effect of a blown-out shot as the initiatory powers of the ignition of gas, and its suspension in the surrounding air, such inflammation may, in the complete absence of fire-damp, be propagated to a greater distance than the results of small experiments would warrant one in assuming. But it can scarcely be maintained that the air of a mine in which the coal gives off gas at all can be at any time free from fire-damp; and as the existence of very small and unexpected quantities of that gas in the air of a mine may suffice to

bring about the ready propagation of flame by coal-dust, and thus to develop violent explosive effects, it would appear needless to assume that coal-dust may, in the entire absence of fire-damp, give rise to explosions, even of only limited character, in coal-mines, in order to account for casualties which cannot be ascribed to the existence of accumulations or sudden outbursts of fire-damp." (Report of March 23, 1881.)

Report of French Fire-damp Commission, 1882: "We consider that we have established: (1) That certain varieties of coal-dust maintained in suspension in the air may there be ignited without its being necessary that the air should previously contain a more or less considerable quantity of combustible gas. . . . (4) That in all cases, except that of lignite dust, the speed of propagation of ignition in an air charged with dust is extremely slight and practically nil. (5) Lastly, that ignition can only be communicated by very large flames to dust held in suspension, and only to a slight extent."

Mallard and Le Chaleteer, Annals des Mines, 1882, vol. 1, page 1: "The experiments made by the authors show that dust, in order to be combustible, should be the product of very gaseous coal, yielding at least 30 per cent. of volatile matter in distillation. This explains the rarity of accidents due to dust, since, in the majority of mines, the dust does not fulfill these conditions."*

For some years prior to and since this period every explosion that has occurred in mines has been closely investigated, for the purpose of determining to what extent the presence of coal-dust was responsible, either as the primary cause or contributory to the damage done, both in the loss of life and the destruction of property. The mine inspectors of Great Britain have been especially vigilant, and, with the unexampled facilities at their command, have doubtless been the most successful.

Mr. J. B. Atkinson, inspector of mines for the first district (east of Scotland), and Mr. W. N. Atkinson, inspector of mines for the tenth or North Staffordshire district, have been particularly positive in stating their belief that coal-dust ignited by blown-out shots was the primary and only cause of many destructive explosions. Mr. W. N. Atkinson, addressing a meeting of the North Staffordshire Institute of Mechanical and Mining Engineers, said he arrived at the conclusion that coal-dust alone was capable of causing and actually did cause the most extensive coal-mine explosions by investigation of the Seaham colliery explosion in 1880; that conclusion had been strengthened and confirmed by the experience he had

*The coal of Cherokee and Crawford counties contains 36.77 per cent. of volatile (combustible) matter.

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since had in investigating several large explosions, particularly that at Ludhoe, in 1882, Usworth, in 1885, and Elmere, in 1887. In each of those cases the explosion had originated from the flame of a blown-out shot fired near the intake air-shaft, and large quantities of pure fresh air were passing the place at the time the explosion occurred.

The Prussian fire-damp commission, which experimented under conditions conforming as nearly as practicable to the prevailing conditions in mines, demonstrated, to their own satisfaction, at least, that coal-dust alone will cause an explosion when the air of the mine is free from gas.

The first commission appointed by the British government to investigate this subject had reported that coal-dust in mines was an element of danger when exposed to the flames of a blown-out shot, and made some recommendations regarding extra precautions that should be taken before firing shots, which were incorporated in the general rules of the mining laws as amended in 1887. Section 42 of that act also gave the inspector of mines the power to discontinue the use of powder in mines in his district unless the rules regarding shot-firing were complied with.

The legislature of Kansas, in its session of 1889, after the investigation of the Frontenac calamity, passed two restrictive measures regarding the taking of powder into mines, and regulating the manner in which and the time when shots should be fired.

An act to amend an act entitled "An act to provide for the health and safety of persons employed in and about coal-mines," etc.: "It shall be unlawful for any person to take into or have in his possession, in any coal-mine shaft, slope or pit in this state more than 12½ pounds of powder or any other explosive substance at any one time," etc. . . . "All owners, lessees, operators of, or any other person having the control or management of any coal-shaft, slope, drift or pit in this state employing miners to work therein, shall employ shot-firers to fire the shots therein. Said shots shall be fired once a day on each day when any such shaft, slope, drift or pit is in operation, but shall not be fired until after all miners and other employees working therein shall have been hoisted out of said mine."

Agitation on the subject still continued, especially in this country and in Great Britain.

The "Colliery Guardian," of London, England, the scientific, theoretical and practical organ of the trade in that country, and the "Colliery Engineer and Metal Miner," of Scranton, Pa., which occupies a like position to the trade in this country, have printed

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column upon column of correspondence, giving the ideas, opinions and experience of different persons on the question, and have written many editorials calling attention to the importance of the question, and urging continued investigation and experiment by the government for the purpose of shedding more light on the matter.

The "Colliery Engineer," of Scranton, in an editorial in July, 1891, commenting on the reports of the various commissions appointed by European governments to investigate this subject, the results of practical experiments of individuals, and the opinions of several competent authorities on the cause of many disasters, says: "In the face of such evidence, the leading mining engineers and colliery managers of the world have naturally arrived at the conclusion that coal-dust is an element of danger in mines that is of primary importance. Many explosions that have in the past been attributed to fire-damp must have had their intensity increased, if they were not wholly caused by coal-dust. Explosions of fire-damp could not have produced the results that followed; for there has been evidence that fire-damp, if at all present, was only in such quantity as would produce a slight local explosion. . . . That coal-dust in an atmosphere containing an amount of gas so small as to be unnoticeable with the ordinary safety-lamp is inflammable, and a great source of danger, is a fact recognized now by all leading mining authorities. That coal-dust in an atmosphere entirely free from gas is a dangerous element in the mines, is held by the majority of the mining authorities of the world, and as practical experiments have in many instances demonstrated this fact, it is evident that, to secure safety in bituminous and semi-bituminous mines, efforts must be made to eliminate this element of danger. . . . The bulk of the evidence presented on this subject shows that the dust of coals containing over 10 per cent. of hydrocarbons becomes dangerous under the following circumstances: (1) The existence of a certain quantity of dust; (2) the dust being set in motion, raised in clouds; (3) a flame of sufficient intensity to heat the dust, so that the gases which it contains are given off and become inflamed."

Observations of W. C. Blackett, published in the transactions of the Federate Institution of Mining Engineers: "First a shot stirs up a cloud of dust and ignites it; this combustion causes air disturbances in all directions, stirs up the dust in advance, and this fresh dust ignites, and transmits the explosion, which travels both with and against the air current, as long as there is dust to ignite."

In an editorial in 1892, commenting on the report by the commissions of Great Britain, France, Belgium, Prussia and Austria on this subject, the "Colliery Engineer" says: "The United States

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should also establish such a commission, and equip it with means and facilities to carry out similar investigations and make a similar report, as has been advocated for some time past by the 'Colliery Engineer.' . . . In no country in the world is such a report as can only be framed by a well-organized and financially equipped commission more necessary. It will form a basis on which to build uniform and efficient mining laws, which will result in a greater security to the labor employed and the capital invested in mining in the various states."

Again, in August, 1894, in an editorial commenting on an explosion which occurred at Albion colliery, at 3:10 p. m., June 23, 1894, by which 290 lives were lost, the same paper says: "Another disastrous explosion that can be charged to coal-dust. . . . In this instance the only reason that the death list did not embrace the names of over 1,000 men and boys was the fact that it occurred at a time when only about one-fifth of the 1,500 employees were in the mine. . . . The fact that the explosion spread throughout the entire mine, which was well ventilated by a Shiel fan, is strong proof of the presence of coal-dust. . . . If our readers will note the details of mine explosions where large numbers of men were killed, they will invariably find that they have occurred in bituminous mines where there is a large proportion of volatile hydrocarbon in the coal. . . . It seems to us that the time is at hand when some effort should be made to remove this element of danger from the mines of every civilized country, by legal enactments requiring the removal of the dust or its effectual dampening in bituminous mines. Pennsylvania, in her present bituminous mine law, provides for this: General rule 60—'In mines where coal-dust has accumulated to a dangerous extent, care should be exercised to prevent such dust from floating in the atmosphere by sprinkling it with water, or otherwise, as far as practicable.' The inspector should see that this rule is rigidly enforced, and thus prevent injury to both the miners and the property of the mine owner. Other states whose mine laws do not contain a similar provision should speedily follow Pennsylvania's example."

At the instigation of the powerful miners' unions of Great Britain, another commission to investigate this subject was appointed by the government on February 9, 1891, and continued their investigations and experiments for a period extending over three years. After consulting with the home secretary, the services of Mr. Henry Hall were again secured for further practical experiments. This gentleman had in 1890 continued experiments begun in 1875, the result of which only tended to confirm the opinion pre-

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viously formed, that dust alone was explosive. He again experimented with the dust of the Lancashire coal-field in January, 1893, and by instruction of the commission he undertook a series of practical experiments with samples of coal-dust collected from all of the principal coal-fields of Great Britain, including Durham, Lancashire, Yorkshire, Derbyshire, Staffordshire, Wales, Monmouthshire, Somersetshire, Forest of Dean, and Scotland. Experiments were conducted in May, June and July. These further and comprehensive experiments, conducted under circumstances and conditions in every way analogous to those prevailing in mines, had the effect of convincing conservative John Bull, in the person of this commission, that coal-dust per se was the cause of mine explosions, and it was so expressed, in the following guarded language, in these conclusions:

1. The danger of explosions in a mine in which gas exists even in very small quantities is greatly increased by the presence of coal-dust.

2. A gas explosion in a firey mine may be intensified and carried on indefinitely by coal-dust raised by the explosion itself.

3. Coal-dust alone, without the presence of any gas at all, may cause a dangerous explosion, if ignited by a blown-out shot or other violent inflammation. To produce such a result, however, the conditions must be exceptional, and are only likely to be produced on rare occasions.

4. Different dusts are inflammable and consequently dangerous in varying degrees; but it cannot be said with absolute certainty that any dust is entirely free from risk.

5. There appears to be no probability that a dangerous explosion of coal-dust alone could ever be produced in a mine by a naked light of ordinary flame."

Recommendations: Mr. Wood stands alone in his desire to prohibit all shot-firing whether by gunpowder or by any high or so-called flameless explosive in mines which give off gas, and no mine, he considers, is safe from an irruption of fire-damp, except under very exceptional circumstances; and in place of explosives he would substitute the maul and wedge. He admits that the wedge could not be used in rock, and in that case allows that some of the patent explosives, if under proper supervision, and only fired when the miners were out of the pit, might be used with perfect safety. On a review of the whole evidence on this point, the use of powder in mines, the commissioners have come to the conclusion that, whatever minor objections may be established against the use of high explosives, their employment would greatly limit the risk of explosions in dry and dusty mines. Having regard, however, to statements having been made by several witnesses that the abolition of the use of gunpowder would stop the working of many collieries, and bearing in mind the great variety of conditions under which different mines have to be carried on, as well as the various qualities and quantity of dust, and the methods of working, they do not feel justified in recommending, the universal abolition of the use of gunpowder. On the other hand, they think that the conclusive proof which the evidence has afforded of the great additional danger caused by the use of gunpowder justifies a considerable advance in the direction of the abolition of the use of gun-

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powder in dry and dusty mines, unless a sufficient and effectual means of watering the dust be systematically carried out. The evidence taken as to the action of the so-called flameless explosives leads the commissioners to believe that several of them may be practically safe for all purposes.* The commissioners are of opinion that the practice of using bituminous shale, or other material containing volatile inflammable matter, or clay mixed with coal-dust for stemming (tamping), increases the danger from blasting.

The bill drawn to conform to the conclusions reached and the recommendations made by this commission provides that the mine inspector, when he believes a mine to be in a dangerous condition through the presence of fire-damp or coal-dust, shall so notify the management, and if his opinion is confirmed by a coal-mine board of arbitration, (to be appointed, one for each district, composed of three men: one, the chairman, shall at no time have been a mine owner or manager; one shall have been an owner or manager; and one, a man who has worked in or around mines,) the mine will, after the expiration of 14 days from the date of notification, come under the provisions of the act relative to firey or dusty mines, which provides for the discontinuance of the use of powder, unless watered to the satisfaction of the inspector.

This bill suited neither party, miners, owners, nor mine inspectors, and seemed to cause endless feeling and strife. Several conferences have been held between the parties interested; but up to the present time no agreement has been reached. It would seem to place additional responsibility on the shoulders of a class of officials whose duties are now sufficiently onerous, besides leaving it an open question as to the amount of gas or dust required to constitute a dangerous mine.

A few extracts on this subject from the reports of the mine inspectors for 1894 may be here submitted:

"The suggestion of the recent coal-dust commission, that the owner of a mine of a dry and dusty nature may be relieved of the obligation to discontinue the use of gunpowder, if he has made provision for watering the dust, is very unsatisfactory and incompatible with the opinion the commission expressed in their report."

The danger from failures of ventilation is met by the compulsory use of safety-lamps, and in the same way the possible failures of the watering system ought to be provided against by the compulsory exclusion of all flaming explosives. Moreover, the fact that already many mines, working seams of every description, are successfully carried on without the aid of gunpowder appears to have been lost sight of, and the inconvenience and expense that its universal prohibition would entail have been greatly overestimated. (Henry Hall, inspector for district No. 7.)

I had hoped that the commissioners would have more decidedly dealt

*See quotation from Nova Scotia mine inspector.

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with the remedial measures to be adopted, and suggested clear and practical rules and regulations for statutory enactment, instead of leaving the inspector to set in motion the slow, cumbersome and costly mode of arbitration when he is of opinion that the provision for watering dust in a mine is insufficient, together with the onerous duty of classifying the firey or dry and dusty mines in his district. (Report of Arthur H. Stokes, inspector eighth district.)

While not agreeing with all the conclusions and proposals set forth in the report, I think it offers a sufficient basis for legislation, and it is undoubtedly an important and authoritative pronouncement on the coal-dust question. . . . Very little has yet been done to remove or mitigate the cause of the danger from coal-dust. The purpose of the precautions hitherto taken has been to prevent its ignition, rather than to render wide-spreading explosions of coal-dust impossible, and this is the object to which the attention of mining engineers should now be specially directed." (Report of W. N. Atkinson, inspector tenth district.)

For many years the danger arising from the presence of coal-dust in mines has received a large amount of attention, not only in this country but on the continent. It was hoped that the completion of the labors of the royal commission appointed in 1891 would remove some doubts still existing in the minds of a section of the mining community as to that extreme danger which many experts have pointed out as accompanying the deposits of coal-dust in mines, more especially where fire-damp is known to be produced, and particularly where blasting is practiced. The report of the commissioners was issued during the past year, and a careful study of it, while it may not remove all previous doubts, cannot fail to result in good, for the conclusions arrived at are apparently in accord with those of experts on the subject. It is when the recommendations of the commissioners are considered that disappointment will be felt by many who had anticipated the recommendation of more drastic measures with regard to explosives and blasting. Personally, I have long wished for the total abolition of gunpowder in all mines producing fire-damp and in all dry and dusty coal-mines. . . . It thus appears that reliance on effectual watering is recommended as a safeguard against the acknowledged danger from the use of gunpowder in dry and dusty and firey mines. The question will arise: What is effectual watering? It has never been proved to what extent a mine, or a roadway in a mine, must be watered to prevent the extension of an explosion resulting from a shot or the ignition of a small quantity of fire-damp. The means suggested by the commissioners by which their recommendations are to be applied to mines are, in my view of the matter, not so satisfactory and sufficient as the subject demanded. (Report of Joseph T. Robson, inspector thirteenth district.)

The following, from the report of the Nova Scotia inspector of mines for the year 1894, may be of interest as showing the attitude of that province on this question:

The lessons of experience, have, however, been taken more closely to heart here apparently than in England, and so much heed has been given to the action of flameless explosives, that credence was given some years ago to the recommendation of the Novia Scotia commission on explosives, that the use of so-called flameless explosives, while safer than gunpowder, should be permitted only with all the precautions surrounding the use of gunpowder where gas has been found. This recommendation is now repeated by the North of England Institute Commission, which reported the other day. The indica-

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tions are that in a short time, in England, the practice followed in Nova Scotia will be adopted: that of prompt and ready relegation of a mine to the gassy rank whenever it is found that gas appears periodically even in minute quantities, and the prohibition of explosives. Already here a large proportion of coal is cut by maul and wedge, and mining experience is not looking upon any so-called flameless explosive hitherto introduced with such trust as to permit its use except with the greatest precaution.

There is but little additional knowledge to be gained on the question by examination of the records of our own country, principally because the government, federal or states, has not taken any active steps to investigate the subject. Necessity for action on the part of the federal government has been repeatedly pointed out by the "Colliery Engineer," of Scranton, Pa.; but simply because the miners themselves have failed to push it, through their organizations or otherwise, no action has been taken, the government probably considering, and justifiably so, that so long as those most interested in the solution of the question were indifferent no great danger could be apprehended.

January 27, 1891, an explosion occurred at the Mammoth colliery, Pennsylvania, killing 109 men. While this explosion doubtless originated in the ignition of a small quantity of gas, the destructive force of the explosion was considered due to the presence of coal-dust, the bodies of the men killed being covered with soot and dirt. The coroner's jury exonerated the management from all blame, it being proved that the colliery was well ventilated and considered safe.

An explosion occurred at the Spring Hill mine, Nova Scotia, February 21, 1891, by which 119 men and boys were killed. The committee which examined the mine to ascertain the cause says: "A hole had been drilled through a slip and a large cartridge used. When the blast was fired comparatively little power was expended in blowing down the slip, and the flame from the cartridge fired the dust that had been stirred up by the concussion."

On May 10, 1892, an explosion occurred at the Roslyn colliery, Wash., killing 43 men. The "Colliery Engineer" says: "All the elements necessary to cause a coal-dust explosion were present. . . . We are justified in the opinion that coal-dust was a more potent factor in the explosion than gas."

The "Colliery Engineer," of August, 1892, commenting on the danger of sudden outbursts of gas, says: "A shot fired in a chamber was the original cause of the outburst of gas which exploded and killed 15 men at the York Farm colliery, July 23, 1892."

Messrs. Rutledge, Woodson, and Stewart, mine inspectors for Illinois, Missouri, and Kansas, respectively, at the request of Gen-

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eral Manager McDowell of the Missouri Pacific coal companies, investigated an explosion that occurred in one of the company's mines near McAlester, I. T., January 7, 1892, by which 56 men lost their lives. These inspectors considered that coal-dust was largely accountable for the disaster. In their report to the general manager they say: "The coal is of a highly bituminous nature, very dry and dusty, and gives off small quantities of fire-damp. Powder should be very carefully and judiciously used. No shots to be fired unless properly undercut in rooms; in entries, coal to be sheared on one side and properly undercut, and a sufficient interval must be given between the firing of each shot to allow the smoke to pass away and the subsidence of dust."

An explosion at Como, Colo., December 9, 1892, by which 24 men lost their lives, was attributed to coal-dust. As reported in the "Colliery Engineer," a charge had been fired which did not dislodge the coal; a second hole was drilled close to the first; when the second charge was fired, instead of bringing down the coal, it broke into the first hole, and the flame of the powder extending out into the room fired the dust."

June 27, 1895, a correspondent of the "Colliery Engineer" draws attention to two well-authenticated dust explosions in lignite mines: one in October, 1894, in one of the leading mines of Washington, by which four men were killed; the other at the Black Diamond colliery, Mount Diablo, Cal., in 1886, killing 11 men. No fire-damp had ever been detected in either mine.

We have had two explosion in our own neighborhood recently, though not in our own state, both explosions occurred at Rich Hill, Mo. One occurred in October, 1895, killing two men; the other December 11, 1895, by which one man was killed; both occurred at night, while the shot-firers were in the act of firing the shots prepared by the miners during the day. The latter was of tremendous force, hurling the cages out of the shaft, the head-house, tower construction, and inside workings of the mine being badly damaged. This shaft, according to the report of the state mine inspector, was considered one of the best-ventilated and safest mines in the state. The coroner's jury exonerated the company, and says the accident was caused by too rapid firing; that is, firing shots in quick succession.

The writer has requested the opinion of several of the best informed mine officials and miners of the state for publication, with a view to shedding more light on the subject; but while all manifest an earnest desire to discuss the matter verbally, very few care to write their opinions for publication. Only two, Mr. David Mackie,

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general superintendent of the Central Coal and Coke Company, and Mr. Robert Craig, general superintendent of the Osage Carbon Company, have responded to the request, and their opinions, together with the copy of the report of the committee, of which Mr. Mackie was a member, to investigate the cause of the Frontenac explosion, are here submitted:

Scammon, Kas., December 9, 1895.

Bennett Brown, State Mine Inspector:

Dear Sir—Please find inclosed the report made after making an investigation of the Frontenac mine No. 2, November 14, 1888. It will give you some idea of how the mine was laid off; also about how we found everything when we made the investigation; and you can use it or not just as you think best. I still think that fine coal-dust will increase the flame after an explosion is started, but no one can explode coal-dust of itself; and it is a question in my mind whether sprinkling would heve done much good in this case, as we found the floor of the mine very damp—could take up a handful of the fine coal-dust and leave the imprint of my fingers in it after pressing it hard in my hand. The best and safest way to avoid explosions is to see that all powder taken into the mines is kept in a good box prepared for that purpose, under lock and key, and no more than is required for the day, and that shot-firers are employed as we now have them to attend to the blasting. This is one of the best laws ever enacted in Kansas, and it is ahead of all the sprinkling that could be done. I remember, when we started up No. 5 mine at Weir City, after we had got in about far enough to start our cross-entries and while we were using the battery, we put off three large blasts at once, and the concussion from same blew down our upcast, and flame and dirt came out at the mouth of the shaft. Now this was not for want of sprinkling, as we had from one to four inches of water all over the floor of the mine. When we fired two large shots it was all right, but just as sure as we had three large shots we had bad results; so this goes to show that sprinkling is no sure remedy; and I am satisfied that, if it had not been for the shot-firing law, we would have had many explosions since the Frontenac one, even if we had sprinkled the floor of the mine enough to have given us trouble by making the floor of the mine heave up and the pillars sink down. I have mined coal in Scotland over 40 years ago where the fine coal-dust was so fine and hot that it would almost scald your feet, and coal that contained over 20 per cent. more gas than our Cherokee coal, and we never had any explosions. You may ask what the reason was we had none. It was simply that coal-dust is not an explosive; and as we had to mine all our coal and cut it and wedge it down, using no powder, you can see that, as we used no explosives, and could not explode the dust, we had nothing to cause an explosion, there being no gas in the mine but black-damp, (sorry to say at that time we had more of that than we wanted), but am glad that later on the mining law was put in force and that they now do as we do, try and comply with the law. I do not think now—since we have the shot-firers' law—that if it is complied with we will have any more explosions of a destructive nature. Am only sorry that the shot-firers will not be more careful while doing the blasting, and not rush around as quick as they do, to try and get through with it in a few hours. Still it a great improvement from the old way of every miner firing his own shots, even in the careless way they rush around, and not so many lives are in danger. Yours truly, D. MACKIE.

Scammon, Kas., December 9, 1895.

Bennett Brown, State Mine Inspector:

Dear Sir—At the request of George Findlay, State Mine Inspector of Kansas, I went to Frontenac, Kas., November 14, 1888, to assist in the investigation of mine No. 2, owned and operated by the Santa Fe Coal Company, and located about 3½ miles northeast of Pittsburg, Crawford county, Kansas. Robert Craig, general superintendent, William Hamilton, William Ellwood, mine-boss, and myself, made a thorough investigation of this mine to determine the cause, if possible, of the disaster that occurred about 5:20 p. m., November 9, 1888, the time the miners were firing their shots. The mine was in the condition left by the explosion, no work having been done except a few necessary repairs put on the fan and overcast, and temporary stoppings put up with brattice cloth to get sufficient ventilation to enable volunteers to explore the mine to rescue those who may have been left alive. The entries, rooms and other working-places had not been disturbed since the explosion.

The shaft is about 110 feet deep, had been operation about 12 months, and was one of the best equipped in Kansas, having all the latest improvements, large coupled hoisting-engines, self-dumping cages with safety catches; also, a good 15-foot fan constructed on the Gubal plan which acts as a suction or exhaust, being near the escapement shaft, size 7x11¾. This fan is capable of producing 30,000 cubic feet per minute, running about 55 revolutions. According to the testimony of the engineer in charge it had not been running less than 50 revolutions per minute that day. This escapement shaft is also the return for the air, or upcast shaft, the hoisting shaft being the downcast.

The underground workings are laid out on the latest improved plan, and worked on the room-and-pillar method. The main entries run east and west, are 12 feet wide, 5½ feet high, well timbered, and protected with ample pillars left between main and parallel entries running on north and south side, each entry 6x5 feet in the clear. The cross-entries run north and south, and are double entries 6x5 feet in the clear, turning off rooms from each entry. The distance between each entry or set of cross-entries is about 400 feet, leaving 200 feet that each room requires to run to meet the room from opposite set of entries. The air splits into four divisions, two at extreme end of east main entry, one split taking the north entries and rooms, returning down north parallel on side of main east entry to west side of shaft, then over the overthrow to upcast shaft. The other takes south side entries and rooms and returns down parallel entry on south side to upcast shaft. West side splits at extreme end of west entry, one split taking north entries and rooms returns on parallel on north side of main entry (east) passing over overthrow to upcast on south side. The other takes south entries and rooms and returns on parallel entry (east) to upcast. This method of ventilation shortens the travel of air and reduces friction which takes less power to produce the current. J. J. Atkinson asserts that each man inhales about one-fifth of a cubic foot of air per minute, and converts about 7 per cent. (by volume) of this into carbonic acid gas, which, with about 3¾ times as much free nitrogen, he exhales along with about 66⅔ per cent. of the air he breathes in an unchanged state.

The largest lamp used in mining converts less oxygen into carbonic acid gas than a workman. Both give off watery vapor as well as carbonic acid gas. When coal is on fire it gives off, in burning, carbonic acid, carbonic oxide, and sulphurous acid gases. The explosion of gunpowder gives rise to

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carbonic acid, nitrogen, carbonic oxide, and steam, besides carbureted and sulphureted hydrogen in small proportions. So by circulating or splitting the air into four divisions it makes the air purer on each division, as there is only one-fourth of the foregoing gases to encounter. Also, where blasting is done there is less smoke to annoy the workmen, and not the same chance of carbonic oxide gas to generate, as the air is not so densely adulterated. It also makes it safer in the event of an explosion, as the division or split where the explosion occurs is the only part of the mine disturbed in most of cases. About the only gases found in our western mines are carbonic acid gas, carbonic oxide, and carbureted hydrogen gas.

In our investigation we could not find any of the aforesaid gases in any quantity that would cause an explosion. And am satisfied that gas had very little to do with the cause of disaster. Blasting powder was the principal, if not the sole, agent of the explosion. We believe that a keg of powder in cross-cut between third and fourth entry, about 67 feet from face of room No. 10, exploded, which also exploded three more kegs of powder about 25 feet from the same on the side of the fourth north entry, this coming in contact with several more kegs, assisted with the fine and heated coal-dust raised by the aforesaid exploded powder, gave force to the explosion as it went along towards the bottom and expended itself at the mouth of the shaft.

On second investigation, November 17, 1888, accompanied by William Hamilton, of Weir City, and Mr. Ellwood, mine-boss, we went into the mine, it having been reported that gas had been seen in parallel entry on north side of main, east. We could not find any gas outside of the parallel face of entry, but by applying naked or open light of lamp to a crack in the face of coal lighted gas therein. The volume did not exceed two cubic inches and died out in two or three seconds. In cross-cut about 75 feet back of face of main east entry, on south side of said entry, a keg of powder exploded in a cross-cut not yet through. This keg was taken down on the morning of the day of explosion, as told to Mr. Ellwood, by the brother of the man who owned it.

In fifth room, third north, on east side of mine, we found an exploded powder keg 58 feet from mouth of room No. 8 of third north; found gas in a crevice in the coal, but had to fan this with hand to show on lamp as it did not appear outside of crevice.

In room No. 10, as heretofore mentioned, on third north, we found a very little gas in drill hole from which tamping had been blown out; applied light of lamp to same and ignited it. The volume in this case did not exceed four cubic inches. It would not show on applying the lamp light the second time.

In room No. 7 of the third south entry, on east side, we found a keg which had apparently been exploded. This was found near a powder box which was locked and had in it according to our judgment, by shaking the box, nearly a full keg.

In conclusion, will say that after a careful examination of Santa Fe mine No. 2, considering the evidence in this case, I find nothing with which to censure any one in charge of said mine. All the precautions provided by the present mining law of this state seem to have been fully complied with. The disaster was, in our judgment, due to careless and excessive use of powder, which we are now trying to remedy by having regular men do the shooting, with instructions that, should any miner not do some mining or cutting, his shot should not be fired; also, that they start firing on the return of the air, giving time between shots for the coal dust raised by concussion and gases

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extracted from combustion of powder to be carried off before the next shot is fired. This, with an improvement in the mining law compelling mining and cutting to be done, would enable the miners to make more and better coal, with a little extra labor and a greater safety to life and property.

D. MACKIE,
WILLIAM HAMILTON.

Mr. Craig, of Osage City, writing of the Frontenac explosion, says:

I examined the mine a good many times and in company with a good many persons for the purpose of finding out the cause of the explosion, and from those investigations I came to the conclusion that it was caused by powder. I found either 9 or 10 powder kegs that had been exploded, some of which must have been nearly full, as they had been taken down the shaft on the morning of the explosion.

I think it originated in the fourth north entry or in the cross-cut between the third and fourth north entries on the east side of the mine, where five men kept their powder at one place, and another man kept his powder within 20 feet of the others, which made four or five kegs, equal to 100 pounds, of powder at or near the same place, all of which we found exploded and all the men found at or near that place were very badly burned.

The indications of fire on the roof and coal rib at that place was unmistakable. The same indications appeared more or less at every place where we found an exploded keg; at and near these places there were slight traces of a little coal-dust having been charred and sticking on the end of a pit car and on some props about half the size of a hazel nut, but away from where those powder kegs had been exploded there was nothing of the kind to be seen. I noticed particularly that on the room and entry roads the dust appeared the same after as it did before the explosion, and I am fully convinced that if coal-dust as it appears in the mines of southeastern Kansas was explosive or as inflammable as the coal-dust theorists try to make it appear, all the dust in the eastern portion of that mine would have been burned or coked and would have so appeared on the floor of all the rooms and entries traversed by the explosion, but such was not the case.

The damage to the mine was comparatively little, considering the number of lives lost. Excepting the men found at or near where the powder had exploded, they either lost their lives by suffocation or concussion. There was perhaps 1,800 feet of air going direct from the main shaft east on the main entry, and as the force of the explosion met that volume of air, heating and expanding it, and at the same time displacing it, the pressure must have been considerable in the main entry and at the shaft, and as one side of the main shaft was blocked at the bottom by pit-cars, reducing the size of the opening, the force of the compressed air rebounded, breaking down the doors on the first north and south entries, looking for more room to get to day by way of the air shaft, blowing down one end of the fan-house, which was easily replaced, the fan continuing to run all the time, not being damaged any. There were only a few sets of curbing and a few guides displaced at the bottom of the main shaft, all the doors on the east and a few sets of timbers in the main entry blown down; also a few of the stoppings were partly blown out. I think most of the damage done near the shaft bottom was by the rebound and compression. By midnight, after the explosion, one side of the shaft was put in shape and hoisting with the cage. I believe this terrible accident was caused

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by some unfortunate miner (one of those six who had their powder at one place) accidentally setting fire to the powder in his keg, which communicated from one keg to the other on its way to open day by the way of the main and air shafts, taking the course of least resistance, doing no damage in the first pair of entries north and south beyond the opening to the air shaft, all four of which were as dry and dusty as any portion of the east side of the mine.

The American Institute of Mining Engineers (1894) in discussing a paper on coal-dust, says: "Apart from the theoretical difficulties of the problem, the practical question at once arises, if Mr. Stewart's theory of this case is correct, how are we to explain the fact that no previous shot in these collieries or in any others is known to have initiated such a coal-dust explosion?" In its final report (1886), the first British royal commission on this subject says very sensibly: "If coal-dust was the principal agent in coal-mine explosions, every blown-out shot occurring in a very dry and dusty mine should actually be attended by a more or less disastrous explosion or conflagration; and looking therefore to the enormous amount of powder expended in shot-firing in this and other countries, and to the not inconsiderable portion which blown-out shots must constitute in many localities of the total number of shots fired, disastrous explosions should be of more than daily occurrence if this view was correct." The foregoing expresses my views exactly, and think it will apply perfectly to the conditions and practical experience existing in the coal-fields of southeastern Kansas. My dear sir, I will say right here that you will find the testimony on the coal-dust theory (because it is only a theory, and so-called by the American Institute of Engineers as late as 1894) very conflicting, and taking it for granted that you are an advocate of the coal-dust theory, the first question that might be put to you is, What do you know about coal-dust being explosive from your own personal knowledge? Have you ever made any experiments with the coal-dust from any of the Kansas mines or any other coal-mines, and why it is that every blown-out shot in a dry and dusty mine is not attended with a more or less disastrous explosion, seeing that there is plenty of dust to communicate, carry and extend the flame to every portion of the mine? but the facts are, it does not do it.

Mr. William Morgans, a leading expert of England, says, in speaking of the Altoft's explosion, "that fire-damp was known to occur in that colliery," but the explosion was attributed to coal-dust alone. The official report afforded reason for considering that fire-damp was the backbone of that explosion, and that it occurred where gas was afterwards found. Those who believe in explosions of coal-dust alone must find some better example than Altoft's, which belonged to the armory of their opponents, because fire-damp was given off in that colliery. "As yet," he says, "there was not a single example to be brought forward of a colliery explosion in any of the dusty workings of this country (England) which were free from fire-damp, notwithstanding that blasting was extensively carried on in them day by day." I might go on indefinitely quoting what might be considered good authority that coal-dust is not explosive, but will stop, knowing full well that this coal-dust theory is like other theories, having advocates both for and against. However, I wish to say further, that about two weeks since I read the official examination of Mr. Ralph Moore, one of her majesty's mine inspectors for Scotland, on the explosion that occurred in the Blantyre colliery some years ago, in which a great many lives were lost. Mr. Moore was inclined to the coal-dust theory, but his answers to the questions put by the chairman of the commission were lame in the extreme, and failed entirely to establish his dust theory, and upon

cross-examination he had to admit that there were nothing but safety-lamps used here on account of the gas, and there were at least 60 acres of waste where the coal was all taken out and yet he tried to contend that enough gas could not accumulate in that space to do the damage that was done. Mr. Joseph Dickinson, her majesty's senior mine inspector, made a report on the same explosion, and held that it was a gas explosion, and his answers to the questions put were reasonable, practical, and common-sense like, and altogether different from Mr. Moore's.

I mention this to show how unreliable a report might be (though dubbed with her majesty's mine inspector) and how great minds differ, and how conflicting testimony is on the same subject or thing.

Referring again to Mr. Moore, although he seemed to make rather light of the gas theory in the Blantyre explosion, notwithstanding his confession that no naked light was allowed in the mine, and as I knew Mr. Moore personally to be an educated gentleman and a trained mining engineer of many years' experience, and as I was manager five years in his district, and knowing, as I do, from personal observation that all the mines in that district give off a great amount of fire-damp, you will pardon me for being somewhat skeptical on reports and opinions that appear in print, or given from the witness stand when I know them to conflict with facts, reason, and common sense.

In conclusion, I know that powder and fire-damp are explosive; but do not believe that the dust in our Kansas coal-mines is.

Osage City, December 26, 1895.

I understand that an officer of one of the largest coal companies in the state, a young man of superior attainments, both practical and scientific, has been making some experiments on lines corresponding to these adopted by European experts, to demonstrate to what extent, if any, coal-dust is conducive to mine explosions; but through press of other duties he had to suspend investigation before securing results justifying publication. He writes, however, that he hopes at an early day to be able to give scientific information that will be of value to those seeking more light on the subject.

The writer has had no personal experience with coal-dust explosions; he has been in several mine disasters; but all of them were clearly traceable to the presence of gas (fire-damp) in the mine. It is therefore with much diffidence that he ventures to submit his own opinion. In all my researches I have not been able to satisfy myself that an explosion has ever occurred in any bituminous coal-mine in which the presence of gas had never at any time been discovered. I am also well aware of the fact that there never was an explosion in any mine in this state until the shafts to open the vein had penetrated to such a depth that gas was known to issue from the crevices of the vein and associated strata, not, of course, in quantities to cause any alarm; but it was known to be there. It has been demonstrated on indisputable authority—Abel, Galloway, and others—that a very small quantity of fire-damp, less than 1 per

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cent. in volume, mixed with the atmosphere of the mine, renders coal-dust inflammable to the point of being explosive when stirred up and exposed to fierce flame such as that caused by a blown-out shot. It is also affirmed by the same authorities that less than 3 per cent. of gas in the atmosphere is only discoverable by the most expert examiners with the aid of the safety-lamp, and that even they fail to discover any signs of gas when it is present in quantities of less than 2 per cent. It is well known to all men who have given the subject any thought that the minimum and maximum proportion of gas and air alone, forming an explosive mixture, is 6 per cent. gas to 94 of air, and 16 per cent. of gas to 84 of air; at both of these extremes the explosive force is very feeble, and, unless under very extraordinary conditions, not likely to cause much damage. The atmospheric pressure which confines this gas to the crevices of the coal-vein and the associated strata equals $14\frac{1}{2}$ pounds to the square inch; the pressure due to ventilation in the average mine in southeastern Kansas is inconsiderable, yet even that is a factor. As stated by Mine Inspector Hall, Professor Herschel, and Mr. Joseph Dickinson, a blown-out shot in a narrow heading (entry) has the effect of creating a vacuum; that is, the atmospheric pressure is for the moment removed from the area of coal-face and associated strata affected by the shot. It will not be disputed that an overcharged shot will have the same effect. We can readily perceive how, when the pressure that keeps these occluded gases pent up in the strata is removed, the chamber of a mine may be filled instantly with explosive gas. The air rushing back the moment the force of the shot is spent prevents further escapement, and, diffusing with the gas already liberated, reduces the whole below the explosive point.

That this might not always be the case, however, is patent to every man, as the quantity of gas liberated depends upon varying circumstances, such as the condition of the atmosphere at the time the shot is fired, the quantity of gas occluded in the vein at the point the shot is placed, the force exerted on the atmosphere by the explosion of the powder, etc. The diffusion of the air with the gas liberated failing to reduce the mixture below or above the proportion necessary to explosive effect before the flame of the shot had expired, assisted by the gases generated through imperfect combustion of powder, together with the high temperature caused by the flame of the shot and the heated coal-dust thrown up and held in suspension, give all the elements and conditions necessary to a powerful and destructive explosion. The explosion having occurred, a vacuum is created over the entire area affected. The creation of a vacuum necessarily compresses the atmosphere at other

points; when reaction takes place, this compressed air, rushing to fill the vacuum at the rate of 333 feet per second, destroys all equilibrium, and in a second, so to speak, from the time the fatal shot is fired the excavated space affected by the explosion is transformed into a seething, flaming furnace, and the galleries of the mine are subject to the same condition as the surface of the ground in the track of a cyclone. It would seem that this supposition is strongly supported by the experience of Mr. Mackie, who says, "When we fired two large shots it was all right; but just as sure as we had three large shots we had bad results," conclusively showing, either that the two large shots did not liberate a sufficient quantity of gas to cause an explosion unassisted by coal-dust, or that the expansive force of the powder alone when he had three large shots was sufficient to fill the mine with flame, rushing from the mouth of the upcast shaft with force enough to blow down the smoke-stack, which is not at all likely.

The reason why Mr. Mackie did not see any coal-dust explosion in the extremely dusty pits he describes in Scotland is, that in those mines the coal was mined by hand labor, and no one claims that coal-dust of itself will cause an explosion through coming in contact with the flame of a miner's lamp, although there are several well-authenticated instances of coal-dust having exploded on the surface of the ground through coming in contact with an ordinary light.

In reaching the above conclusions, I am strongly influenced by the opinion expressed by Professor Abel and many others, that no coal-mine—except when the vein lies very close to the surface of the ground—can ever be considered absolutely free from gas (fire-damp), and there can be no absolute immunity from explosions in coal-mines where dust is present in large quantities, in which powder is used to win the coal.

The miners as a body, through their organizations and otherwise, and mine operators should petition Congress to appoint a commission composed of able, scientific and practical men to investigate this and all other matters connected with coal-mining, who, in their report should recommend one general, uniform mining law, the enactment of which by the different states would give the trade and those connected with it uniform protection and responsibility.

This article is compiled at the request of several mine officials and miners of the state, for the purpose of drawing the attention of mine managers, miners and shot-firers to the extreme and ever-present danger to life, and the destruction of property attending the careless and indiscriminate use of powder in the coal-mines of southeastern Kansas, and the necessity for observing the law relative to shot-firing.

RECORD OF MINE MAPS, BOILER INSPECTIONS, ETC.

The following companies filed maps of the underground workings of their mines:

The Cherokee & Pittsburg Coal-Mining Company, all of its mines.
The Western Coal-Mining Company, all of its mines.
The Kansas & Texas Coal Company, all of its mines.
The Wear Coal Company, all of its mines.
The Central Coal and Coke Company, all of its mines.
The Pittsburg & Midway Coal Company, all of its mines.
The Fuller Coal-Mining Company's mine.
The Arnott & Lanyon mine.
The J. H. Durkee Coal Company's mine No. 1.
The Southwestern Coal and Improvement Company's mine No. 6.
The Penitentiary mine.
The Home Mining Company, both mines.
The Leavenworth Coal Company's mine.
The Osage Carbon Company, all of its mines.

The following companies have filed certificate of boiler inspection:

The Cherokee & Pittsburg Coal-Mining Company, all boilers.
The Kansas & Texas Coal Company, all boilers.
The Wear Coal Company, all boilers.
The Scammon Coal Company, all boilers.
The J. H. Durkee Coal Company, all boilers.
The Central Coal and Coke Company, all boilers.

Nearly all of the companies have responded to the law requiring airways to be examined twice every week and result filed with the Inspector, but so far as air measurements and returns are concerned the law has not been complied by any company.

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STRATIGRAPHY OF THE KANSAS COAL-MEASURES.

The following condensed summary of the stratigraphy of the Kansas coal-measures from the Kansas University Geological Survey, by Prof. Erasmus Haworth, of the Kansas State University, gives a much better and more accurate description of the area, thickness, location and value of the Kansas coal-measures than it is possible for the Inspector to give with the limited practical knowledge he possesses on the subject. It is therefore published as a part of this Report for the benefit of those who are now or may think of going into the business.

DIVISION OF THE KANSAS COAL-MEASURES.

So many different plans have been followed by geologists of the Mississippi valley in dividing the coal-measures, that one who is laboring in a new field has no positive criterion by which to be guided. By some the coal-measures have been divided into two divisions, the lower and the upper; by others into three, the lower, middle, and upper. Rarely have the same division lines been made, or the same bases of classification been used, so that we are left in doubt in almost all instances why any particular division was made at any particular place. According to the different state reports of our nearest neighbor to the east, Missouri, Broadhead used a sandstone with no special characteristics as the division line between the lower and middle coal-measures, and a second sandstone of equally unimportant characteristics for the division line between the middle and upper. Why these particular sandstones should be chosen rather than other formations he does not say, neither are we informed why the whole coal-measures should be divided into three divisions rather than into two, or four, or any other number. Winslow, in his more recent report, does not attempt to divide the Missouri coal-measures at all, but he does not take ground against it; so the reader is left in doubt to a certain degree regarding his views on the subject. But Doctor Keyes, in volume II of the Iowa report, 1894, brings up strong objections to the older method of division, and suggests what seems to be a better basis of division,

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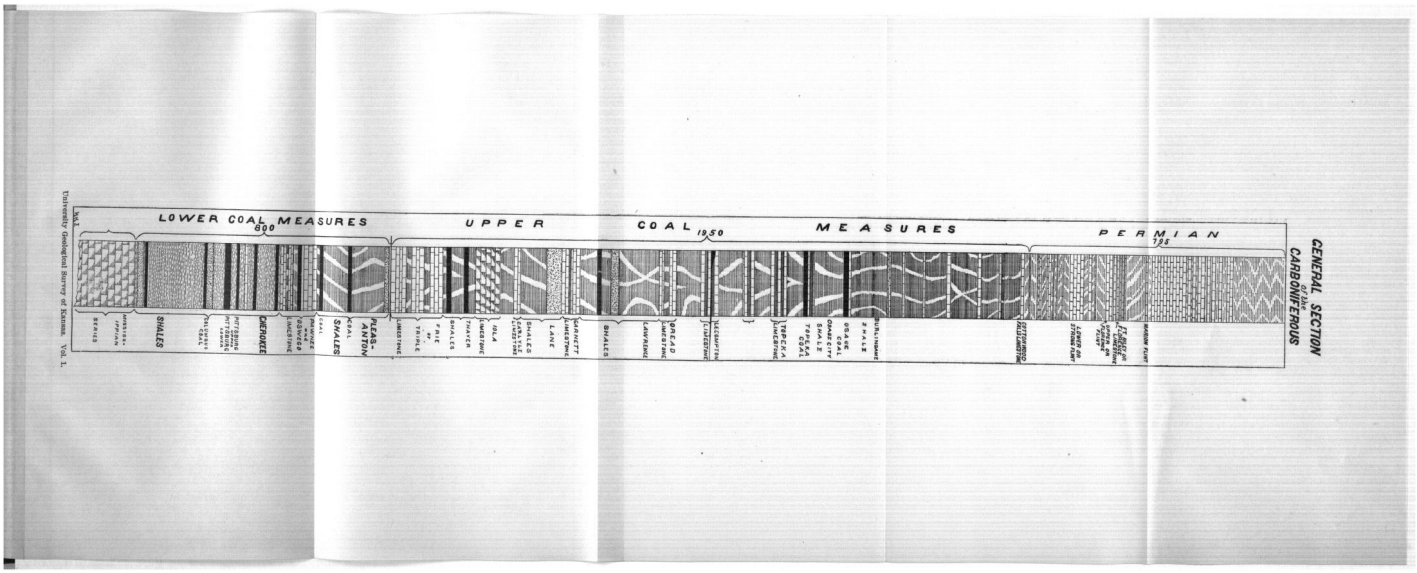

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provided one is used at all. We shall have occasion to refer to this later in this paper.

It would seem reasonable to assume that in all matters of divisions and subdivisions of the coal-measures the same general methods be adopted and the same principles followed that are used in determining the number and locations of the subdivision lines of any other great geologic formation. The custom of geologists of all countries is practically the same in this. At least one of two conditions is always required to make a division which in application is more than local. One of the conditions is that there must have been a break in the succession of formation, a time break, indicated by general unconformity, such as is produced when a surface is lifted above ocean water and more or less eroded before later formations are placed upon it, or when considerable orographic movement has occurred leaving the strata already formed in an inclined position, so that the new formations will not be conformable with them. The other condition accepted universally as a sufficient basis for making a division or subdivision in stratigraphy is a positive variation of any character in the flora or fauna of the formations concerned. There may be grounds for difference of opinion, or difference in custom regarding the degree of variation which should obtain, but all admit that if the change is sufficiently great a division of the formation should be made, either with or without unconformity.

The coal-measures of Kansas are 2,750 feet thick, and cover an area of approximately 20,000 square miles. It would seem desirable, therefore, for the sake of convenience to subdivide them into two or more groups. But when a section of country has been studied in sufficient detail to trace the different great classes of formations across the whole area, and to determine their limits vertically, as has been done for the Kansas coal-measures through the assistance of the numerous deep wells which have recently been drilled in our state, it becomes possible to make many subdivisions to which local geographic names can be applied, thereby in great measure limiting the convenience which may be derived from other kinds of subdivisions. It is doubtful whether any real convenience will arise by making any division of our coal-measures other than those already made and to which local geographic names have been assigned, for it is now possible to speak exactly with reference to any portion whatever of our coal-measures anywhere in the state by a proper use of the terms already introduced.

It is the concerted opinion of the different individuals who have been engaged with the writer in field-work that the Kansas coal-