Reports

Coal Mine Explosions: Seasonal Trends

Abstract. *An analysis of disaster reports on coal mine explosions indicates that gas explosions are randomly distributed throughout the year, whereas dust explosions (which may or may not be triggered by a gas explosion) occur with greater frequency during the dry fall and winter months. The lack of adequate moisture during cold weather tends to increase the rate and severity of the dust explosions.*

Boyer (*1*) noted that disastrous coal mine explosions seem to be more frequent in the winter than in the summer. He and others (*2, 3*) have suggested two possible reasons for this.

1) Changes in barometric pressure are generally more abrupt and intense in the winter months. Presumably, low barometric pressure causes expansion of the methane that has accumulated in underground cavities and crevices (*4*). This methane then flows into the mine, making an ignition possible.

2) Mines are drier in the winter because of the low moisture content of the air (*5*). This means that the coal dust is drier and more easily dispersed and ignited during the cold months (*3, 6, 7*).

To date, there has been no attempt to ascertain which of these two factors is more important. McIntosh (*2*) has been able to associate many mine disasters with the passage of a cold front; however, when a cold front passes both the barometric pressure and the air moisture generally fall, so there is no simple way to separate the two factors.

In a study of the factors that affect methane migration in coal beds, we found that the barometric pressure is not particularly significant (*8*). The permeability of the solid coal bed in the working area of a development section is generally 10 millidarcys or less, and the methane pressure 30 m (100 feet) into the solid coal can easily approach 7×10^5 newtons per square meter (100 pounds per square inch) or more in a gassy mine. Methane flows into the mine from the coal because of this pressure difference, and it is most unlikely that fluctuations in the barometer will have any effect on this flow.

While development sections are those driven into solid coal, other areas of the mine contain spaces where methane may accumulate. These can be unventilated rooms that have been sealed off, or they can be gobs (worked out areas where pillars have been taken and the roof allowed to collapse). Gas in gobs may originate in coal left behind, or in adjacent strata composed of porous sandstones or other coal beds. Gobs are much more permeable than the coal bed in development areas of the mine; Stevenson (*9*) showed that gobs will indeed emit more methane during periods of low barometric pressure, while development areas are not affected. This gas from gobs might make mines more dangerous during barometric lows, except that few ignition sources are to be found in such areas because fewer men work there.

We reasoned that if gas from gobs were an important factor in causing the seasonal trend, then this should be evident from accident reports: there should be a higher incidence of explosions that originate near worked out areas and gobs in the winter.

Humphrey (*10*) summarized the circumstances surrounding the major (five or more killed) and minor coal mine disasters caused by explosions between 1911 and 1958, and descriptions of disasters after 1958 were available to us from coal mine inspection files. We analyzed each of the major disasters individually to ascertain whether the explosion originated in a development area or near a gob. In about half the cases the information was not complete enough to place the disaster in either category; however, in the half that we could categorize, no trend toward an increased proportion of gob accidents in winter months was evident. This seemed to indicate that barometric pressure changes were not a contributing factor in the seasonal accident trend. Accordingly, an attempt was then made to determine the effect of moisture content in the mine air. To do this, we reexamined the accident reports to compile those major disasters due to dust only. These are disasters where the accident investigators concluded that dust was directly ignited, without gas participating as an intermediate stage. Typically, these took place in mines known to be relatively free of methane, and where the dust was ignited by a blown-out or "windy" shot.

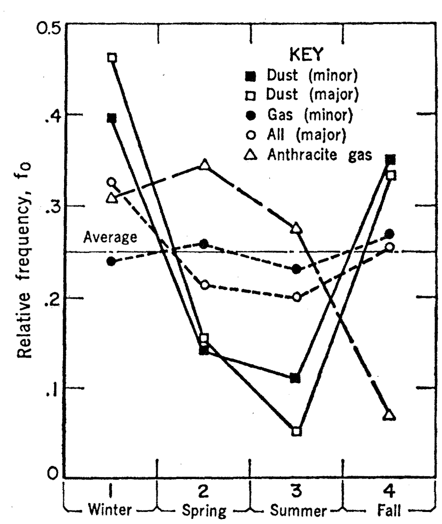

Fig. 1. Relative observed frequency of occurrence of major and minor gas and dust explosions.

The disasters were then grouped on a quarterly basis (January to March, and so forth). Figure 1 gives the relative frequency of occurrence of all major disasters and of the "dust only" major disasters for the period 1911 to 1970. It may be seen here that there is a slight seasonal trend for all major disasters, and this is the trend Boyer observed; however, this trend is far more pronounced for the major dust disasters. The same general observations hold true for relative frequencies obtained with data based on the production rate of coal (explosions per ton of coal mined in a season).

Boyer has pointed out that there is no seasonal trend in minor disasters (zero to four fatalities per incident). Most of these disasters could be categorized as "gas only" or "gas and dust"; however, about one-sixth could be separated out as "dust only." Figure 1 also gives the relative frequency of the minor gas and dust disasters for the period 1941 to 1970. Again, the former exhibit no pronounced seasonal trend, whereas the one-sixth that are due to dust only exhibit the same trend found for the major dust disasters.

Anthracite dust is not explosive; it follows that explosion disasters in anthracite mines are "gas only," and no subjective judgments of an accident investigation team are involved. Major disasters in anthracite mines are also shown in Fig. 1 for the period 1911 to 1970. There is no increase in the relative frequency for the winter months, which provides more evidence that it is dust and not gas that accounts for the seasonal trend.

If we assume that a major mine explosion is a rare and random event unaffected by the occurrence of any other similar event then the probability that a number of such explosions will occur in a particular time interval (for example, 1 month) should be given by the Poisson distribution function. This was found to be the case for a number of 10- to 30-year intervals. However, when we considered the number of explosions that occurred during each of the four quarters over the period 1911 to 1970 we found that there is a statistically significant difference in the results obtained for the major (gas and dust) explosions. Similarly, the major explosions attributable to dust showed a statistically significant difference; however, those attributable to gas (total minus dust) appeared to be randomly distributed throughout the year.

Similar results were obtained when anthracite mine (gas) explosions were analyzed for the period 1911 to 1970, and minor gas and dust explosions in bituminous mines for the period 1941 to 1970. That is, the gas explosions appeared to be randomly distributed throughout the year, while the dust explosions occurred with greater frequency during the fall and winter months (that is, during cold weather).

Boyer's report (*1*) contains indirect evidence that dust is at the root of the seasonal trend, even though he did not call attention to it. He showed that the worst disasters had the strongest seasonal trend. Roughly, it might be said that these disasters resulted from the most extensive explosions which, in turn, involved the most dust. If this is true, then the more that dust was involved, the greater the seasonal trend.

The notion that humidity is an important factor in the incidence of disastrous explosions in the winter is hardly a new one. Scholz (*3*) called attention to a humidity effect in 1908. A year later, Eavenson (*6*) calculated the quantity of water lost by mines in the winter and the quantity gained in the summer. For mines that circulated 2800 to 4200 m^3 (100,000 to 150,000 cubic feet) of air per minute, about 21 to 69 tons of water per day would be lost in the winter and about 12 to 33 tons per day would be gained in the summer. Similar results are obtained in today's mines. Eavenson also presented tabulations of explosions and fatalities on a monthly basis, and the results are similar to those shown by Boyer (*1*) and in Fig. 1.

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Do the Pyramids Show Continental Drift?

Abstract. *The mystery of the orientation of the Great Pyramids of Giza has remained unexplained for many decades. The general alignment is 4 minutes west of north. It is argued that this is not a builders' error but is caused by movement over the centuries. Modern theories of continental drift do not predict quite such large movements, but other causes of polar wandering give even smaller shifts. Thus, continental drift is the most likely explanation, although somewhat implausible, especially as relevant measurements have been made over a 50-year period, whereas geophysical measurements of sea-floor spreading relate to million-year time scales.*

Flinders Petrie (*1*) made the first (modern) detailed survey of the pyramids of Giza (*2*), but his observations seem to have been overlooked by scientists outside archeology. He concluded that the average of some six alignments from the pyramids of Cheops (Khufu) (see Fig. 1) and Chephren (Khafra) was about 4′ west of true north, with an error of 1′. This indicated to him that the earth's pole had shifted by this amount.

Petrie argues that the east and west sides of each pyramid must have been set independently because the pyramids were built centered on a high point of bedrock. The entrance to Cheops' pyramid is in the form of a shaft with two distinct elevations, each section requiring independent alignment. As these are made of well-dressed and well-preserved rocks the alignments are still highly accurate, differing by only 1′. This is the origin of Petrie's estimate of alignment error, and it is well within the limits placed by the acuity of the eye, which must have been used unaided by the builders.

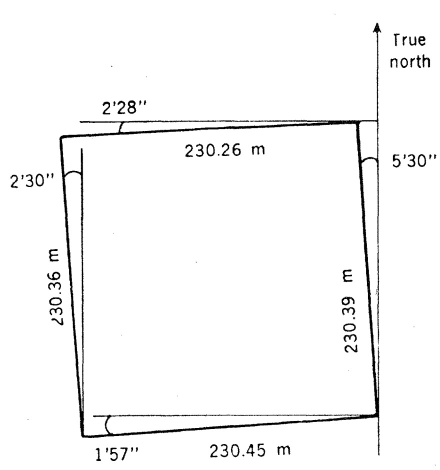

Fig. 1. The Great Pyramid of Cheops.

An independent assessment of the builders' accuracy is afforded by the north and south sides of both pyramids. There is no direct astronomical method of east-west alignment, so that right angles must have been constructed. They were done with an accuracy of about 1.5′.

The northerly alignment must have been intended to be true north as there is no way of aligning to a point just off true north. A star so close to the pole would still describe a small circle in the sky, and this circle would alter considerably in its size in one generation owing to the precession of the equinoxes. Any thought of a magnetic alignment can be discarded because the magnetic variation over one generation would be enormous when the magnetic pole is near the true pole. In any case, the ancient Egyptians were not thought to have the lodestone, and this could never