

# FORECASTING EXPLOSION CONDITIONS IN COAL MINES

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That depressions in atmospheric pressure result in increased emission of methane in coal mines is a well-known fact. That the same depressions, when followed by cold, dry air masses, produce a rapid loss of moisture from coal dust is a more recently recognized relationship (McIntosh, 1957). Increasing methane content and drying coal dust are conditioned changes toward greater risk of methane or coal-dust explosions. Knowledge of the magnitude of these changes in content of methane and moisture in coal dust could be of some importance in the coal-mining industry, particularly where the variation in explosive elements is great.

This paper presents a simple method by which a mine superintendent could determine the approximate increase in methane accompanying a predicted low atmospheric pressure. Furthermore, suggestions are made for continuing research into forecasting possibilities associated with the drying of coal dust.

Coal fields are found throughout the United States under varying climatic conditions. Explosions have occurred in all major fields. The forecasting information presented here pertains primarily to the Eastern Region of the Interior Coal Province which includes the Illinois coal fields.

The methane and coal-dust research studies were made in Peabody Coal Company mines No. 14 and No. 17.

## FORECASTING METHANE CONTENT

The meteorological aspects of the forecasting procedure must, of course, be left in the hands either of the United States Weather Bureau or of private industrial forecasters. A few words about the general weather conditions should suffice here.

Low pressure cells that produce depressions over the Eastern Region of the Interior Coal Province have their source of origin or regeneration along the eastern margin of the Rocky Mountains. This region on the High Plains to the east of the Rocky Mountains is often broken into three or four separate areas and called the Alberta source, the Colorado source, and the Southwest source. In reality, this linear region is a continuous north-south zone of cyclogenesis.

The barogram record from a barograph operated in Marion, Illinois, was inspected for drops in pressure of one-half inch or more over a 36-hour period. Any such drop in pressure would result in a marked increase in methane content of mine atmosphere. The Marion record covered a period from September,

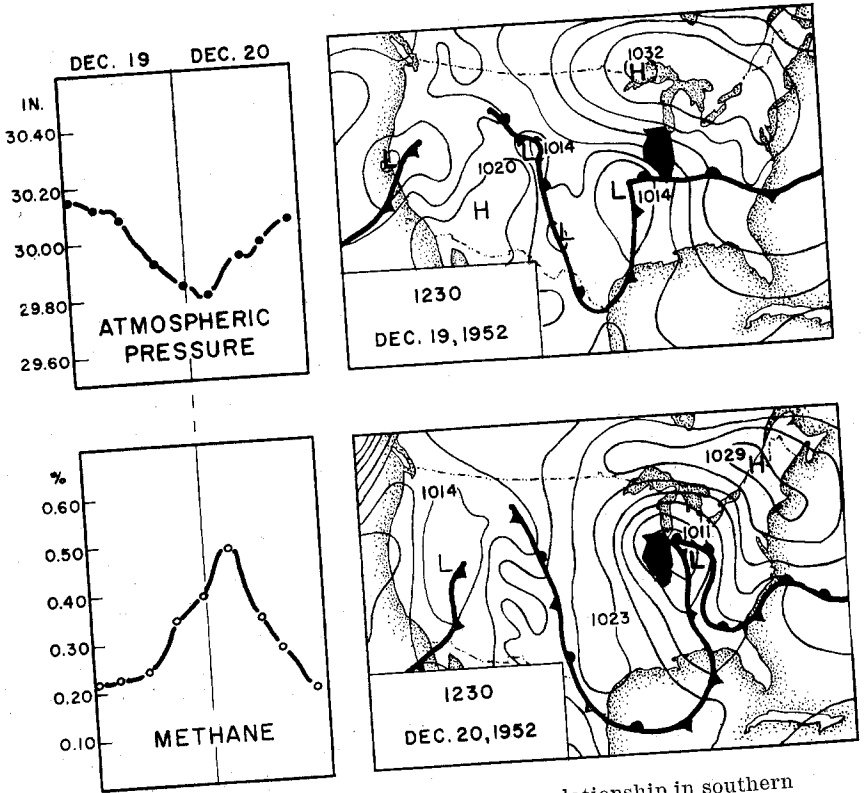


Fig. 1.—Atmospheric-pressure-methane relationship in southern Illinois coal mine.

1939, into November, 1952. Synoptic weather maps were available for 37 of the depressions marked by at least one-half inch fall in pressure. The source region of the 37 cyclones is shown in Table 1. This table indicates that cyclones producing significant drops in barometric pressure over southern Illinois come more often from the Texas and Colorado source regions than from farther north.

The effect of a drop in atmospheric pressure over a southern Illinois mine is illustrated in Figure 1. The weather maps in this figure show a deepening low moving from the

southwest toward the northeast across Illinois. Microbarographs, on research loan from the U. S. Weather Bureau, were located in a mine entry at the point where air samples were taken and on the surface a short distance from the mine shaft. These recording instruments were used by the author to obtain the pressure trace shown in the upper of the accompanying graphs. The upper graph indicates the depression of atmospheric pressure at the mine resulting from the cyclonic passage. The lower graph shows the change in methane content of the mine as the cyclone passed over the mine

TABLE 1.—Source of Deep Lows Observed in Southern Illinois Coal Field 1939-1952.

Source of low	Number of lows
Southwest.....	15
Colorado.....	11
Wyoming and Montana.....	5
Alberta.....	6
Total.....	37

The rising and lowering atmospheric pressures produce changes in methane content because of the pressure differential set up in the mine between entries and methane storage cavities. The term "methane storage cavities" as used here refers to rooms with permanent or temporary stoppings, crevices, fissures, and other places where methane may accumulate with little disturbance from ventilating air.

Falling air pressure at the surface is accompanied by a like pressure change in air ventilating the mine. The result is lower air pressure in mine entries and working spaces than in adjacent, sealed-off rooms. During such periods air moves from methane storage cavities to entries, bringing with it a high methane content characteristic of the atmosphere in the cavities. When atmospheric pressure in the entries is high there is a tendency for air to infiltrate the methane storage cavities.

The relationship between atmospheric pressure and the methane content of mine atmosphere is shown in Figure 2. The methane content of the 72 air samples shown in Figure 2 represents the total sampling used in this research work. All

samples were taken from the same spot in the main return entry about one-half mile from the air outlet. Most sampling was started as a cyclonic depression approached southern Illinois and was continued during the ensuing fall and rise in pressure. Sampling on occasion, however, was continued through anticyclonic periods and thus represented both cyclonic and anticyclonic conditions. An attempt was made to obtain air samples at six-hour intervals, but the intervals varied somewhat depending upon accessibility of the sampling spot.

The overall arrangement of dots in the scatter diagram gives an inverse ratio, with higher methane readings associated with lower pressure readings. Close observation reveals that the alignment of dots is not a straight line. Little increase is noted in methane content as one follows the dot pattern from higher to lower pressures until the pressure level between 29.9" and 30.0" is reached. Below this pressure zone there is a more marked increase in methane per unit change in pressure than observed at higher pressures. The zone between 29.9" and 30.0" is a pivotal or fulcrum zone determined by the average atmospheric pressure for the elevation of the

TABLE 2.—Loss of Life in Dry-Air Explosions.

Explosion number	Number of persons killed
I.....	5
II.....	52
III.....	33
IV.....	111
V.....	119

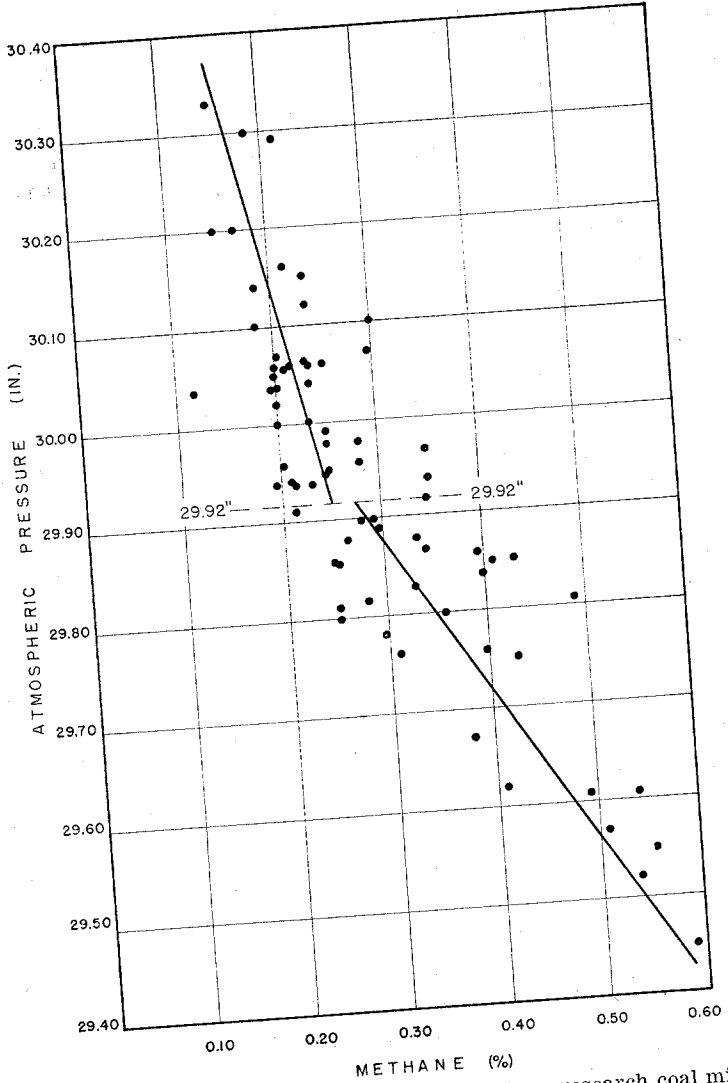


FIG. 2.—Scatter diagram of methane content from research coal mine.

research coal seam. The coal seam was almost exactly at sea level. Average sea-level pressure is 29.92" and, since this figure fits into the pressure range of the pivotal zone, it was used as the pivotal point where the pressure differential changes direction. Above this point

the average atmospheric pressure in the entries tends to be greater than in the storage cavities, and below 29.92" the average pressure in the entries tends to be less than in the methane storage cavities. The line of regression plotted for points found above and below the dividin

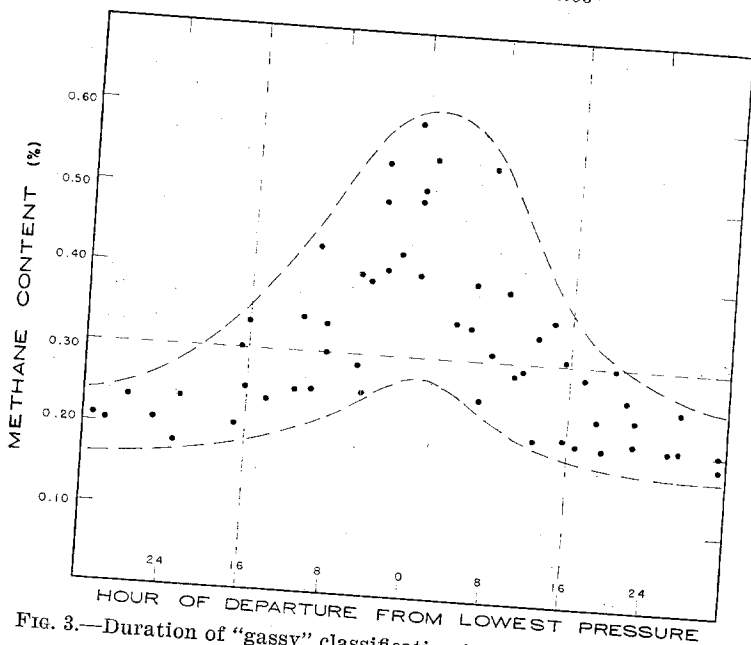


Fig. 3.—Duration of "gassy" classification in main return entry.

pressure-level help one visualize the above-mentioned difference.

A mine is classified as gassy when the mine atmosphere is found to contain methane in excess of 0.25% (Coal Mining Act, 1953). Ventilation of mines is thus set to keep the methane content close to or below the gassy classification. Actually, there are few non-gassy mines. Note in Figure 2 that the lines of regression depart from the selected pivotal pressure-level slightly above the 0.25% content. Below the pivotal pressure-level the line of regression indicates a methane content above the gassy classification.

Dots in Figure 3 represent the methane content in 57 of the 72 previously-shown air samples taken from the southern Illinois coal mine during the passage of 7 distinct atmospheric low-pressure cells or troughs. The methane content in

the return air of the mine is shown along the vertical axis. The horizontal axis is a time scale in hours diverging from the time of lowest pressure indicated on the scale as zero (0). Dots have been placed to the left or right of zero in accordance with the time departure from zero hour.

The methane content in this mine moved into the gassy classification as much as 24 hours before the time of lowest pressure. The progression from non-gassy to gassy classification, however, came most often from 8 to 16 hours before the low-pressure passage, and this gassy classification continued for approximately the same length of time after zero hour.

The graphical tool used in forecasting the increase of methane in a mine is illustrated in Figure 4. The solid line M is the line of regression determined from the pres-

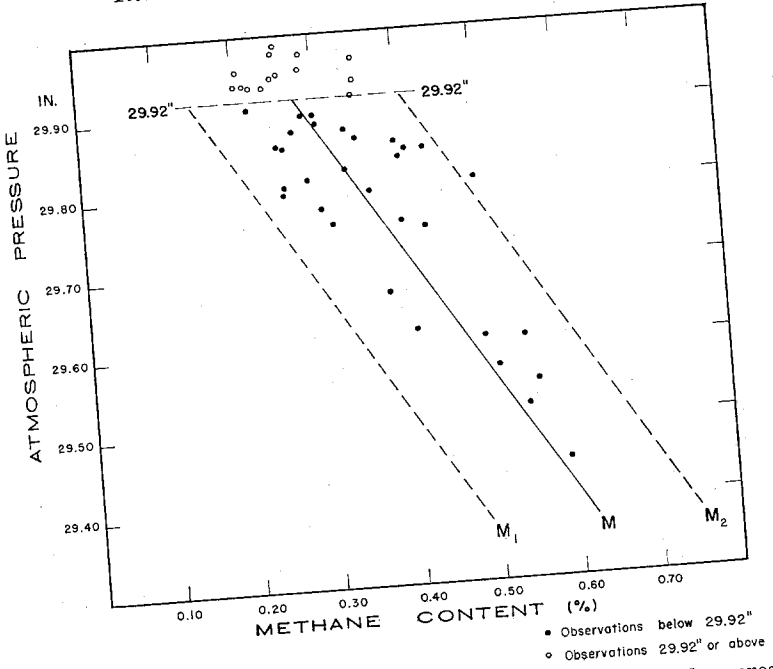


Fig. 4.—Chart used in determining methane content for a forecast low pressure.

sure and methane statistics for the methane amounts noted below the pivotal pressure of 29.92" in Figure 2. Given a forecast of low pressure, the best estimate of methane content will be found along line M, and between the dashed lines, M<sub>1</sub> and M<sub>2</sub>, 95% of the time.

Given (1) the time of low passage, and (2) the forecast barometric depression, the mine superintendent, by observing the time when the barometer drops below the pivotal pressure, may determine the approximate duration of gassy conditions and percentage of methane content at the time of lowest pressure.

A mine superintendent could use a simple inverted T-scale to plot the probable increase in methane. An example of such a construction is pictured in Figure 5. For exam-

ple, the time of low-pressure passage over the mine is forecast for 9:00 p.m. This time is represented on the time scale by zero (0) hour. The atmospheric pressure falls below the pivotal pressure for the mine at 6:00 a.m. on the day of the expected low pressure. The 15 hours representing the time difference between 6:00 a.m. and 9:00 p.m. is marked off to the left of zero hour. The pressure forecast calls for a reading of 29.50". The expected methane content is found as shown (Fig. 5, "B") by moving horizontally from the forecast pressure of 29.50" to the line of regression M and then dropping vertically to the methane scale. The methane scale indicates a reading of 0.53%. This reading is marked on the vertical axis of Figure 5 (A) and forecast

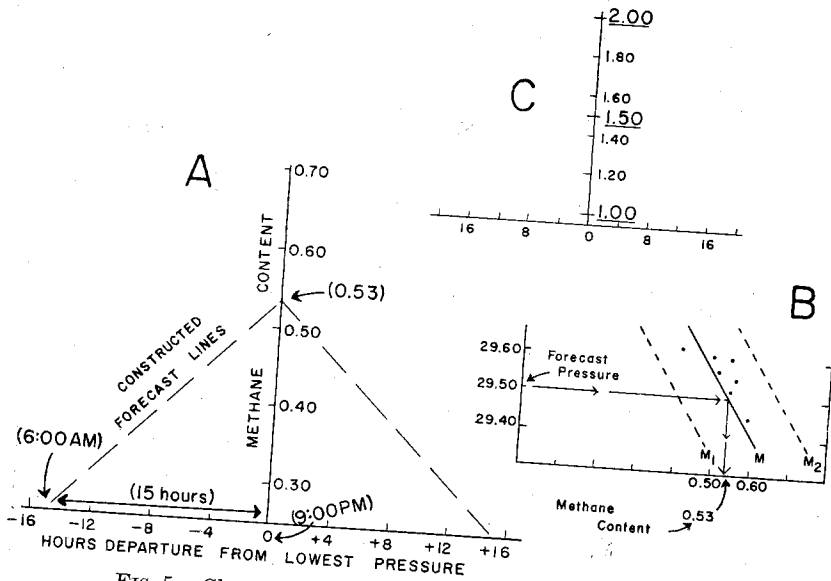


FIG. 5.—Chart used in diagramming forecast conditions.

lines drawn to minus 15 hours and plus 15 hours on the horizontal time scale. Such a graph would indicate a gassy mine condition from 6:00 a.m. one day until noon the following day with a maximum methane content of 0.53% at 9:00 p.m.

Some areas in mines, because of technical or natural reasons, have an unusually high methane content even under normal working conditions. Such areas are inherently dangerous during an atmospheric depression. These areas should have special attention in methane testing and forecasting. Scatter diagrams can be drawn from these more limited areas and special forecasting graphs with higher readings on the methane scale, as in Figure 5 (C), could be used to make forecast plottings. The readings of 1.0, 1.5, and 2.0% have been emphasized because of the significance associated

with these figures as noted in the Illinois Coal Mining Act (1953) in connection with extreme precautions and removal of men from areas having such high methane content. Every mine has its own individual characteristics. The scatter diagram discussed here would be valid only for the mine from which the air samples were taken.

#### COAL-DUST DANGER PERIOD

Experimentation in two Illinois coal mines has established the fact that change in air masses, when the second air mass is cold and dry, results in a rapid loss of moisture from coal dust. Research with the coal dust has indicated a loss of from 7 to 11% of the total moisture content in coal dust within 24 to 36 hours after such a change occurs. Such a loss of moisture from

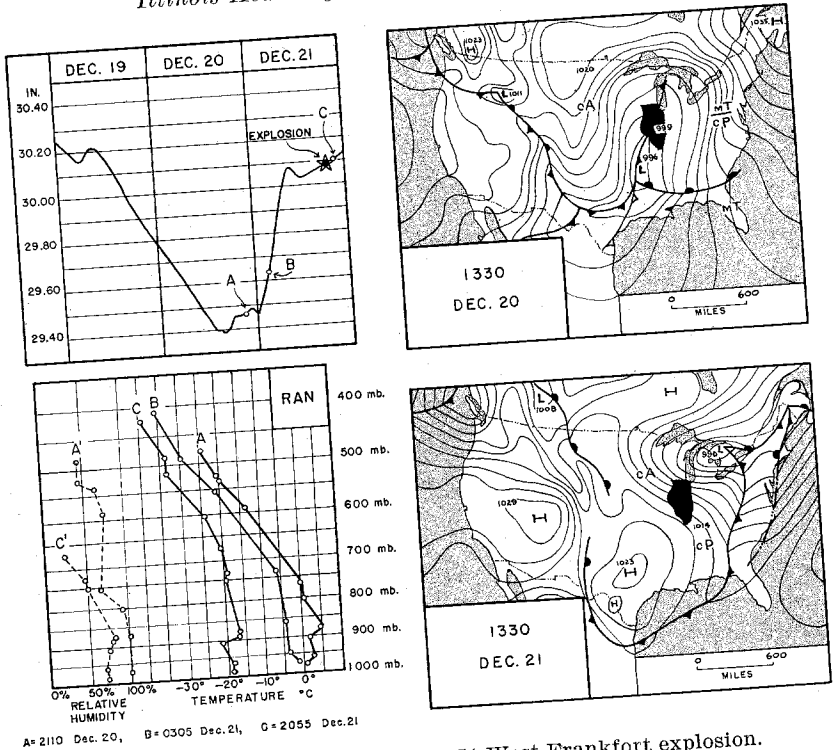


FIG. 6.—Weather charts for the 1951 West Frankfort explosion.

coal dust permits the dust to be more easily dispersed into the air, where it may be ignited.

Coal-dust explosions result in more extensive mine damage and generally greater loss of life than explosions resulting from methane gas only.

With these facts in mind we may take a look at some relationships between weather, coal dust, and mine explosions. Figure 6 pictures weather maps for December 20 and 21, 1951, with two accompanying charts. The upper chart represents the barogram trace from a weather station near the location of a coal-mine explosion. The lower chart pictures the radiosonde information for December 20 and 21, 1951. The

barogram trace and maps show the low-pressure area passing over Illinois late on December 20. The explosion took place late December 21.

Lapse rates, A, B, C, plotted from Rantoul radiosonde observations were taken at the times shown by letters and arrows along the barogram trace in the upper chart. The 24 hours elapsing between A and C brought a drop in surface temperature of 36.7° F. The loss in the air-mass temperature is evident at all elevations.

The relative humidity dropped from 100 to 72% during the 24 hour between A and C. Although this lowering of the relative humidity gives some indication of a drop in air moisture, the true moisture loss

is masked by the accompanying drop in temperature. The vapor pressure at the time of A was 0.203"; it dropped to 0.024" at the time of C. With such a drop in vapor pressure, loss of moisture from the coal dust should have been considerable. The large area of destruction in the mine was evidence of the important part coal dust played in spreading the explosion from the point of ignition.

Coal-mine explosions occurring since the advent of the radiosonde are limited in number. But one of the first steps in determining forecasting possibilities associated with danger periods in coal dust would be to make a thorough investigation of the radiosonde information available for these few coal-mine explosions.

Samples of the atmospheric pressure patterns similar to those mentioned above are presented in Figure 7. The barograms are all associated with mine explosions in the Eastern Region of the Interior Coal Province. In each of the cases shown, the explosion occurred between 22 and 28 hours after the time of lowest pressure. Cold air masses followed the low pressure, placing the mines under the influence of cold, dry air approximately 24 hours before the explosions. Four of the five explosions associated with the pressure patterns shown in Figure 7 resulted in a large loss of life (Table 2).

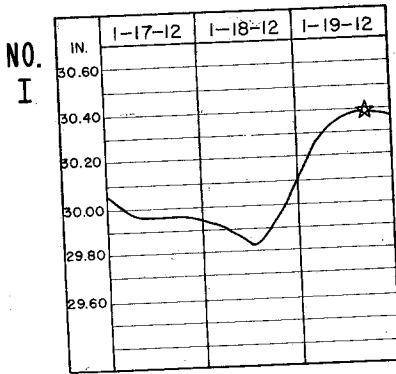
Thus, we find similarity not only in the weather and time relationships, but also in the generally high loss of life in these explosions.

Number IV and Number V in Figure 7 represent the barograph traces for the Centralia (1947) and the West Frankfort (1951) explo-

sions. Both of these explosions took place under mining practices prevailing at the present time. The pressure fell a little more than 0.7" in one case (includes .34" fall during last 13 hours of March 22) and 0.8" in the other. In both instances the lowest pressure was approximately the same. Both explosions took place about 28 hours after the lowest pressure and when the pressure had risen to 30.06 to 30.08". In both cases the vapor pressure had been below normal during one of the three days prior to E day, had fallen below 0.080" on the day of the explosion, and remained low during the following three days. And in both cases more than 110 lives were lost.

The vapor-pressure changes associated with the Centralia and West Frankfort explosion periods are shown in Figure 8. Water-vapor content of the air on both explosion days is far below normal. There must have been rapid drying of coal dust within that part of the mine affected by the dry, cold air.

Much more research needs to be done in connection with the effect of air-mass exchange upon coal-dust moisture. The relation of moisture to dispersibility of dust, however, is not the only line of research awaiting attention. For instance, there is some indication of differences in the development of static electricity under conditions of moist air and dry air. Some theories set forth the idea that explosions have an electric origin rather than a thermal one (Hartmann, 1954). The drying period following a cold frontal passage could be a period of rapid increase in static electricity on the



★ EXPLOSION

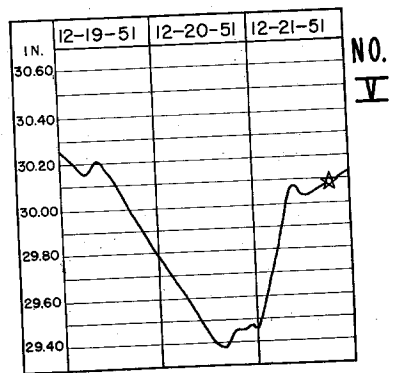
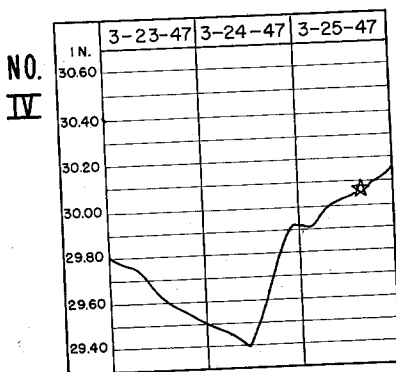
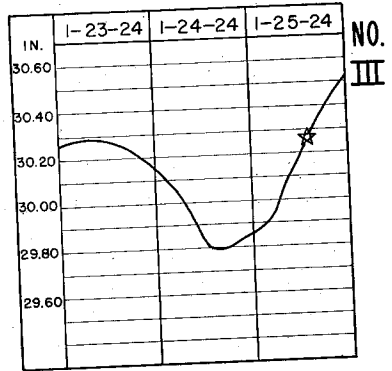
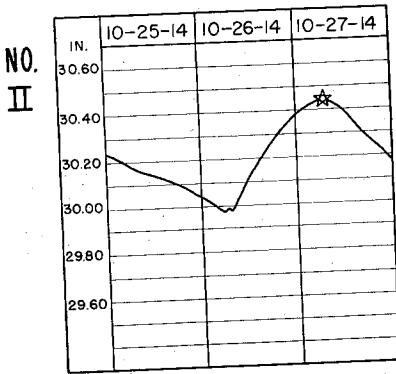


FIG. 7.—Pressure patterns of post-frontal explosions.

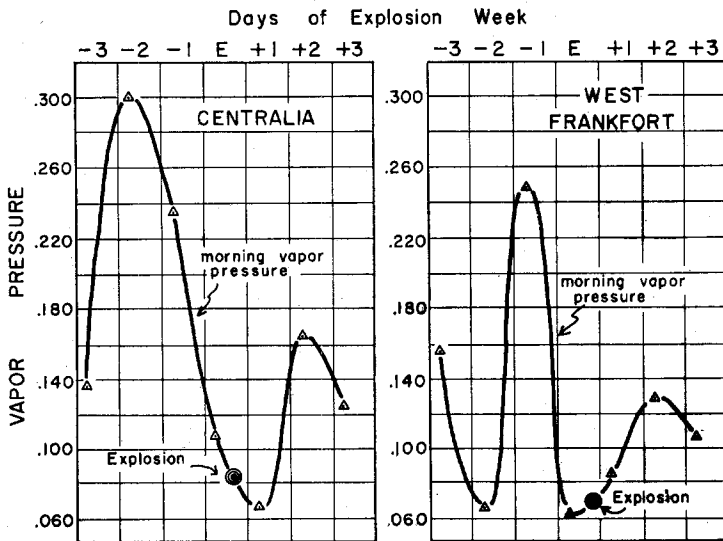


FIG. 8.—Vapor-pressure patterns for the Centralia and West Frankfort explosions.

coal dust. It might not be out of place to suggest an investigation of this aspect in relation to a possible connection with explosions.

#### SUMMARY

The establishment of a regression line on a scatter diagram of methane observations may be used to forecast periods of excessive methane content in coal mines. Given the time of an expected low-pressure passage and the lowest associated pressure, the mine superintendent may determine the duration of gassy mine conditions, the time of greatest methane content, and the maximum amount of methane expected.

Dangerous coal-dust conditions

are seemingly closely associated with post-cold frontal drying. More work must be done in connection with relationships between water vapor of the air, coal-dust moisture, coal-dust dispersion, and possibly with the development of static electricity, before a system of forecasting dangerous coal-dust conditions can be established.

#### LITERATURE CITED

- HARTMANN, IRVING. 1954. Dust explosions in coal mines and industry. *Sci. Monthly*, 79: 97-108.
- ILLINOIS DEPARTMENT OF MINES AND MINERALS. 1953. *The coal mining act*. Springfield, pp. 76-77.
- MCINTOSH, CHARLES B. 1957. Atmospheric conditions and explosions in coal mines. *Geog. Rev.*, 47: 155-174.